POLITECNICO DI TORINO

Facoltà di Architettura

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Tesi di Laurea Magistrale

HOUSEHOLDS CONSUMPTION ANALYSIS.

The Italian residential situation and the possible introduction of dynamic pricing on the study case: Cortau House

Relatore

Stefano Paolo Corgnati

Correlatore

Valentina Fabi

Candidata

Valeria Migliore

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A mia sorella.

"Sognate grandi cose. Sognate che con voi il mondo può essere diverso. Se voi date il meglio di voi stessi aiutate il mondo a essere diverso. Non dimenticate, sognate."

[Papa Francesco]

SUMMARY

RINGRAZIAMENTI

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ABSTRACT

Lo studio alla base di questo lavoro nasce a partire dalla consapevolezza che gli edifici rappresentano la gran parte dei consumi finali di energia di un paese, infatti come riportato da molteplici analisi gli edifici sono responsabili del 40% dell'energia finale richiesta in Europa. Questo in quanto all'interno degli edifici vengono utilizzati numerosi apparecchi e sistemi al fine di garantire un adeguato comfort per gli utenti.

Questo lavoro, a partire da un'attenta analisi letteraria, mira a comprendere quali siano i consumi, principalmente quelli elettrici, del settore residenziale di varie nazioni, in particolare in Italia. La ricerca è stata finalizzata a raccogliere i dati utili per capire quanto consuma esattamente un edificio residenziale tradizionale, quali materie prime sfrutta maggiormente e soprattutto in base a quali elettrodomestici e caratteristiche fisiche consumano più o meno durante tutto l'anno. È stato possibile raccogliere dei dati significativi riguardo ai consumi degli apparecchi grazie a molteplici campagne di monitoraggio, svolte in diverse nazioni, compresa l'Italia; tra le più importanti riportate vi sono quelle del progetto Micene, Eureco e Remodece.

Lo studio non si è limitato solo a quantificare i consumi residenziali, ma anche i relativi costi, partendo da un'analisi sul sistema elettrico italiano, su come era prima della liberalizzazione e su come è oggi (con una "parziale" liberalizzazione del mercato), fino ad arrivare alle attuali tariffe presenti sul mercato nazionale e sul perché possono ancora più o meno funzionare.

La parte innovativa del lavoro riguarda invece lo studio di tariffe dinamiche, non ancora presenti in Italia, ma già applicate all'estero; Di queste tariffe più note, sono stati analizzati vantaggi e svantaggi, grazie all'esperienza dei paesi che le hanno già applicate; soprattutto sono state individuate le barriere che al momento ne impediscono l'effettivo utilizzo in Italia, ma anche delle possibili soluzioni per poterle introdurre in futuro.

A seguito di questa analisi, è stato possibile effettuare consapevolmente la simulazione del caso studio, la Cortau House, per verificarne comfort, consumi e costi in un intero anno, applicando diverse tariffazioni, sia quelle attuali italiane che due dinamiche. La particolarità in questo caso risiede nel fatto che la Cortau House non è un classico edificio residenziale, ma un edificio nZEB, all-electric, quindi un edificio ad altissima prestazione energetica in cui il fabbisogno energetico molto basso o quasi nullo è coperto in misura significativa da energia da fonti rinnovabili in situ (in questo caso pannelli fotovoltaici) o nelle vicinanze; senza tralasciare che per definizione ha un livello di prestazione energetica ottimale anche in funzione dei costi.

Per la simulazione del caso studio è stato utilizzato il software IDA Indoor Climate and Energy software (IDA ICE), grazie al quale l'edificio è stato diviso in 10 zone termiche, in ognuna delle quali sono stati inseriti tutti gli elementi considerabili come "apporti interni" ovvero gli elettrodomestici, gli apparecchi di illuminazione e gli occupanti. Per quanto riguarda gli occupanti sono state scelte tre tipologie differenti, ovvero le più rappresentative (da dati ISTAT): Giovane coppia, Coppia Anziana e una Famiglia (4 persone), che trascorrono il loro tempo all'interno delle case in modo differente. Per l'inserimento degli elettrodomestici e degli apparecchi di illuminazione sono state prese come riferimento le schedule con le curve di carico del Progetto Micene (effettuato in Italia dal 2000 al 2002). Si è pensato però, quali curve fra gli apparecchi inseriti potessero essere facilmente spostabili durante la giornata, in modo da utilizzarli durante le ore più convenienti della giornata, a seconda della tariffa applicata. Da questo pensiero sono partite le simulazioni di tre scenari: Scenario Base, Scenario Demand Response e Scenario Dynamic Pricing. Nel primo scenario (Base), applicando le tre tariffe italiane (Monoraria, Bioraria e Trioraria), sono stati inseriti tutti gli apparecchi domestici e di illuminazione presi dal Progetto Micene e prevedendo l'accensione della pompa di calore dal mattino alla sera. Nel secondo scenario (DR) invece, sempre applicando le tre tariffe italiane, per gli elettrodomestici con carichi facilmente spostabili, sono state ipotizzate delle curve di carico in base ai prezzi differenti delle fasce delle tariffe. Riguardo alla Pompa di calore, anche questa è stata modulata in base alle tariffe e alla presenza degli occupanti. Nel terzo scenario Dynamic Pricing è stato seguito lo stesso metodo del secondo scenario, questa volta però inserendo due differenti tariffe dinamiche (Tou4 e Tou4 Picco), che hanno prezzi e fasce orarie differenti da quelle italiane. Questo scenario (DP) è stato diviso in due parti: Advance e Comfort. Questo perché il caso Comfort mira a constatare che, all' interno di tutte le zone, si verifichino le condizioni di comfort per l'utente e che vengano mantenute le temperature di 20°C in inverno e 26°C in estate. In questo caso non è stato simulato l'intero anno, ma solo due giorni, uno lavorativo e uno festivo, sia in inverno che in estate; grazie alla simulazione fatta ora per ora, è stato interessante constatare quanto tempo impiegano una zona notturna e una diurna della casa ad abbassare la propria temperatura operativa di 1°C.

I risultati emersi hanno provato che fra le tariffe tradizionali la più vantaggiosa è risultata la Trioraria, nello scenario DR e non in quello Base. Fra le due tariffe dinamiche invece è risultata leggermente più vantaggiosa la tariffa Tou4 rispetto alla Tou4 Picco.

Alla fine è stato dimostrato che un uso più attento e pensato degli apparecchi in base alle proprie tariffe domestiche, in particolare con delle tariffe dinamiche rispetto a quelle attuali italiane, portano notevoli vantaggi sia a livello di consumi che di costi; soprattutto in un edificio ad alte prestazioni come la Cortau House, i vantaggi si ottengono anche a livello di comfort.

ABSTRACT

The study behind this work stems from the awareness that buildings represent most of the final energy consumption of a country, as reported by multiple analyses, the buildings are responsible for 40% of the final energy required in Europe. This is because within the buildings many devices and systems are used to ensure adequate comfort for users.

This work, starting from a careful literary analysis, aims to understand the consumption, mainly the electric ones, of the residential sector of various nations, particularly in Italy. The research was aimed at collecting useful data to understand exactly how much a traditional residential building consumes, which raw materials make the most use and above all based on which appliances and physical characteristics they consume more or less throughout the year. It was possible to collect significant data regarding the consumption of the appliances thanks to multiple monitoring campaigns, carried out in various countries, including Italy; among the most important reported are those of the project Micene, Eureco and Remodece.

The study was not limited to quantifying residential consumption, but also the related costs, starting from an analysis of the Italian electricity system, how it was before liberalization and how it is today (with a "partial" liberalization of the market), up to the current rates on the national market and why they can still more or less work.

The innovative part of the work concerns the study of dynamic tariffs, not yet present in Italy, but already applied abroad; Of these best-known rates, advantages and disadvantages have been analysed, thanks to the experience of the countries that have already applied them; above all, the barriers that currently prevent their effective use in Italy have been identified, as well as the possible solutions to be introduced in the future.

Following this analysis, it was possible to consciously make the simulation of the case study, the Cortau House, to verify comfort, consumption, and costs in a whole year, applying different rates, both the current Italian and two dynamics. The peculiarity, in this case, lies in the fact that the Cortau House is not a classic residential building, but a nZEB building, all-electric, therefore a building with very high energy performance in which the very low or almost zero energy requirement is covered to a significant extent from energy from renewable sources in situ (in this case photovoltaic panels) or nearby; without neglecting that it has an optimal level of energy performance also in terms of costs.

For the simulation of the case study, the IDA Indoor Climate and Energy software (IDA ICE) was used, thanks to which the building was divided into 10 thermal zones, in each of which all the elements considered as "internal contributions" were included equipment, lighting fixtures, and occupants. As for the occupants, three different types have been chosen, that is, the most representative (from ISTAT data): Young couple, Old Couple and a Family (4 people), who spend their time inside the houses in a different way. For the insertion of household appliances and lighting fixtures, the schedules with the load curves of the Micene Project (carried out in Italy from 2000 to 2002) were taken as a reference. It was thought, however, which curves between the inserted devices could be easily moved during the day, to use them during the most convenient hours of the day, depending on the rate applied. From this thought, the simulations of three scenarios started: Basic Scenario, Demand Response Scenario, and Dynamic Pricing Scenario. In the first scenario (Base), by applying the three Italian tariffs (One-Time slot, Two-Time slots, and Three-Time slots), all equipment and lighting appliances were taken from the Micene Project have been included and the heat pump is switched on from morning to evening. In the second scenario (DR), on the other hand, always applying the three Italian tariffs, for appliances with easily movable loads, load curves were assumed based on the different prices of the tariff bands. Regarding the heat pump, this has also been modulated according to the rates and the presence of the occupants. In the third scenario, Dynamic Pricing, the same method of the second scenario was followed, this time, however, inserting two different dynamic rates (Tou4 and Tou4 Peak), which have different prices and time slots from those in Italy. This scenario (DP) was divided into two parts: Advance and Comfort. This is because the Comfort case aims to see that, in all areas, the comfort conditions for the user are verified and that the temperatures of 20 ° C in winter and 26 ° C in summer are maintained. In this case the whole year has not been simulated, but only two days, one working and one public, both in winter and in summer; thanks to the simulation did hour by hour, it was interesting to note how long it takes a night area and a daytime of the house to lower its temperature of 1 ° C.

The results showed that the most advantageous among the traditional tariffs was the tariff Three-Time slots, in the DR scenario and not in the Basic scenario. Among the two dynamic tariffs, on the other hand, the Tou4 tariff was slightly more advantageous than the Tou4 Peak.

At the end it was shown that a more careful and thoughtful use of the devices according to their own domestic tariffs, in particular with dynamic tariffs compared to the current Italian ones, bring considerable advantages both in terms of consumption and costs; especially in a high-performance building like the Cortau House, the advantages are also obtained in terms of comfort.

ROAD MAP

Chapter 01

1 INTRODUCTION

1.1 Background

I attended several courses in Physics during my university career. I approached this subject since when I studied for the Bachelor's degree, and it immediately fascinated me, even though it was tough. The first course I attended was "*Fisica Tecnica Ambientale*" of the second year of the Bachelor's degree with Professor V. Serra, in which I learned in general what this subject can handle, starting to learn about thermal and mechanical phenomena (such as fluid mechanics, thermodynamics, and psychrometry), phenomena of building thermo-physics and also of lighting and acoustics. The following year, I had the opportunity to deepen the part of physics regarding interior lighting, in the atelier of interior architecture with Professor V. Minucciani and A. Pellegrino. During the course, I learned how the study of lighting is a very important part of a project. During the Atelier, my group and I designed the interiors and lighting of a family home and different parts of the Caltagirone ceramics museum.

I became more and more interested in this subject with the courses I attended during the Master's Degree: the first year, I joined the course "*Progettazione Fisico Tecnica dell'Edifico: Efficienza Energetica e Impianti*" with the professor M. Filippi, in which the subject has been deepened more in the field of thermal design of the enclosure, air conditioning and ventilation systems, natural ventilation techniques, energy systems serving buildings (including photovoltaic panels and solar thermal), environmental quality requirements indoor air and thermo-hygrometric comfort. During this course I first heard about the user's "comfort", how it can be measured, how it can be achieved, but also about what it does not allow to reach it.

Still in the first year of study, I had the opportunity to have my supervisor S. P. Corgnati for the first time as a professor of Physics in the Atelier of "*Architettura ed economia urbana A*". In this case, I dealt for the first time with a project in the hotel sector in the municipality of Cesana (TO) and for the first time I was asked to design a hotel that respected the criteria of thermo-physical design of the building, starting from the choice of fixtures and stratigraphy, from the calculations of transmittances, up to the design of the heating and DHW plant, trying to make the most of natural resources. At the end of this workshop, I decided to start the work for my thesis by choosing Technical Physics as an argument, asking Professor Corgnati to be my thesis tutor.

During the second year of the Master's degree, in the first semester spent in Erasmus, at the UPC - ETSAB - Universitat Politecnica de Catalunya of Barcelona, I wanted to follow a course in

Technical Physics called "*Condicionament y serveis III*", divided into two parts, one first concerning the theory of lighting and a second concerning conditioning system.

Once back in Italy, being able to choose between the various workshops of the Politecnico, I decided to attend the one of Professor G. Mutani, called "*Progettare e certificare la qualità energetica degli edifici* " in which I learned, through the Termolog program, how to develop the energy certification of a building (Drafting of an EPA) and how the results of an EPA vary through different measures, which have been applied to a case study chosen in Piedmont (e.g. door and window replacement, coat addition, boiler replacement or new plant).

So after having been able to follow several courses concerning the physics of the building and being passionate about these, I decided to undertake the work for my thesis deepening the topics of technical physics very interesting, but that during the lessons have been little detailed, that is what concerns consumption and user comfort.

1.2 Object

The analysis of this work focuses on household electrical consumption not of a traditional Italian dwelling, but on a nZEB (nearly Zero Energy Building) building in Piedmont, Cortau House, whose characteristics are illustrated in one of the following chapters (6.2).

The work aims to collect data that could potentially serve as a basis for comparing the consumption of a traditional home, with a high-performance building such as a nZEB. In particular, in this paper, we will analyse how a diversification of current and dynamic tariffs could have a different impact on the consumption of the case study.

In fact, this study aims to collect data on the hypothetical consumption of Cortau House associated with three different types of occupants: Young couple, Family and Elderly couple.

For each type of occupant, we wanted to check which of the current Italian rates (One-time slot, Two-time slots, and Three-time slots) was the most convenient for everyone. The peculiarity of this work, however, is not being limited to the rates already present in Italy, but also simulating a scenario in which two dynamic TOU (Time Of Use) rates are applied, already present in many other European countries.

At the end of the work, it was possible to establish which tariff was the most convenient for each type of occupants. The work produced 3 groups of scenarios, for a total of 30 scenarios to evaluate the consumption and costs of the different occupants with the various tariffs; furthermore, another scenario was simulated, applying a dynamic tariff, for a winter day and for a summer day (for each of a working day and a public holiday), to evaluate also the internal thermal comfort of the occupants in a day, for one room in the night-zone and in the day-zone.

1.3 Methodology

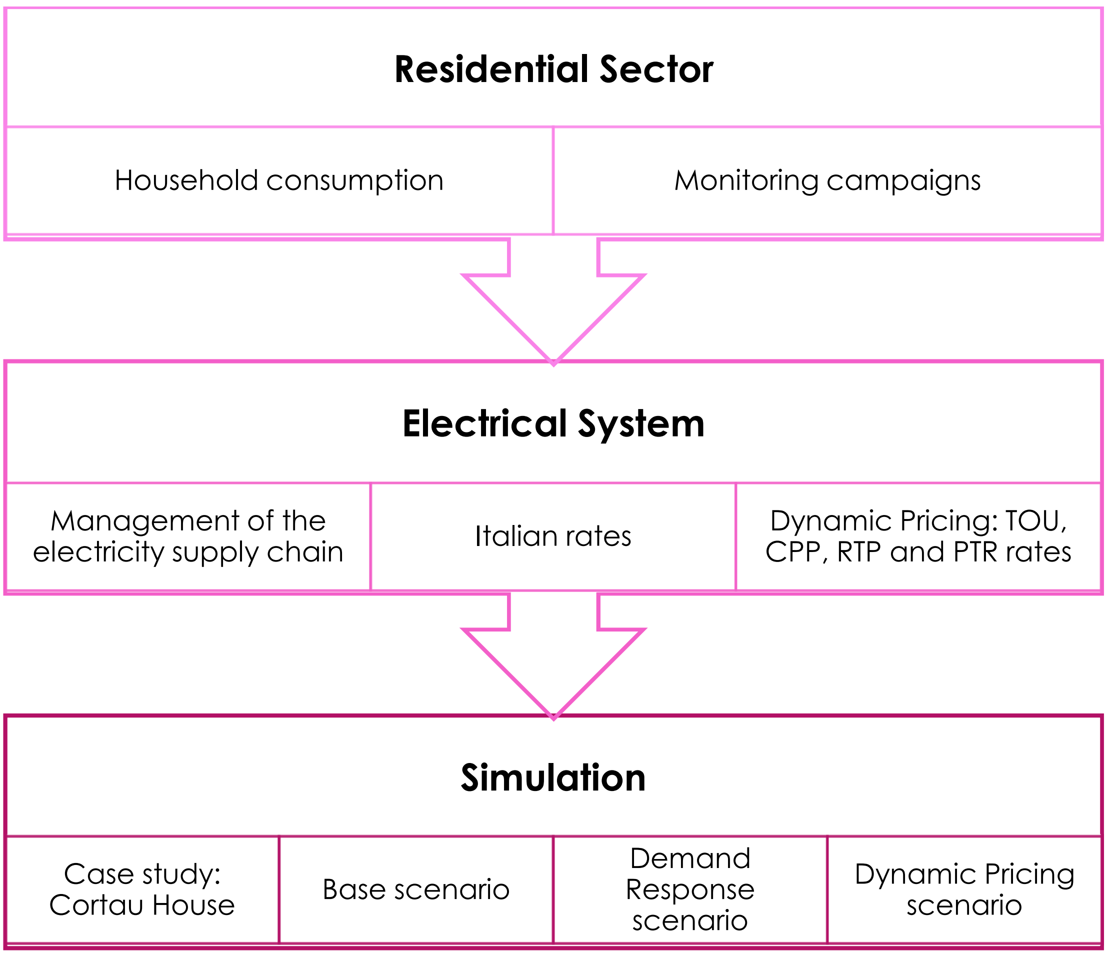
The work carried out and presented in subsequent chapters began with careful research regarding the **residential sector** and **its consumption**, trying to understand how the residential sector influenced the global consumption of a nation (in particular Italy), and then analysed in detail the various residential consumption. The research, also thanks to some of the most important consumption monitoring campaigns (Eureco, Remodece and Micene), made it possible to highlight why users waste more energy (in order: Miscellaneous, Equipment for cold and Lighting); a general look was also given to the variation in the energy mix that has affected these years and which has also influenced the variation in consumption over time

The analysis then focused on the **Italian tariff system**, starting from how it works and from who runs the electricity supply chain that goes from the production phase up to the consumption of the end users. Furthermore, the issue of the liberalization of the Italian electricity market has been addressed, starting from before even liberalization was implemented, until today, where liberalization took place only in a "partial" way. This study was also carried out in order to show the effectiveness and the feasibility of **dynamic tariffs** compared to the traditional ones present in our country, hoping for a complete liberalization of the Italian electricity market one day. This is why the current Italian tariffs (One-time slot, Two-time slots, and Three-time slots) have been analysed and the dynamic tariffs (TOU, CPP, PTR, RTP) are explained with relative advantages, disadvantages, also showing examples of other nations that have already introduced them into their own tariff systems. Obviously, their hypothetical introduction, In Italy, would be subject to technical, energetic, regulatory and market barriers and also to the users who have been taken into consideration. However, everything could be circumvented thanks to practices to facilitate introduction into the national context.

The last part of the thesis is related to the **simulation of the case study**, the **Cortau House**, through the IDA ICE software, with which in addition to electricity consumption and costs of the different rates, it was also verified that the conditions of comfort of the environment internal are always respected, despite the variations of the heat pump set-point in the different scenarios. A further case simulated also concerns the analysis of the temperature ramp, which undergoes changes always due to the set point temperature that varies in the different schedules; this case was useful to see how long it takes the temperature to decrease by one degree, not in any ordinary building, but in a nZEB, considering that the Heat Pump schedule has been set so that the conditions of thermal comfort are always maintained of interior environments.

The study concludes with the results related to the simulations of the different scenarios and to the reflections regarding the possible continuation of this study in the future also on other cases.

Scheme of the methodology:



Chapter 02

2 CHARACTERISTICS OF THE RESIDENTIAL SECTOR

2.1 The residential Sector in EU and Italy

Buildings have always been part of our life. For several years now, many studies have confirmed how the characteristics, design, and details of the buildings where we live, work and spend our free time affect our productivity, our health, and our interactions, and relate also to the energy that these buildings consume. Obviously, the amount of energy used for heating, cooling, ventilation and domestic hot water (DHW) systems is strictly linked to the need to create pleasant and comfortable environments for all those who spend there their time, whether it is their workplace or their own home. The success of a building is therefore deliberated by considering not only how comfortable it is, but also its low consumption that make it a sustainable building at the same time.[1] These are the criteria we are trying to satisfy because the increase in consumption in the last years is linked to the fact that well-being has been associated with the use of more and more electronic devices and appliances. The sector that will be analysed in detail will be the residential one, which includes the largest stock of buildings in Europe and which is responsible for an important part of energy consumption [2]; the non-residential sector, in fact, represents 25% of the existing stock against 75% of residential buildings, much more complex and different from each other. These residential buildings in the EU-27 [3] make up about 17.6 billion m2 of total area, of which 15.1 billion m^2 are heated. 72% of these buildings are located in European countries (Spain, Germany, Poland, Italy, and France).

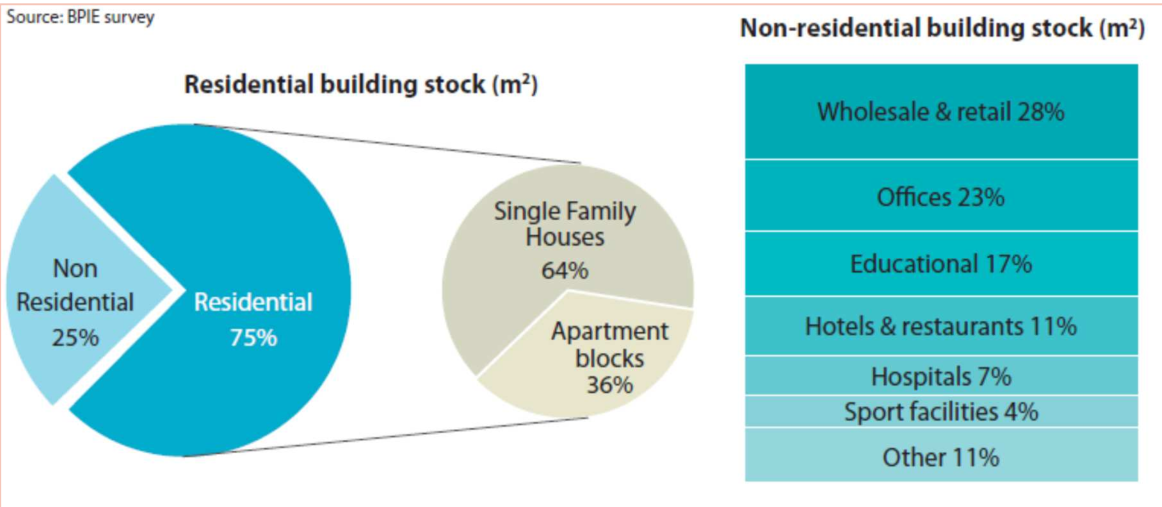


Figure 1. Building stock in Europe. Source: BPIE.

As often reported, buildings are responsible for 40% of the final energy consumption required in Europe. The most energy-consuming sector is, in fact, the one concerning buildings (services and households), followed by the transport sector.

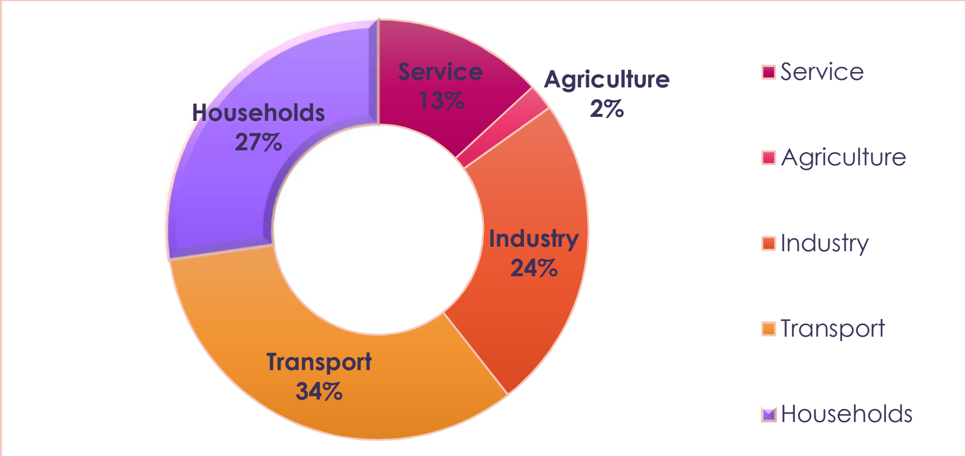


Figure 2. Final energy consumption by sector in the EU, 2009. Source: DG ENER.

In this sector, it is important to take into account the age of buildings,[2] because this feature is closely related to the energy consumption of households, which often live in homes where no work has been done to increase their performance and decrease their consumption.

BPIE has chronologically classified the European buildings of each nation and has grouped them into 3 chronological segments:

- Recent: buildings from 1991 to 2010;
- Modern: buildings from 1961 to 1990;
- Old: buildings up to 1960.

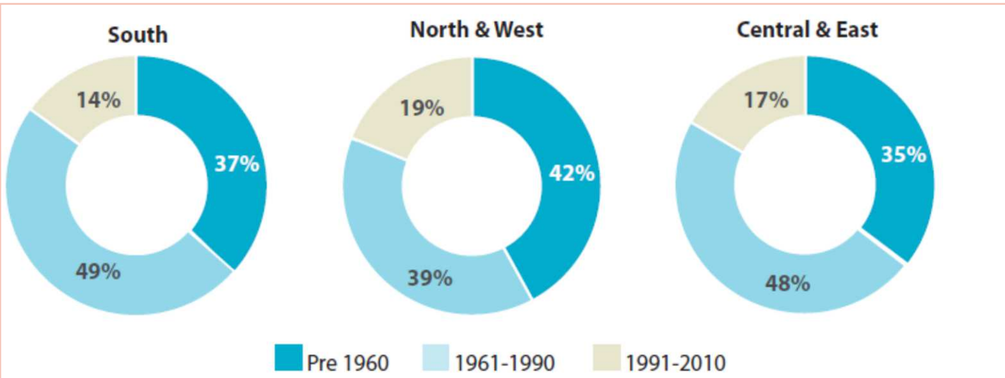


Figure 3. Age of housing stock in EU. Source: BPIE.

The recent buildings are the least consistent part in all European countries, where they exceed buildings built before the 1960s, when the building regulations were still much less restrictive and controlled, far from the standards for sustainable construction and energetic certification that today is necessary. The countries with the oldest buildings were UK, Sweden, Czech Republic, Denmark, Bulgaria, and France. The building boom took place between 1961 and 1990 when the number of buildings even doubled. The data on the energy consumption of buildings have shown that this bracket of buildings is the one where there could be the greatest potential energy savings, as some buildings of the '60s were even worse than those of the previous years, just because of the absence adequate insulation. In those years, there were no strict standards for the insulation of the enclosures.

The residential sector with whom the analysis deals is the Italian one. From sources known as Revenue Agency (Agenzia delle entrate), "Istat" (National Institute of Statistics) and the Department of Finance (Dipartimento delle Finanze), data show that, like other European countries, even in Italy the sector that occupies most of the territory is the residential one. In fact, data from the Finance Department demonstrate that the housing sector covers 54% (34,711,635.00 units) of the number of real estate units (2014)[4]. From the 2017 report of the Revenue Agency on real estate in Italy [5] it turns out that the gross surface of the buildings is equivalent to about 4 billion m^2. The average area of a house in Italy, calculated as the ratio between the total area and the number of total housing units, is 117 m^2. The regions with medium-sized houses are Umbria (134 m^2), Friuli Venezia Giulia and Veneto (132 m^2). Smaller dimensions are found in Basilicata (106 m^2), Liguria (96 m^2) and Valle d'Aosta (93 m^2). The ratio between the total area and the number of inhabitants (resident population) is a simple indicator of the potential housing needs. The living space of 2014 compared to 2013 showed a slight increase (+ 0.5%) at the national level. The average area of housing remains almost unchanged with an increase of 0.2%, as well as the average area per inhabitant and the average area per household, which show an increase of 0.5% and 0.4% respectively compared to 2013.

Year 2014				
Regional Area	Living Space (mln m2)	Average Living Space (m^2)	Average area per inhabitant (m^2)	Average area for family (m^2)
Northwest	1.060,00	110,7	65,7	146,1
North East	813,9	125,6	69,9	161,2
Centre	771,9	117,6	63,8	145,3
South	919,1	115,9	65	168,3
Islands	481,4	115,7	71,3	175,7
Italy	4.046,30	116,6	66,6	156,7
2013	0,50%	0,20%	0,50%	0,40%

Table 1. Indicators of living space - Regional data. Source: Revenue Agency.

A quarter of this Italian residential heritage consists in buildings built before 1946; 1,832,504 buildings have been built before 1919; among these, 4.1% is also in poor state of conservation [6]. Of these, the older buildings belong to the North-West (over 21%) and the Centre (18.5%), while the South and the Islands have the highest percentages of buildings that are, for any period of construction, in poor state of conservation.

Almost 70% of the buildings have been built before the building energy efficiency standards were introduced; moreover, ¼ of our building stock has not undergone any maintenance or upgrading treatment.

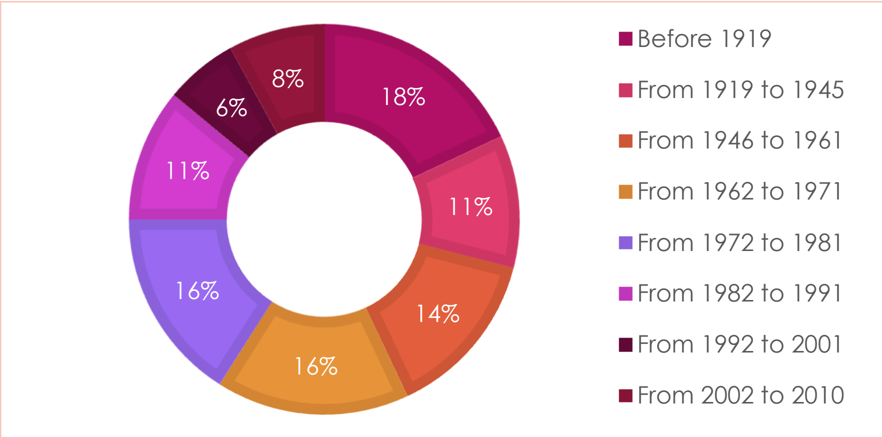


Figure 4. Italian buildings for era of construction. Source: Istat and the Land Agency.

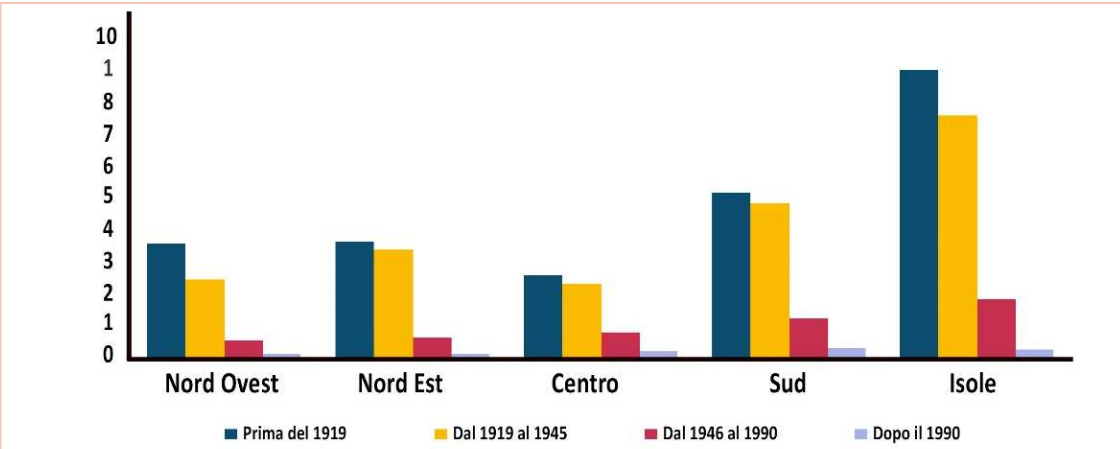


Figure 5. Residential buildings in poor state of conservation by construction era and geographic area. Source: Istat Census 2011.

According to the ANACI association (National Association of Condominium and Real Estate Administrators) that supervises condominiums, it results that 14 million homes in Italy are occupied by residents, in which more than 45 million people live, equal to 75% of the Italian population. It is clear that, however, the distribution on the territory is not homogeneous (Lombardy and Lazio together represent 27% of the condominiums present in our country and over 30% of the occupied dwellings). Over 60% of the condominiums were built before 1976, the year of the law n.373 [7] which, through technical prescriptions, aimed at regulating savings and energy efficiency, and at the coming into force of the subsequent law n.10 / 91 [8], which specifically aimed at containing energy consumption for thermal uses in buildings. However, 82% of the condominiums in Italy had already been built. So, 30% of the condominiums are currently in a mediocre and poor state of conservation from a qualitative point of view also for this reason. Still, on the Italian residential situation, it is possible to have a vision of which building types are present in our territory thanks to an Italian project Tabula (Typology Approach for Building Stock Energy Assessment) [9] [10]. The classification was based on: climatic zone, building size and construction period.

Italy is classified according to six climatic zones from A to F based on the Degree Days (Gradi Giorno: GG)[1] by to the D.P.R. n. 412/1993 in order to classify the different types of buildings; these areas were then grouped into three climatic areas. Furthermore, buildings are classified according to type (4 types) and age (8 periods):

Climatic Area	Degree Days	Climatic Zone
A	< 600	Mediterranean Coast
B	600 - 900	
C	901 - 1.400	
D	1.401 - 2.100	
E	2.101 - 3.000	Medium
F	> 3.000	Alpine

Table 2. Degree Days in Italy. Source: Eurometeo

[1] The Day Degrees (GG) are calculated as the summation, extended to every day of a conventional annual warm-up period, of the daily differences (positive only) between the conventional ideal temperature for the heated environment (20 ° C), and the average daily temperature of the external environment.
If the value of the difference is negative, it is not taken into consideration because, in this case, the living environment does not need to be heated.
A low day degree value indicates that the outdoor temperatures are very close to the conventionally established temperature for the heated environment (20 ° C) and that the climate is, therefore, less rigid.
On the other hand, a high day degree indicates that daily temperatures are often less than 20 ° C and therefore the climate is more rigid.

The types are grouped into:

- One-family house: single unit, with 1 or 2 floors, isolated or bordering another building.
- Terraced house: single unit, with 1 or 2 floors, bordering other residential units.
- Multi-family house: small building includes a limited number of housing units (from 2 to max 5 floors).
- Block of flats: large building with a high number of housing units (condominium).

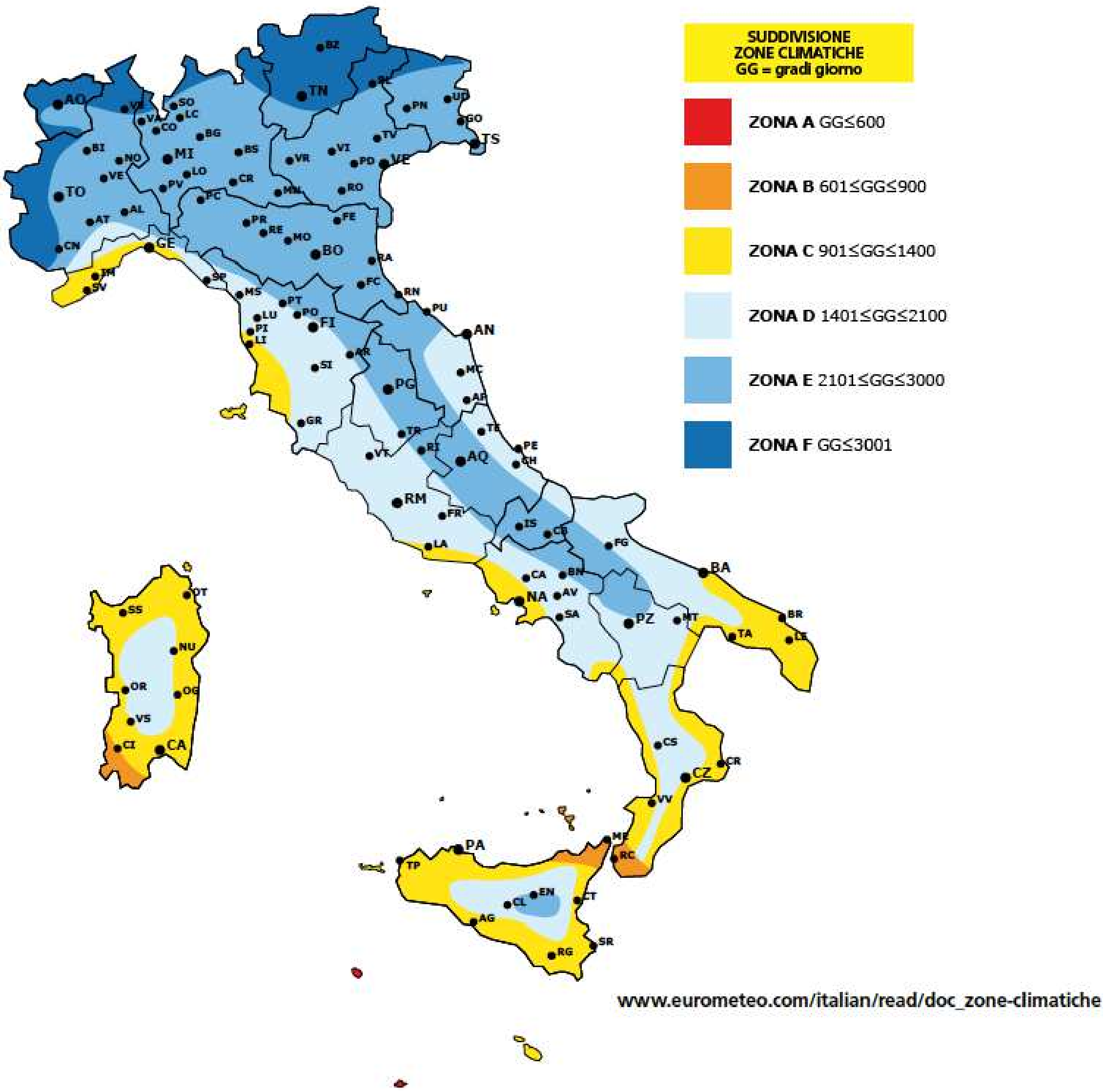


Figure 6. Degree Days geographic map in Italy, DPR 412/93. Source: Eurometeo.

2.2 Factors that influence residential consumption

Age is not the only factor that influences residential consumption. From the age, even the building envelope (e.g. levels of insulation, windows ...), which vary according to the climatic conditions of the place, is discriminating; in fact, there will also be different behaviour characteristics depending on the geographical position (for example specific temperatures for different seasons) that will be discriminating for the choice of heating and cooling systems. Furthermore, both the type and the number of occupants living there strongly affects internal consumption, e.g. a young couple uses appliances or heating services in different way and time than a family of three or four people or an old couple.

From 2010, an important international research to refer to is ANNEX 53 (Total Energy Use in Buildings - Analysis and Evaluation Methods) [11] [12] [13] which has conducted its study to investigate different methods of forecasting the total energy consumption of residential buildings, studying the factors that influence them, in order to evaluate new energy-saving policies and techniques. Annex identified six factors that influence household consumption and grouped them into two macro groups: **Technical and Physical Factors** and **Human Factors**.

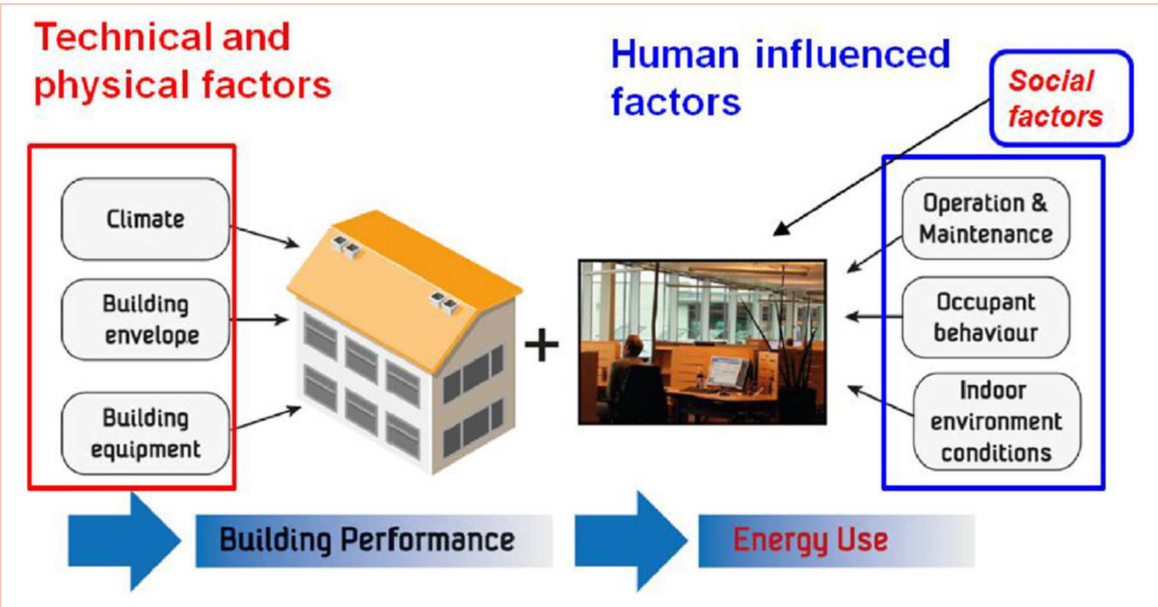


Figure 7. Six influencing factors on building energy use. Source: Annex 53.

The first group concerns technical and physical factors, linked to the building envelope, to its air conditioning and technical support systems, all elements that cannot be modified by man or that are characterized by easily definable physical parameters. In fact, thanks to these factors it is possible to define the performance of the building. Instead, the factors of the second group are those factors that can vary and be objects of definition by men. In addition to the two macro groups, there would be another factor, defined as **Social Factor**, which concerns a very wide field such as the habits of building use, the price of energy, the political conditions of the occupants and the main energy sources of area. The parameters, that are not strictly technical and physical, which can influence energy use and the performance of buildings are many and not negligible. In fact, it can be deduced that the performances calculated considering the standard input data will give calculation results, which, however, may differ from the actual use of energy of the building once in use.

One of the follow-ups carried out in the research of Annex 53 (which will also be useful for the case study of this thesis) concerns just one factor within the macro group of human factors, namely the Occupant Behaviour, as it also influences the energy use of residential buildings in a non-indifferent way. In this part, examined in detail by the Annex 53 project, the reactions and actions of people have been observed in response to internal and external stimuli and their responses in adapting to the environmental conditions. This research had the aim to achieve a better understanding of the total real energy consumption data, thus forming a reliable and complete database, based not only on standard input data. As already mentioned, it is well known that the performance and consumption of a building in a projected state may significantly differ from the performance and consumption that it actually offers [14]. Therefore, only a well-organized and complete database of all information, based on information from buildings in monitored use, would reduce the gap between what is said in the project state and what really is that project underway. These are the reasons that in the United Kingdom pushed a consortium of industries and universities to create the 'Carbon Buzz' platform [15] to compare the energy performance of the project with those actually achieved. Following the British experience, researchers of Roma Tre University and UCL-University College of London and Aedas R & D, of the Carbon Buzz group, have then developed an Italian platform that helps to report design, technological and management choices with energy performance and CO_2 emissions [16] through structured data and comparisons. These instruments led researchers to be able to investigate what are the best choices not only in the projects but also in reality, abandoning the countless constructions that were only theoretical. Obviously, it has always been very difficult to define clearly a relationship between physical parameters (easily monitored) and occupant actions, not very predictable.

All occupant actions have always been performed to create a comfortable indoor environment and are influenced by several factors that can be divided into Physical, Biological and Physiological. These three factors, closely related to each other, are collected in a single group of: Internal driving forces; the External driving forces equally affect the energy consumed to achieve the comfort of the occupant. They are listed in detail below:

- **Internal driving forces:**
  - **Biological**: Age, gender, health situation, clothing, activity level, eating and drinking habits for examples.
  - **Psychological**: Occupants tend to satisfy their needs concerning thermal comfort, visual comfort, acoustical comfort, health, safety, etc. Furthermore, occupants have certain expectations for indoor environmental quality.
  - **Social**: Social driving forces refer to the interaction between occupants. For residential buildings, this depends on the household composition.
- **External driving forces:**
  - **Building/installation properties**: Insulation of buildings, orientation of façades, heating system type, thermostat type (e.g. manual or programmable), etc. are examples.
  - **Physical environment**: Temperature, humidity, air velocity, noise, illumination, and indoor air quality for examples.
  - **Time**: Examples are season of the year, week or weekend day, and time of the day.

2.2.1 Thermal Comfort

Thermal comfort is defined in the ISO 7730 (ISO 2005; ASHRAE 2004) [17] standard as being "That condition of mind which expresses satisfaction with the thermal environment". A subjective definition that is not easily converted into physical parameters.

A more objective definition of thermal comfort indicates that a state of thermal comfort is reached when the thermal storage of the human body is zero (i.e. the temperature of the human body remains constant) and the organism leaves the thermoregulation mechanisms almost inactive behavioural (absence of chills or sweating) and vasomotor thermoregulation (absence of vasoconstriction or peripheral vasodilatation).

Comfort can be influenced by Environmental (microclimate) and Subjective factors (e.g. clothing and physical activity); in addition, there are different physiological and psychological aspects that intervene to balance the body temperature, which differs from person to person. The human body is divided into two parts: External (skin and subcutaneous tissues) and Internal (vital organs); these parts have different temperatures[2] and our body performs different

[2] The two areas are characterized by different temperatures: the temperature of the **internal** zone, tcr, which, in conditions of neutrality, is on average equal to 37 ° C. the temperature of the **skin,** tsk,which, under conditions of neutrality, assumes the value of 33.7 ° C.

physiological and psychological processes to balance its temperature, as mechanisms of vasomotor thermoregulation for small differences of temperature or behaviour due to large temperature differences. There are two types of body thermoregulation:

- Vasomotor: in cold environments, it causes vasoconstriction which causes the blood flow to decrease in the peripheral areas, while in hot environments it causes vasodilation which increases the blood supply to the periphery;
- Behavioural: in cold environments, it causes chills and in hot environments perspiration.

At a relatively extended exposure to a constant thermal environment, the body's core temperature remains constant on condition that there is a balance between heat production and heat loss.

The human body gives energy to the surrounding environment through

- Convection with air (through clothes);
- Conduction (from the feet / shoes):
- Respiration;
- Sweating through the skin.

A subject is in a state of well-being when his energy balance is zero, i.e. he is in a state of thermal neutrality for which he neither exchanges nor receives heat from the environment. The variation of internal energy of the body in the unit of time S is expressed as the subtraction of different values:

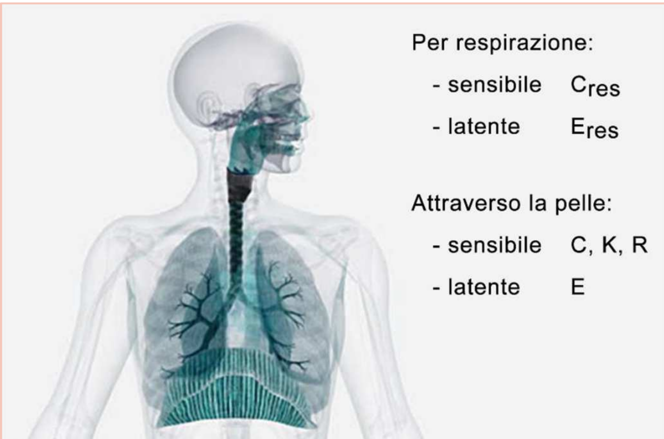


Figure 8. Energy balance of the human body.

$$S = M - W - E_{sk} - R_{res} - C - R - C_k$$

S: increase or decrease of internal energy in the unit of time (Thermal accumulation).

M: energy in the unit of time associated with the metabolism (function of the activity).

W: mechanical power exchanged between the body and the environment: positive if it is performed by the body, negative if it is performed on the body.

E_{sk}: thermal power dispersed by evaporation through the skin.

R_{res}: heat exchanged through breathing, associated with the variation of enthalpy of the breathed air.

C: heat exchanged by convection with ambient air. This amount of heat is negative or positive depending on whether the temperature of the ambient air is higher or lower than the body temperature.

R: heat exchanged by irradiation from the subject with the surrounding environment; this contribution is positive or negative depending on whether the temperature of the surrounding objects is greater or smaller than the surface temperature of the suit body.

C_k: heat exchanged by conduction with objects that meet the body. This term is generally overlooked.

- when S> 0 the body temperature tends to increase;
- when S <0 the body temperature tends to decrease;
- when S = 0 we are in the presence of thermal equilibrium and therefore of potential well-being, a necessary but not sufficient condition due to the self-regulation mechanisms of body temperature.

The heat exchanged by the human body is partly heat sensitive (exchanged for difference and/or temperature variation) and one part is latent heat (exchanged through perspiration, evaporation). The body is a thermodynamic system that receives a thermal power from a source at high temperature (the food), yields thermal power to a low-temperature source (the environment) and thus performs the Work. From an energetic point of view, therefore, the human body can be considered a thermal machine, which transforms the ingested chemical energy in the form of food and drink (through Metabolism) into heat and works with the external environment. The transformation of chemical energy into heat and work takes place through oxidative processes and its size depends on the activity of the subject. For each activity, i.e. for a given external work performed, there will be a corresponding production of heat that the body partially transfers to the surrounding environment. The metabolic power unit used is the

Physical activity	MET
Light intensity activities	**< 3**
sleeping	0.9
watching television	1.0
writing, desk work, typing	1.8
walking, 1.7 mph (2.7 km/h), level ground, strolling, very slow	2.3
walking, 2.5 mph (4 km/h)	2.9
Moderate intensity activities	**3 to 6**
bicycling, stationary, 50 watts, very light effort	3.0
walking 3.0 mph (4.8 km/h)	3.3
calisthenics, home exercise, light or moderate effort, general	3.5
walking 3.4 mph (5.5 km/h)	3.6
bicycling, <10 mph (16 km/h), leisure, to work or for pleasure	4.0
bicycling, stationary, 100 watts, light effort	5.5
Vigorous intensity activities	**> 6**
jogging, general	7.0
calisthenics (e.g. pushups, situps, pullups,jumping jacks), heavy, vigorous effort	8.0
running jogging, in place	8.0
rope jumping	10.0

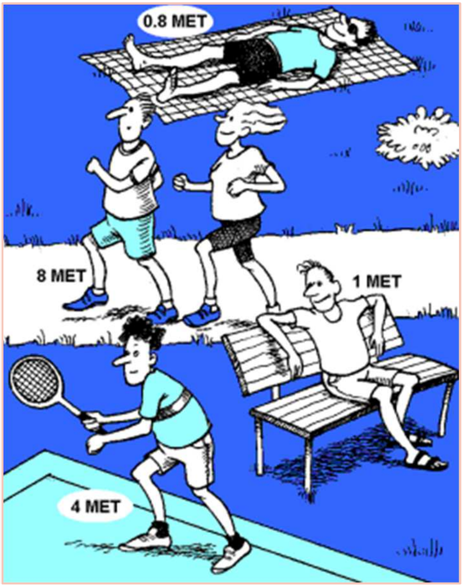


Figure 9. Metabolic activities and related Met. Source: Airnova.

Watt per unit of body surface area or the Met, where 1 Met = 58.2 W/m^2. The Met corresponds to the heat produced, per unit of time and body surface area, by a man sitting and resting.

The area of the body surface of an average man is estimated at 1.8 m^2. Metabolism is one of the six parameters that influence thermos-hygrometric well-being divided into Individual parameters and Environmental parameters (EN ISO 7730/2005):

- **Individual parameters** (related to users):
  - Energy metabolism **M**, depends on the activity carried out [W/m^2 or met] (1met= 58,2 W/m^2);
  - *Thermal resistance of clothing* $\mathbf{I_{cl}}$ [m^{2}K/W or clo] (1clo=0,155 m^{2}K/W).
- **Environmental parameters** (linked to the microclimate):
  - *Air temperature* $\mathbf{t_a}$ [°C];
  - *Average radiant temperature* $\mathbf{t_{mr}}$ [°C];
  - *Air speed* $\mathbf{v_a}$ [m/s];
  - *Relative humidity of the air* φ (UR) [-] or *steam pressure* **pv** [Pa].

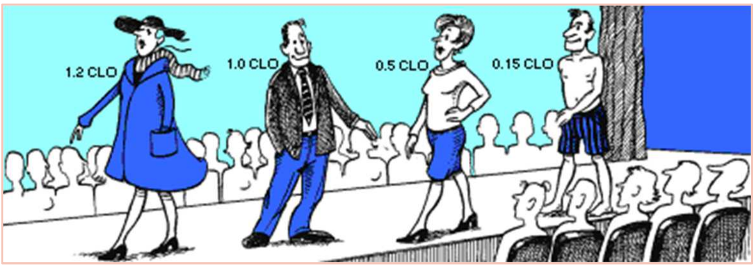


Figure 10. Clothing thermal resistance. Source: Airnova

P. Ole Fanger (1973) clarified that the equation of the energy balance of the body depended on the six parameters listed above, related to each other, through a statistical survey conducted in a climatic chamber on a sample of students (each of them with different clothes, movement conditions and activities). The result was an index used to evaluate the thermal comfort called PMV (Predicted Mean Vote), that is a mathematical function of the 6 parameters that expresses the average value on a scale of thermal sensations with 7 points (varies from -3 very cold to +3 very hot). The Fanger method allows, for each type of clothing (clo) and activity (W/m^2), to calculate the combinations of temperature in the air (° C) and relative speed (m/s) that achieve thermal comfort for people in steady-state conditions.

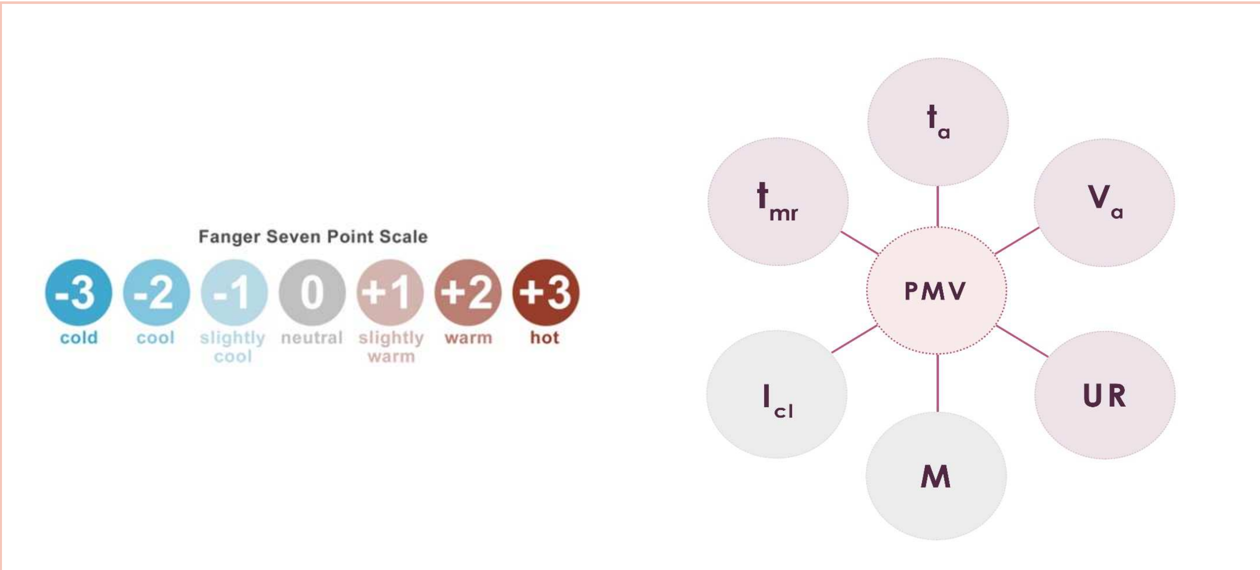


Figure 11. Predicted Mean Vote scale and parameters that influence the PMV. Source: the author.

A correlation model between the subjective human perception, expressed through the vote of comfort, and the difference between the heat generated and the heat released by the human body, was established, which corresponds to the following equation:

$$\mathbf{PMV} = (0{,}303\ e^{-2{,}100 \cdot M} + 0{,}028) \cdot [(M - W) - H - E_C - C_{res} - E_{res}]$$

M: the metabolic rate (W/m^2);

W: the effective mechanical power (W/m^2);

E_c: the heat exchange by evaporation on the skin;

C_{res}: heat exchange by convection in breathing;

E_{res}: the evaporative heat exchange in breathing;

H: the sensitive heat losses.

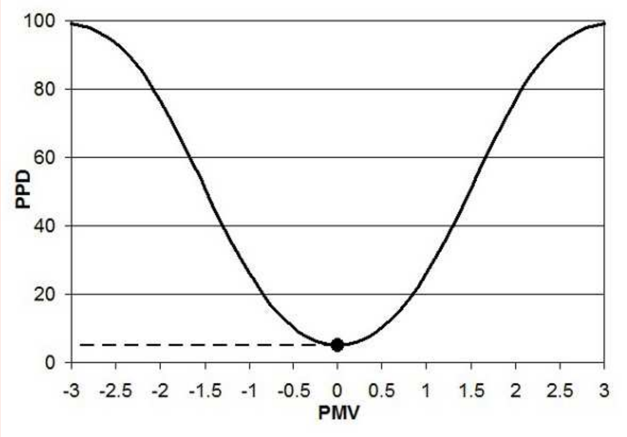


Figure 12. Relation between PMV and PPD.

If the PMV is zero, there are comfort conditions, for values other than zero there are conditions of discomfort, a theoretical result that can be associated, always on a statistical basis, to the percentage of individuals dissatisfied with PPD. It thus occurs that under the best conditions, which correspond to those that most consider welfare, the percentage of positive answers does not exceed 95% of the total, which means that it is illusory to achieve the satisfaction of 100% of individuals. Therefore if: - 0.5 < PMV < + 0.5 then the PPD < 10%, that is, less than 10% of individuals are dissatisfied with the thermohygrometric conditions. The PMV-PPD indices are used in the present thermal comfort regulations Standard EN 15251 (2008) [18], ISO EN 7730 (2005) [19], ASHRAE Standard 55 (2004) [20].

$$PPD = 100-95 \cdot e^{-(0.03353 \cdot PMV4+0.2179 \cdot PMV2)}$$

It is possible to have an optimal average thermal condition but local discomfort causes may occur in an environment (even if respecting the PMV). The UNI ISO 7730 introduces the following causes of local discomfort: High vertical temperature difference: too hot or too cold floor, high asymmetry of the radiant flat temperature and drafts.

The Standard EN 15251[3] defined four categories: high level of expectation, normal level of expectation and moderate level of expectation, acceptable only for a limited part of the year. These categories provided specific PMV-PPD indices limit as shown in Table. ISO EN 7730, consider just the first three categories in the following table.

[3] UNI EN 15251: Indoor environmental parameters for assessment of energy performance of buildings, addressing indoor air quality, thermal environment, lighting and acoustics.

Category	Thermal state of the body as a whole		Local thermal discomfort			
	PPD %	Predicted Mean Vote	Draught rate %	Vertical air temperature difference %	Warm or cool floor %	Radiant temperature asymmetry %
I	<6	-0.2 < PMV < +0.2	<10	<3	<10	<5
II	<10	-0.5 < PMV < +0.5	<20	<5	<10	<5
III	<15	-0.7 < PMV < +0.7	<30	<10	<15	<10
IV	>15	PMV < -0.7 Or +0.7 < PMV	>30	-	-	-

Table 3. Recommended categories of thermal comfort. Source: UNI ISO 7730

For actual regulations, temperature ramp and its relation to human thermal comfort are defined in Standard 55-2004 published by ASHRAE (ASHRAE 2004) and Standard EN ISO 7730 (ISO 2005). ISO_7730 (ISO, 2005) established that If the rate of temperature change for drifts or ramps is lower than 2,0 K/h, it is possible to apply the methods for steady-state condition (PMV).

Standard 55 (ASHRAE, 2004) specifies the maximum change in operative temperature during a period of time: the operative temperature may not change more than 2.2°C (4.0°F) during a 1.0-h period, and it also may not change more than 1.1°C (2.0°F) during any 0.25-h period within that 1.0-h period. If variations are created as a result of control or adjustments by the user, higher values may be acceptable.

Time Period	0,25 h	0,5 h	1 h	2 h	4 h
Maximum Operative Temperature Change Allowed	1,1 °C (2,0°F)	1,7 °C (3,0°F)	2,2 °C (4,0°F)	2,8 °C (5,0°F)	3,3 °C (6,0°F)

Table 4. Standard 55 (ASHRAE, 2004) for maximum change in operative temperature.

2.2.1.1 Adaptive Comfort

The adaptive comfort theory is the result of numerous research by various European researchers (e.g. Nicol) and international researchers (e.g. De Dear and Brager). The concept of adaptive comfort distinguishes the environments from the mechanical climate control from those with partially mechanical and naturally air-conditioned control.

The human body (in addition to the thermoregulation processes) has adaptive levers which allow it to adapt to the climatic conditions to maintain thermal equilibrium in the environment in which it is located. These levers are 3:

- **Behavioural;**
- **Physiological;**
- **Psychological.**

If Fanger tried a method for thermal equilibrium by performing tests with students in a thermostatic chamber with climate control, Brager and de Dear developed an adaptive model carrying out a survey of 160 apartments with both natural and mechanical control in four different continents. It is no longer just a passive subject, as it appeared in the static model (Fanger PMV), but an active agent that interacts with all levels in which he stays.

The comfort model adapts a correlation between the comfort temperature for the occupants ($T_{operative}$) of a building and the outside air temperature (T_{ext}). The adaptive model then introduces control and response algorithms that improve occupants' thermal comfort levels and reduce energy consumption. According to Standard EN 15251: 2007 [18] the correlation to calculate the optimal daily/hour operating temperature is:

$$T_{op} = 0{,}33 * Temp + 18{,}8$$

The T_{op}, operative temperature (or operating), is a partial indicator of thermal well-being; in fact, it summarizes the effect of three quantities: the air temperature, the average radiant temperature, the airspeed; while the other three causes that influence the thermal sensation assume a fixed value equal to: φ_a = 50%, I_{cl} = 1 clo, M = 1 met. The operative temperature can be defined as the uniform temperature of the air and of the walls of the environment, which would cause the same heat exchange for convection and radiation in the real environment. The most rigorous way to calculate it is:

$$\mathbf{Top} = \frac{hr * tmr + hc * ta}{\alpha}$$

where:

t_{mr} = mean radiant temperature;

t_a = air temperature;

h_c = coefficient of convective exchange for humans;

h_r = radiative exchange coefficient for humans;

$\alpha = h_c + h_r$ = coefficient of thermal adduction on the body surface.

In practice, if the difference between average radiant temperature and air temperature is less than 4 °C, the air velocity is less than 0.2 m/s, so we can assume T_o equal to the arithmetic mean of t_{mr} and t_a:

$$To = \frac{\text{tmr} + \text{ta}}{2}$$

At the base of the model of adaptive comfort there is the conviction that the subject, consciously or unconsciously, plays an active role in creating the thermal conditions that he prefers and that, in order to more easily achieve satisfaction with the microclimate, he implements a process of adaptation, (gradual reduction of individual reactions to environmental stimuli). The positive aspects related to this applied method are manifold: a greater control on the part of the user on the environmental variables, more attention to the variability of the mechanical conditions, more consideration for passive environmental control strategies and reduction of the energy and economic requirements to air-condition the environments.

2.2.2 Building performance

In addition to the concept of comfort and the features already explained in the previous paragraphs, it is also important to investigate the physical and technical characteristics and parameters that influence the variations in indoor temperature. The internal areas of the buildings react differently to temperature changes depending on their position inside the building and the characteristics of the building envelope. This is because the thermal environments (internal) are almost never found in a stationary state.

The internal environment, in fact, must be subjected to transitory conditions (and not stationary) and through the temperature ramps and temperature shifts it is also possible to optimize the energy demand of the building, thanks also to internal climate control strategies (set the temperature schedule according to the occupants' presence, internal-external environmental conditions and regulate the periods of the power peaks). It should not be overlooked that internal thermal conditions also depend on certain thermal-physical characteristics of the building envelope, which depend on different physical quantities, which are [21] [22] [23]:

Transmittance (U) [W/m²K]: Heat that is transmitted through 1 m² of wall thickness in one hour, when there is a difference in temperature between the two sides of the wall.

Thermal capacity (C) [J/K]: It expresses the thermal energy accumulated in the wall for an increase of its temperature of 1 ° C. (Ratio between the heat exchanged between the body and the environment and the variation of temperature that follows).

Thermal Shift (S) [h]: Difference of time between the time when I have the max temperature outside and the time when I have the max temperature inside. (Delay in which the thermal wave is transmitted inside. It is important for the behaviour of the envelope during the summer period, it must always be > 9-10 h, optimal is 12 h).

Related to the phase shift is the **Thermal Inertia**, which measures the inclination of a material to accumulate heat and transmit it to the nearby environment. It is due to the mass; a material with a high thermal Inertia and a high phase displacement is a material that is very capable of absorbing heat, but heat that will give way inside very slowly.

Thermal time constant (τ) [h]: (UNI TS 11300) is the ratio between the thermal capacity of the building (C) and the global heat exchange coefficient (transmission and H_t e ventilation H_v).

$$\tau = (C/3600)/(H_t+H_v)$$

It can also be calculated with the Resistance (R) and the Zone areal heat capacity (C_m)

$$\tau = R * C_m$$

Zone areal heat capacity (Cm) [J/K]: (UNI EN ISO 13786) when the enclosure is known, the thermal capacity of the area can be calculated with the elements that delimit the area and which are in direct contact with the indoor air.

$$C_m = \sum k_j * A_j$$

k_j: areal heat capacity of each component;

A_j: element's surface.

Please refer to the simplified calculation of Appendix A of ISO 13786 [22] to calculate:

$$\mathbf{k_j} = \sum \rho_i * d_i * c_i$$

r_i: is the material density [kg/m^3];

d_i: thickness [m];

c_i: specific heat capacity [J/(kg/K)].

The sum is made for all the layers that make up the structure, starting from the inner surface until the minimum value is reached between:

- Half of the total thickness of the element;
- Spessore di materiali fino al raggiungimento del primo strato di isolante (non va considerato l'intonaco);
- Max thickness of 0,1 m.

Thermal resistance (R) [(m²K)/W]: (UNI EN ISO 6946) Temperature difference between two surfaces defined by a structure that induces a unit heat flow through a unit area. It is the inverse of the transmittance (U):

$$\mathbf{R} = 1/U_{tot} \qquad \mathbf{R} = s_i/\lambda_i$$

2.3 Goal for the future: 20 – 30 – 50

As it is now well known, buildings produce a large amount of greenhouse gas (GHG) emissions, mainly CO_2. As already analysed in the first chapter, Europe and Italy have a vast and varied building heritage [24], especially built many years ago, but this should not be seen only as an insurmountable obstacle, but as a significant opportunity and challenge to adapt our architecture to our time. We must, therefore, work so that the overall energy demand of buildings, residential and non-residential, is significantly reduced, together with carbon dioxide emissions, in line with the GHG reduction targets in Europe.

Since the adoption of the Kyoto Protocol, 15 EU member states have begun a targeted path to reduce their collective emissions by 8% by 2012 below the level recorded in the reference year (1990). Since the end of this, it has been decided in fact a path for the reduction of greenhouse gas emissions which has as its nearest objective the "20 20 20 Plan", which is located within the Directive 2009/29/EC [25] entered into force in June 2009 and valid from January 2013 until 2020. The Plan includes:

- Reduction of greenhouse gas emissions by 20% compared to 1990.
- 20% of the energy needs obtained from renewable sources.
- 20% increase in energy efficiency.

It is a Climate-Energy package elaborated by the European Union that will also allow to limit the maximum increase of +2 ° C of global warming (compared to the pre-industrial age) and which does not only concern the sectors that fall within the EU ETS system, but which also considers sectors such as construction, agriculture and transport. The "20 – 20 - 20 Plan" will then go to "40 – 27 - 27", which is the agreement reached by the European Commission on the 2030 Climate-Energy package which provides for the reduction of CO_2 emissions by 40%, a 27% increase in energy efficiency and 27% of renewable energy production at European level [26]. The roadmap does not stop in 2030 but includes another ambitious objective to be reached also within 2050 [25], we are talking about an 80-95% reduction of greenhouse gas emissions in EU countries compared to 1990. Emissions from households and offices can be almost eliminated by around 90% by 2050. Energy efficiency will improve dramatically thanks to:

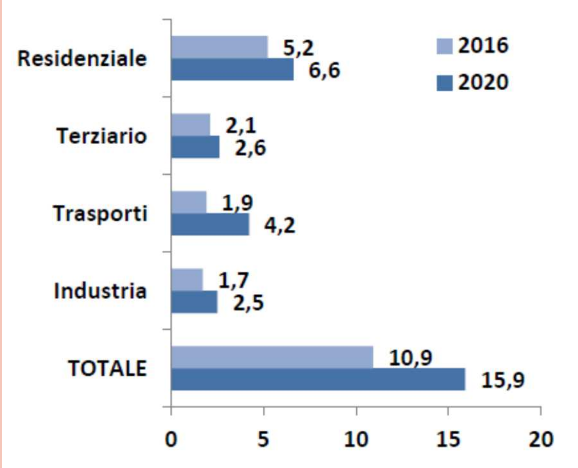


Figure 13. Reductions in final energy consumption expected (Mtep). ENEA.

- Passive building technology for new buildings.
- Almost zero energy buildings should become the norm. Buildings, including homes, could produce more energy than they consume.
- Renovation of old buildings to improve energy efficiency.
- Replacement of fossil fuels with electricity and from renewable sources.
- Adoption of electrical appliances with high energy efficiency standards.

However, a very important role must also be played by behavioural changes and by citizens' accession to these lines of action.

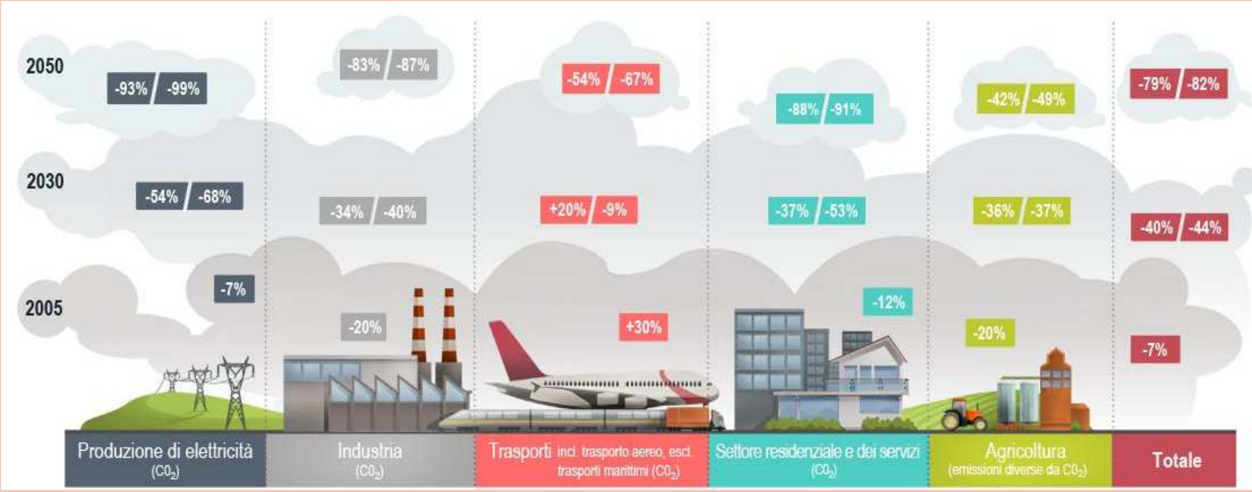


Table 5. Greenhouse gas emission reductions compared to 1990, Roadmap 2050. Source: European Commission.

As for future scenarios related to the domestic sector, changes in residential energy services are also assumed, starting in 2010 [27], projecting them into future years based on factors that influence their evolution, the main driver of the applications is the number of families.

For the implementation of plans that will meet the scenarios for the future,[27] certainly on average the capital costs of the energy system will increase, investments will increase in networks and power plants, in industrial equipment for energy, in systems heating and cooling, in smart meters, insulation materials, in low carbon vehicles, in the exploitation of local renewable energy sources (solar and photovoltaic heating); all this will have a widespread effect on the economy and employment in the sectors of production, services, construction, transport, and agriculture. Furthermore, the scenarios indicate that electricity will play a much more important role than the current situation (in final demand it should almost double, reaching 36-39% in 2050).

Servizio Energetico	2020	2030	2040	2050
Numero famiglie	1.1	1.1	1.1	1.1
Riscaldamento + ACS	1.1	1.1	1.1	1.1
Cucina	1.0	1.1	1.1	1.1
Climatizzazione estiva	1.5	1.7	1.8	2.0
Illuminazione	1.1	1.1	1.1	1.1
Conservazione alimenti	1.1	1.1	1.1	1.1
Lavaggio Biancheria	1.1	1.1	1.1	1.2
Acqiuga biancheria	2.1	3.7	5.4	7.0
Lavaggio stoviglie	1.3	1.6	1.9	2.2
Altri usi elettrici	1.1	1.3	1.4	1.5

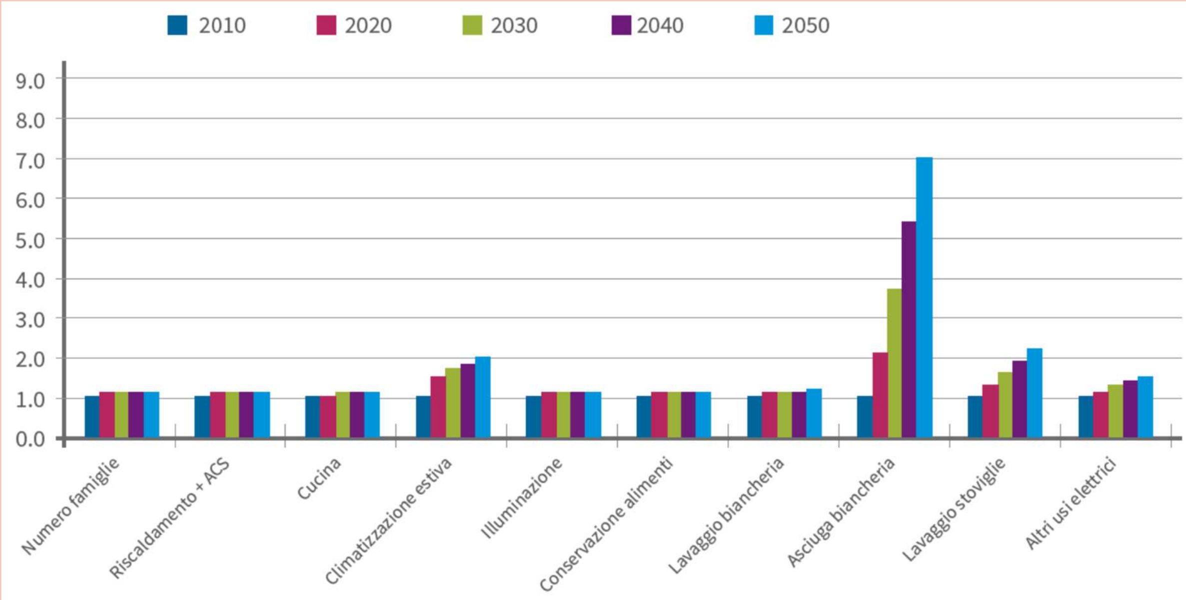


Figure 14. Evolution of Energy Services, Residential Sector (Index 1 = 2010). Source: ENEA.

As indicated in all decarbonisation scenarios, electricity could provide about 65% of the energy demand from passenger cars and light vehicles. Roadmaps obviously do not replace local, regional and national efforts, but they want to motivate and motivate Europe to accept the challenge and to increase the safety and low consumption of their products and services.

Chapter 03

3 DEFINITION OF THE DIFFERENT CONSUMPTION PROFILES OF THE RESIDENTIAL SECTOR

3.1 Benchmark about the household energy end-use

In Europe, buildings are responsible for 40% of energy consumption [3] and around two-thirds of this consumption is connected to heating. Houses have more weight than offices because they account for over 90% of buildings. The energy consumption of buildings depends on many factors that serve to guarantee an adequate, comfortable and liveable environment, such as the temperatures required for heating and cooling or the types of systems installed in the building.

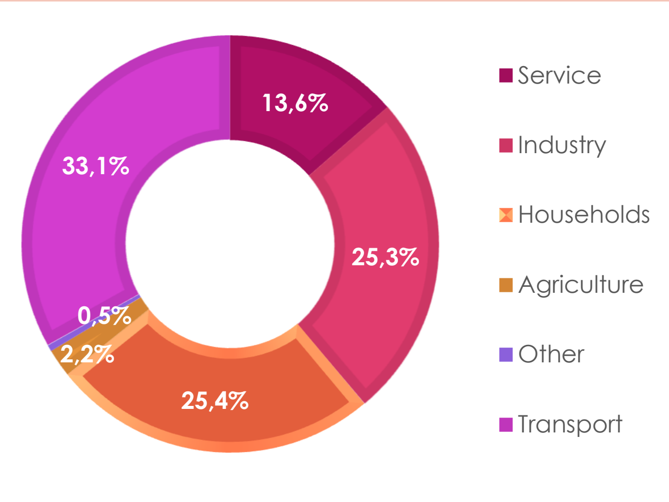


Figure 15. Final energy consumption, EU-28, 2015. Source: Eurostat.

As seen in the previous chapter, the residential sector is responsible for most of the final energy uses of buildings; we see from the data of an Eurostat analysis of the final end use of energy (in the EU-28 in 2015) that the household sector is among the three dominant categories: transport (33.1%), households (25.4%) and industry (25.3%) [28]. In the table below, Eurostat data show the change in final energy consumption (in KTOE) in the various sectors, comparing Italy with the EU28; it is clear that the only increasing value concerns Italy in the residential sector (an increase of 116.40 KTOE from 2011 to 2015). However, in the Italian residential sector the trend from 2011 to 2015 was not only increasing; in fact, there was a significant increase between 2011 and 2012 (+1970.2 KTOE) and in 2013 (+1852.5 KTOE); on the other hand, a slight increase between 2011 and 2015 (+116.4 KTOE), a significant decrease occurred between 2011 and 2014 (- 2832.1 KTOE).

Final Energy Consumptions (KTOE)	2011		2015		Difference 2011-2015	
	EU 28	Italy	EU 28	Italy	EU 28	Italy
Industry	283.222,70	30.107,90	274.737,30	26.023,00	-8.485,40	-4.084,90
Transport	362.255,70	41.821,60	358.628,80	39.540,70	-3.626,90	-2.280,90
Other Sectors	461.771,10	51.201,10	450.590,60	50.880,40	-11.180,50	-320,7
Residential	283.001,40	32.378,10	275.155,20	32.494,50	-7.846,20	116,4
Agriculture	24.249,40	2.702,70	23.441,00	2.663,50	-808,4	-39,2
Services	147.425,40	15.751,40	146.924,40	15.391,50	-501	-359,9
Total	**1.107.249,50**	**123.130,60**	**1.083.956,60**	**116.444,10**	**-23.292,90**	**-6.686,50**

Table 6. Final energy consumption by sector in KTOE (2011-2015). Eurostat data 2017.

In the houses, [2] the main consumption concerns heating, cooling, hot water, cooking and appliances, and the main energy end-use in homes is for space heating. The considerable increase in electricity consumption (38% over the last 20 years) also depends on the increase in the use of appliances in households. In order to identify and understand the consumption of the sector, it is necessary to have a clear understanding of the type of residence that is being analysed, the activity and the services/appliances included. In this case, it will be all the activities and tools related to the activities of private houses/apartments for domestic use, associated with the needs and comfort of the occupants [29].

Household energy end use: The use of energy commodities by a household, to obtain certain energy service (heating, cooling, hot water, etc.).

We can identify six main energy end-uses for the energy consumption in households:_space heating, water heating, cooking, space cooling, lighting and electrical appliances and other uses. The category identified as 'other uses' can be used to consider any other activities not included into five major energy end-uses mentioned above. Households mainly used energy for heating their homes (64.7%), around two-thirds of final energy consumption[30]. The energy used for water heating accounted for 13.9%, so, the heating of space and water accounted for 78.6% of the final energy consumed by households. Energy used for lighting and the use of electrical appliances accounted for 13.8% of the energy used by households, while the cooking appliances represented 5.7%, other end-uses 1.5% and air conditioning 0.5%.

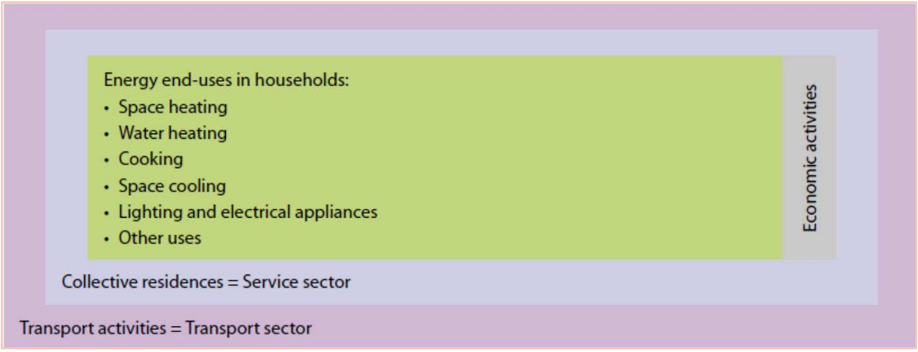


Figure 16. Boundaries of the household sector (in the green area). Source: MESH team.

In detail, residential buildings are characterized by an average demand of around 140 kWh/m^2/y heating [3]; for the supply of hot water, they need an average of 25 kWh/m^2/y and another 20 kWh/m^2/y for summer cooling.

Despite different climates, consumption for heating does not vary considerably between the countries of northern Europe and the Mediterranean area. That is because Nordic countries chose better constructive solutions to isolate buildings from the cold. Thanks to the improvement of construction techniques and greater sensitivity on the energy aspects, thermal performance has improved since 1945 to today (as reported by the Casa Clima Report) [3]. Clearly, the countries that are in colder climates have always had good thermal insulation, while those in warmer climates neglected this aspect.

Annual energy consumption for residential heating was estimated at 2299 TWh in the EU-27, which means an average energy consumption of 152 kWh/(m^2/y). Annual energy consumption ranges from 19 kWh/(m^2/y), for areas with warmer climates, to 215 kWh/(m^2/y) with colder climates. As for residential energy consumption for cooling, it is 26 TWh/anno the consumption of hot water instead is equal to about 20% of the space heating, or 459 TWh/year; this consumption is closely linked to the population of each country (e.g. Germany accounts for the largest share with 91 TWh/year). The consumption of lighting is around 97 TWh/year (EU-27), about 5 kWh on average. The growth of consumption in the residential sector is obviously caused by various reasons [31], as the growth of households, the growing demand for comfort, the increase in the average size of houses, followed by a significant increase in the number of devices in the houses, which also leads to an increase in standby functions. Everything is related to economic growth that led to an evolution of the demand for energy. In particular, an increase in electricity consumption is related to various factors such as [32]:

- Increased penetration of "traditional" equipment, introduction of new equipment and devices, mainly consumer electronic devices and information and communication technologies (ICT).

- Increased use of "traditional" equipment: more hours of TV viewing, more hours of personal computer use (and increased use of the Internet) and greater use of hot water.
- The increase of single-family houses, each with some basic appliances and in general the presence of larger houses and apartments. This translates into more lighting, more heating and cooling; in addition, the elderly population spends more time at home and requires higher indoor temperatures during the winter and more cooling in the summer.

3.2 Variation of the primary energy mix

Buildings are the largest consumers of energy in Europe, with a trend that has seen an increase over the last 20 years. Gas is the most used fuel, while oil use is highest in South Europe. In Central & Eastern Europe, coal is the most used fuel in the residential sector. Renewable energy sources (solar heat, biomass, geothermal and wastes) have a greater share in the South (27% biomass), the North and the West (21% biomass and 6% other renewable sources of energy) [2].

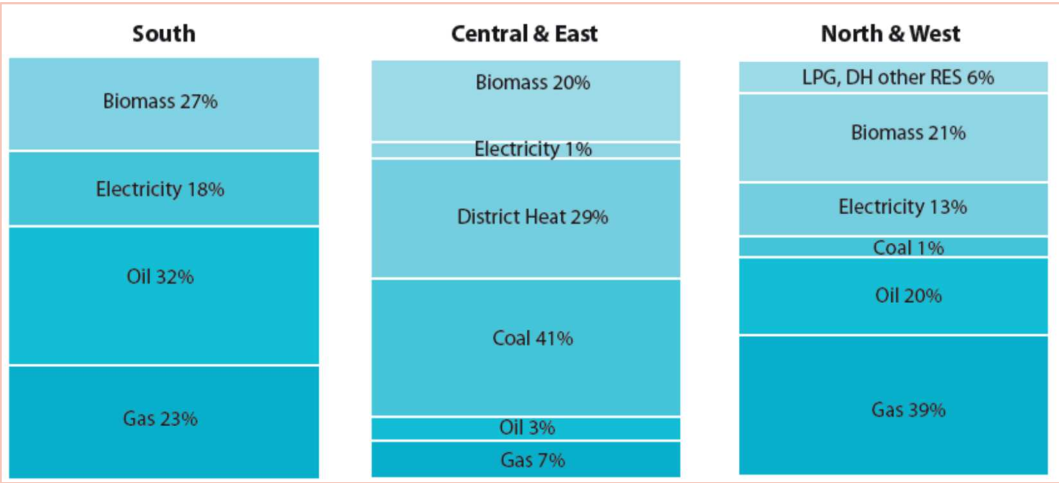


Figure 17. Energy mix in residential sector by region. Source: Eurostat

As for our country, the energy mix has changed than in the past, has seen a gradual replacement of oil with gas and in the last few years also an increase in renewable sources (RES) [33] (from 2000 to 2014 with an average growth rate of 3%). Data from 2015 show that the consolidation of the supply of oil and gas exerted further downward pressure on prices. This reduction was followed by a recovery in consumption in OECD[4] countries [34], in

[4] The mission of the "Organisation for Economic Co-operation and Development" (OECD) is to promote policies that will improve the economic and social well-being of people around the world.

particular in Europe, where the diffusion of renewable sources continued with a significant contribution from emerging economies, and the world trade in coal fell for the first time in 10 years.

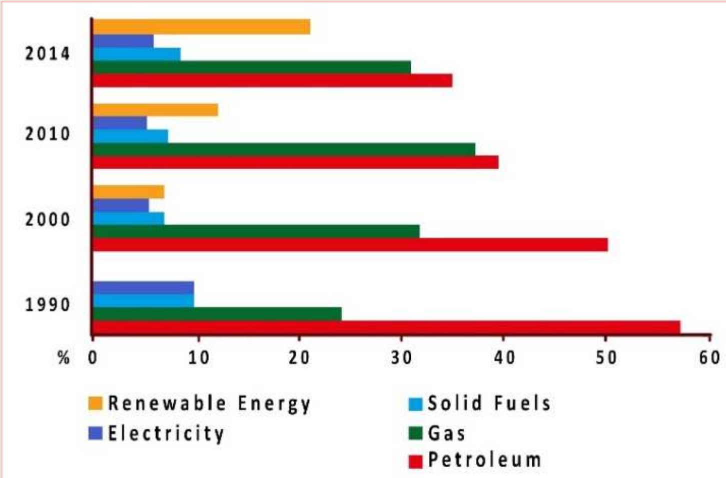


Figure 18. Primary energy evolution in Italy. Source: Enea, data processing Mise.

In Italy the transition, which has been going on for some years, continued towards a more efficient, autonomous and less carbon-intensive energy system, while remaining a significant dependence on foreign sources. In 2015, after a negative trend of 4 years, the demand for primary energy increased, imports increased, especially those of hydrocarbons, and the degree of dependence on foreign countries. Final consumption also increased for the first time since 2010 in all sectors, excluding industry. Regarding the overall demand, the country's gross energy demand in 2015 was 171.289 million tonnes of oil equivalent (Mtep), with an increase of 3.2% compared to 2014. The increase in primary energy demand interrupts the negative trend recorded in recent years and the value of 2015: in absolute terms, it is close to that recorded in 2013. The percentage composition of the energy sources used to cover demand in 2015 has been characterized, compared to 2014, by the substantial stability of oil (from 34.50% to 34.56%), by a slight decline in solid fuels (from 8.25% to 7.85%) and by the increase of the gas one (from 30.55% to 32,28). There was also a small increase in electricity, which went from 5.79% to 5.92% and a decrease in the share of renewable energy from 20.89% to 19.33%.

Nowadays, renewable sources (RES) play a leading role in the Italian energy context, finding widespread use to produce both heat (Thermal sector) and electricity (Electric sector) and as

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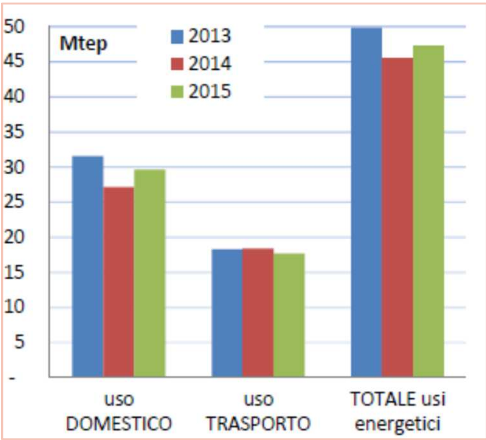
The OECD provides a forum in which governments can work together to share experiences and seek solutions to common problems. The organization work with governments to understand what drives economic, social and environmental change. Their measure productivity and global flows of trade and investment. We analyse and compare data to predict future trends.

biofuels for motor vehicles (sector Transport). In the last decade, several public support initiatives greatly favoured the development recorded by RES.

About electricity demand, an increase of 1.5% in 2015 was seen compared to the previous year (in 2015 it was equal to 315.2 TWh), when a negative change of 2.5% had been registered compared to 2013. The equivalent in primary energy, that is necessary to meet the electricity demand, was equal to 65.5 Mtoe. Electric penetration - the ratio between electricity and global energy consumption - was 38.3%, a slight decrease compared to the 2014 share (39.3%). The demand for electricity in primary sources was 15.6% covered with imported electricity, 36.8% with hydraulic, geothermal and other renewable sources, and for the remaining 47.6% with the transformation of traditional fuels in thermal power plants.

Between 2013 and 2015 the total amount of energy used by households for domestic use (heating / cooling, hot water, kitchen use and home appliances) and for own transport decreased by 5% (-9% in 2014 and + 4% in 2015), falling to 47.3 million tonnes of oil equivalent (Mtep). At the same time, spending decreased by 14% (-9% in 2014 and -5% in 2015).



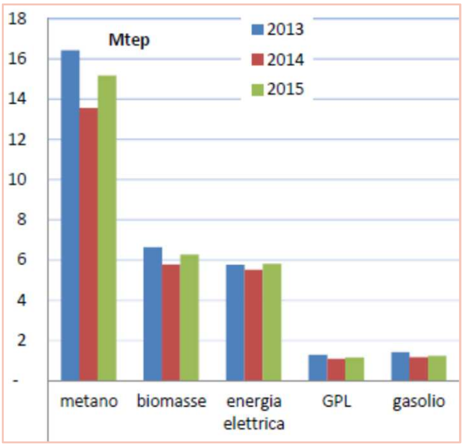


Figure 19. Energy uses (Mtep) of households, by type of use and product used. Source: Istat.

Analysing a wider period, the one between 1990 and 2015, the amount of energy used by households increased by 2.1% [35]. The trend in this period is increasing, but in a discontinuous way: between 1990 and 2005 it remains almost stable, decreasing between 2005 and 2010 (-0.3%) and is strongly decreasing until 2015 (-15.6 % compared to 2010). In 2015, the total consumption is equal to 47.3 million tons of oil equivalent (Mtep). The consumption of energy products by households can be traced back to two major categories: domestic use (heating / cooling, hot water, kitchen use and home appliances) and use for own transport. The main energy product used in domestic uses, in terms of Mtep, is natural gas, called "methane". The other energy products used are electric power and biomass, both built (firewood and diesel fuel) with a constant decrease over time. Compared to other European countries, Italy has an electricity consumption per capita lower than the others, not only because of a high efficiency of energy use in the industrial sector, [36] but also because of the reduced presence of intensive energy activities, a favourable climate, and high energy prices due to the dependence on imports. However, as far as the general level of energy efficiency is concerned, our country is about 7% less efficient than the European average, e.g. in the residential and tertiary sector with buildings that account for over 40% of our country's final energy consumption. But the impact of efficiency policies is not only energy: the effects are mainly on the development and diffusion of technological innovation, industrial growth and related industries in a sector in which Italy still plays a good rule in the European market. Investing in efficiency means bringing new products to the final market, developing and strengthening a national industry, already solid in some sectors such as appliances and boilers.

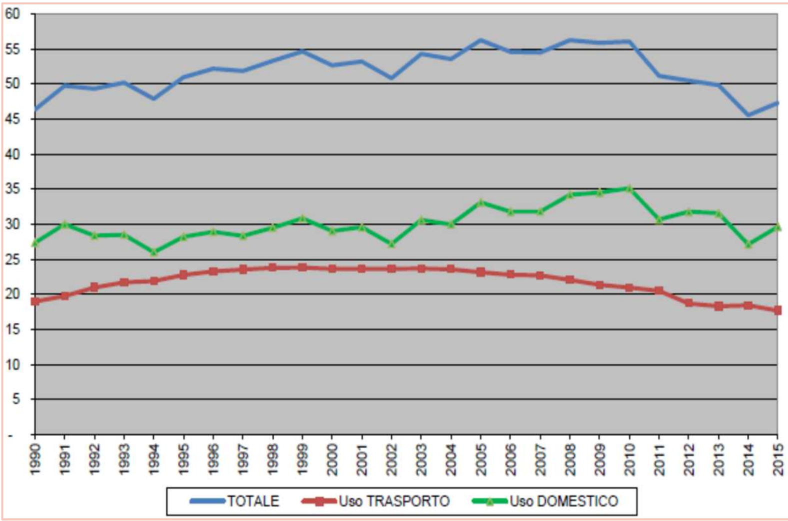


Figure 20. Energy uses (Mtep) of households, by type of use and product used. Source: Istat.

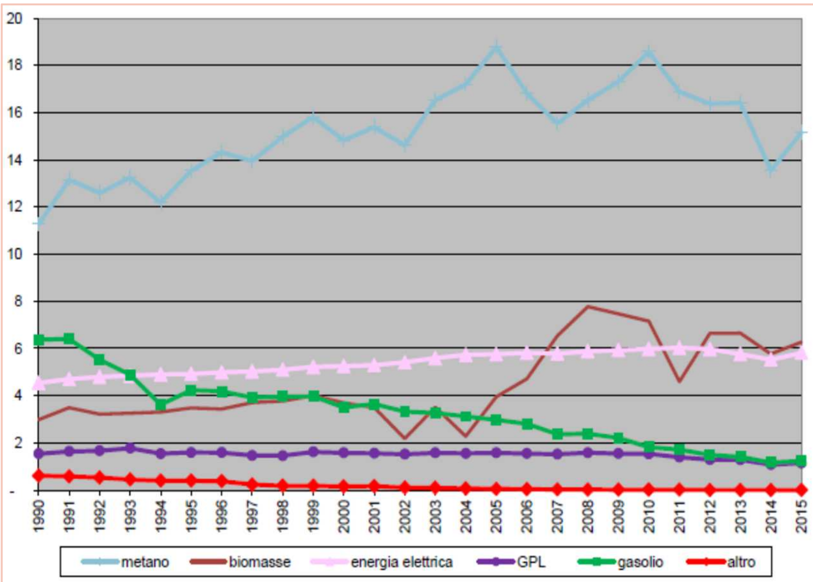


Figure 21. Energy uses (Mtep) of households by product used. Source: Istat.

3.3 Household's consumption and appliances analysed through Monitoring Campaigns

Concerning consumption, the devices present inside the houses and their uses, as already said, have undergone considerable growth both in number and as hours of use by consumers. The domestic sector alone consumes 25% of total final energy and covers about 30% of the electricity demand. This growing energy demand over the years has led governments to introduce numerous initiatives aimed to reducing above all electricity demand, such as energy labelling for all appliances, enhancing energy efficiency in buildings (EPBD[5]) and increasing energy end-use efficiency. Additionally, they proposed changes in taxation to provide financial incentives to increase the uptake of energy efficient services and appliances.

According to IEA [37], the energy consumption of information and communication technologies (ICT) has risen considerably in recent years and now it accounts 15% of global residential electricity consumption.

In IEA Member countries, one-third of the electricity produced is used to power all household appliances such as refrigerators, dishwashers, ovens, lamps and other common household devices.

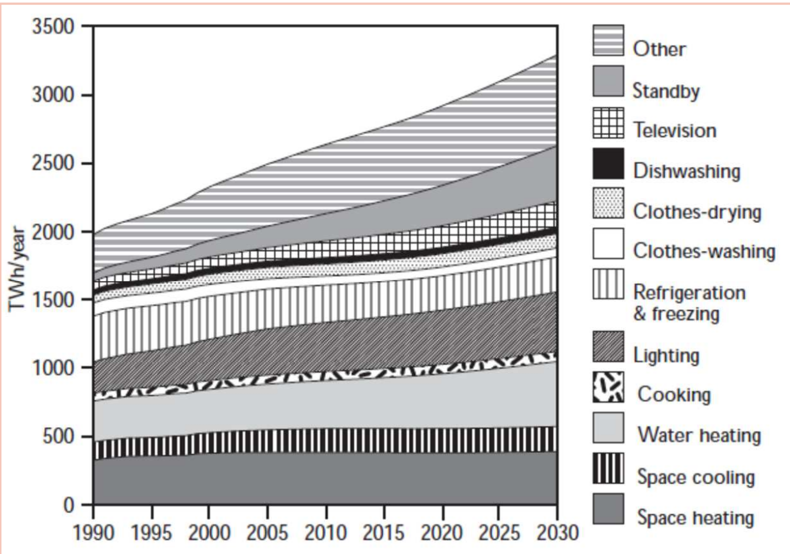


Figure 22. Projected IEA residential electricity consumption by end-use with current policies. Source [37].

[5] The Energy Performance of Buildings Directive (EPBD) is an instrument for enhancing the building regulations on energy performance of the building stock in the EU member states. The directive sets binding targets that must be transposed into national law and implemented via national regulations.

All appliances contribute to increasing the quality of life, but at the same time, they are also the cause of a growing demand for energy and greenhouse gas emissions. Electricity consumption per appliance in households in "real" situation (through monitoring) has not yet been very well documented; based on recent surveys, the total residential electricity consumption is apportioned to the different end-uses devices. For this reason, users in their homes have conducted many monitoring campaigns over the years to understand better the uses and habits of household appliances. Attention is focused on different household appliances (energy yields) and consumer behaviour. Some of the most important data reported were collected mainly in three campaigns: Eureco and Remodece (at the European level) and Micene (for Italy).

3.3.1 Eureco

The European Save project, called Eureco (2000-2001), is one of the campaigns to monitor electricity consumption in the domestic sector, which boasts one of the largest databases. It aims to raise awareness and increase knowledge in this sector in European countries [38]. This project has been developed by carrying out a campaign in about 100 families in four European countries, Denmark, Portugal, Italy, and Greece, to obtain consumption data for the main end uses of the domestic sector. This study collects the most relevant information available today in Europe, concerning the consumption of electricity in the residential sector, where it is possible to find the consumption and load curves of each type of monitored domestic appliance. Eureco actually follows an approach and methodology similar to an earlier project, i.e. Ecodrome (1995-1997) carried out in France, monitoring 20 families. The results of the French project showed that families could save up to 40% of the initial consumption of electrical equipment using efficient appliances, with an average saving of 1200 kWh/year per family.

The objective of the Eureco project was to verify whether the results of Ecodrome could also apply to other European countries. However, the method used for Ecodrome was not followed, which would have been too long, heavy and expensive to repeat in the various countries of the Eureco project.

For the Eureco project, 100 families were monitored in Denmark, 96 in Greece, 102 in Italy and 99 in Portugal (countries that could be the most representative at European level were chosen). In each family, the individual electrical end uses have been monitored every ten minutes, for a whole month, while the characteristics of the monitored sample and the load curves of the samples were reported for each type of end use.

The objectives pursued by the Eureco project were three:

- To describe the status of household appliances in the countries in the most detailed manner possible.
- To discover new trends or consumption, which have not yet been well defined and understood, to be able to anticipate future trends.
- To evaluate the potential savings that could be achieved in the domestic sector, thanks to the replacement of existing equipment by more efficient appliances, and to confirm or not the results of Ecodrome.

The chosen devices to be monitored have been divided into two lists:

First list:

- General consumption of families;
- Cold appliances;
- Lighting;
- Audio-visual Systems;
- washing machines;

Second list:

- Dishwasher;
- Boiler circulation pumps;
- Personal computer;
- Conditioned air.

The measurements made during the measurement campaign used the Diace system for monitoring domestic electrical equipment, which allows individual measurement of energy consumption and absorbed power, while a special device monitored the light sources electronic system called Lamp meter.

In these monitoring campaigns, there are several important aspects to refer to, such as geographic location, housing size, family unit composition, supply contracts, etc.

The Eureco project focuses on that part of consumption that concerns the electrical part and not the thermal part, which, however, during the monitoring campaign, identified that a good part to produce ACS concerns more the thermal and electrical consumption, especially in Italy and Portugal. The data obtained during the monitoring campaign also made it possible to elaborate general data on total electricity consumption in the four sample countries, both per inhabitant and family. The processed data also show detailed graphs with the load curves of the four sample countries during the different hours of the day, highlighting the end uses for which the electricity is consumed (Wh/m2). The summary charts with the percentage distribution of which devices consume at peak times in the months of December and July are also interesting.

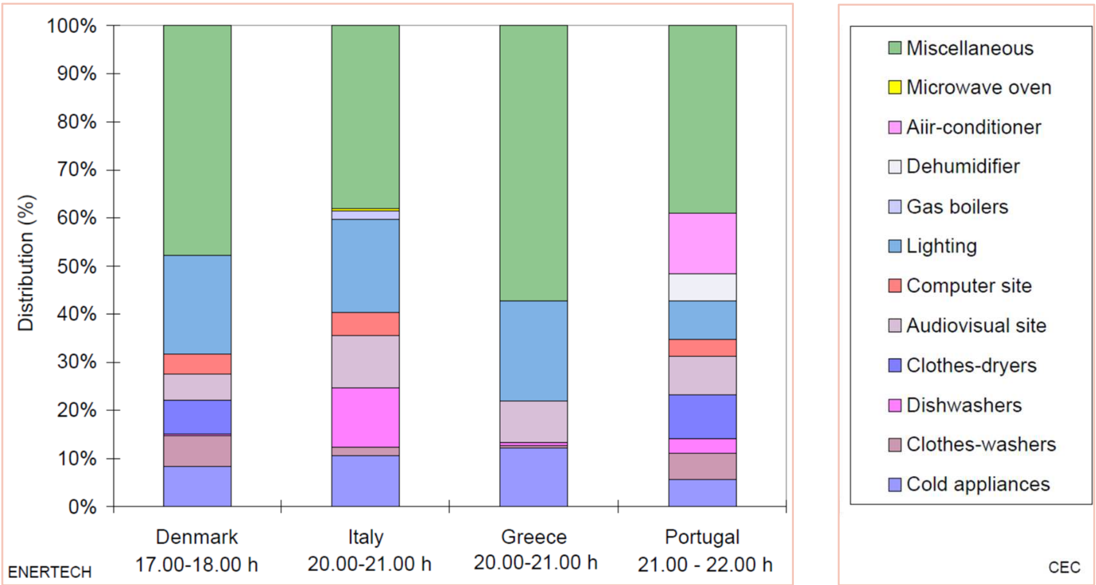


Figure 23. Structure of the power of the appliance demand during the peak-hour in December. Source: Eureco Project.

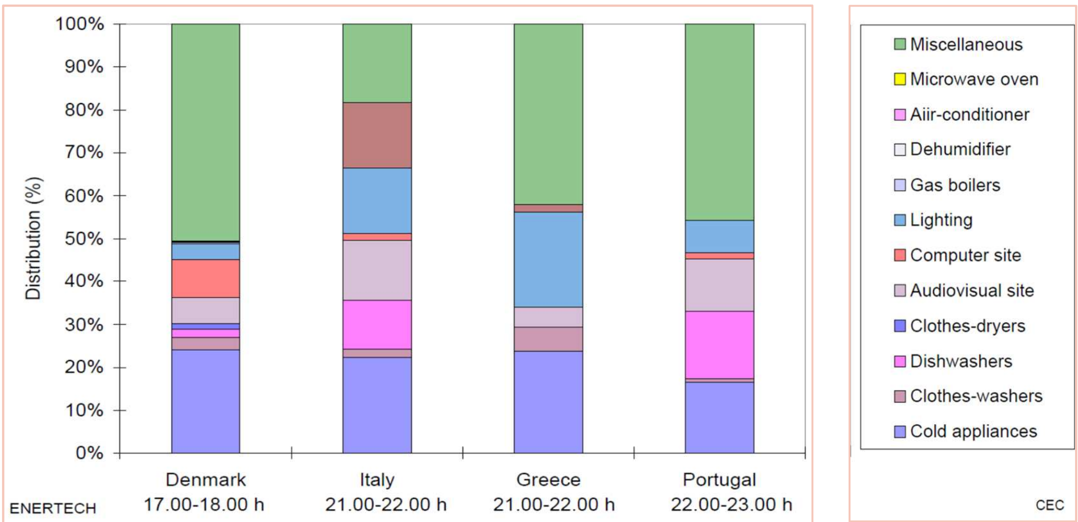


Figure 24. Structure of the power of the appliance demand during the peak-hour in July. Source: Eureco Project.

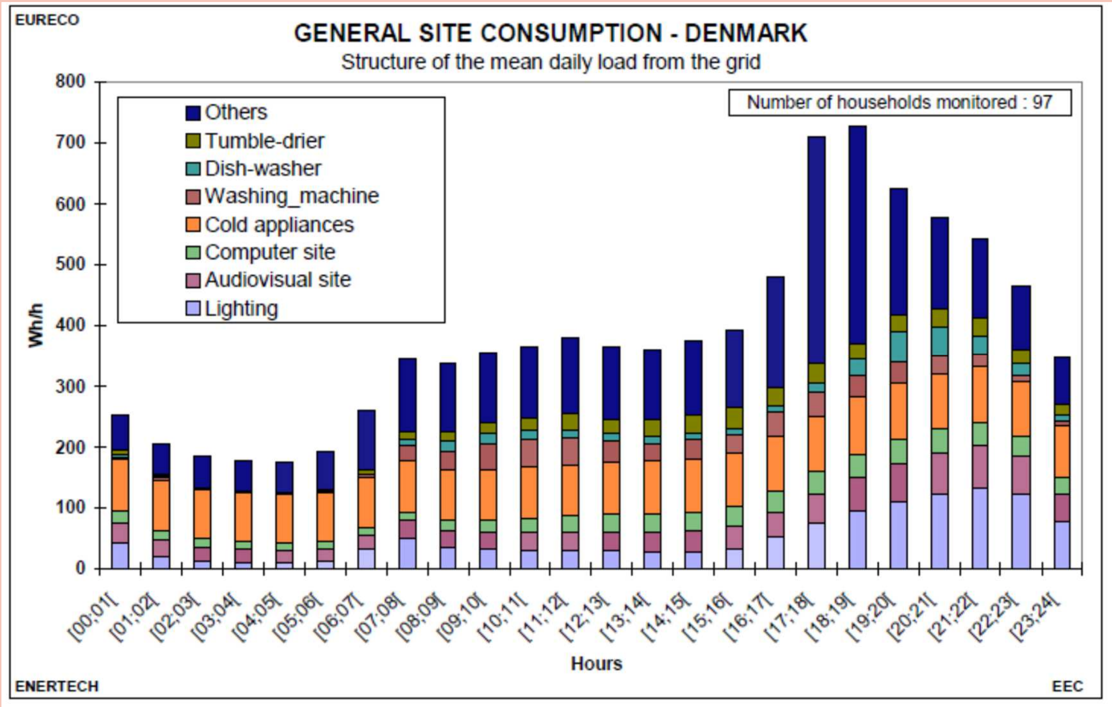


Figure 25. Structure of the load curve (yearly average), Denmark example. Source: Eureco Project.

This structure has been obtained by monitoring the different types of luminaires, systematically checking only the luminaires of the first list (cold appliances, lighting, audio-visual equipment and dishwashers). In fact, the minimum values are shown on the graphs. For this reason, the part of the "Miscellaneous" appliances is also important: in this group, all the unmonitored devices are included (e.g. the standby and water heaters and small kitchen appliances).

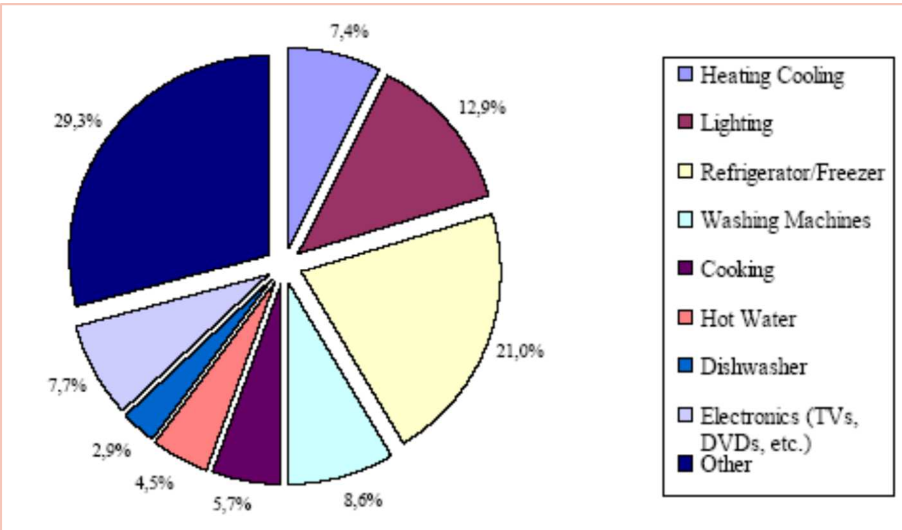


Figure 26. The main end uses of residential electricity consumption in EU countries, 2004. Source: [50].

Comparing the previous graphs of the Eureco project with the graph extracted from Energy efficiency in Domestic Appliances and Lighting, Proceedings of the 4TH International Conference Eedal 2006 (Figure 23), we can see how effectively the percentages of consumption of final uses - coming from the four sample countries of the Eureco project - show a correspondence also with the results that show consumption at European level. In fact, we see that the largest percentage is attributed to "other uses", followed by "appliances for the cold" and "lighting".

Returning to the Eureco project, in addition to the more general data seen above, the annual energy consumption and the profiles of the power demand for each individual monitored device has been also analysed. Depending on what is most appropriate for the different equipment families, the load curves are analysed on an hourly, daily, weekly or monthly basis.

It has been also paid attention to observe the different consumptions of the appliances, according to their age. It has thus been possible to ascertain that, for example, what really affects consumption for washing machine washing cycles is not the age of the appliance but the temperature of the washing cycle.

For the analysis of consumption concerning artificial lighting, the starting point was the subdivision by type of light source present in the four countries, followed by the distribution of the various light sources in the different rooms of the houses. The obtained data showed that in the four monitored countries, the largest electricity consumption occurs in the Lounge - Living room - Dining room (1/3 of the total consumption), followed by the kitchen or the bedrooms, depending on the country. So, living room and kitchen lighting together with 50% and 55% of total lighting consumption. Finally, it can be noted that in some countries bathroom lighting consumption is higher than the lighting consumption of all the bedrooms taken together.

This monitoring campaign also identified how potential energy savings could be achieved, for example [38]:

- Replacement of cold appliances with the most energy efficient models available of the European market. In Europe, the most energy efficient appliances are rated with an "A" on the European Energy Label;
- Replacement of incandescent and halogen lamps with compact fluorescent lamps;
- Reduction or elimination of the standby power waste whenever possible;
- Replacement of clothes washers by class A model, or using cold temperature wash.

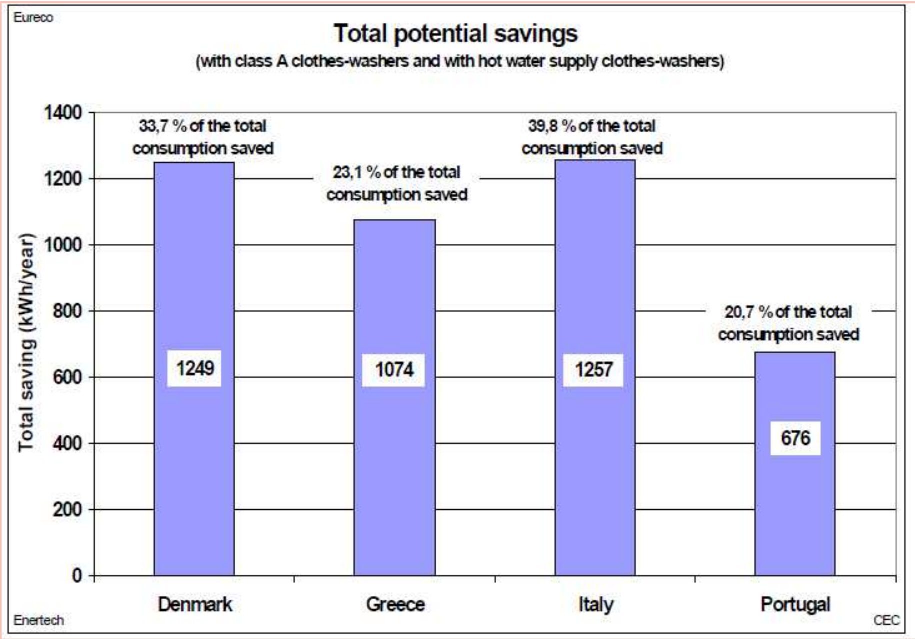


Figure 27. Assessment of the total potential savings. Source: Eureco Project.

3.3.2 Remodece

Another important project, similar to the French campaign Ecodrome and Eureco, is **Remodece** [39] that has as its goal the understanding of current and impending electricity uses by European households resulting from different types of equipment, consumers lifestyles, and comfort levels.

This project was not limited to this, in fact it also assessed the potentially saved energy by introducing more efficient equipment and reducing the standby consumption of various devices.

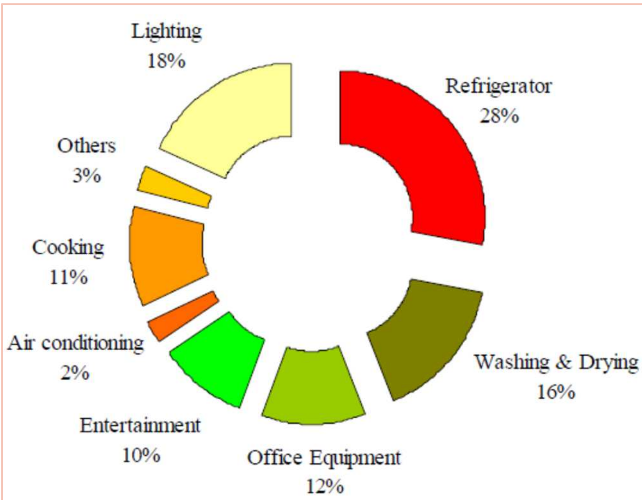


Figure 28. Disaggregation of end-use electricity consumption (Excluding Electric Space and Water Heating). Source: Remodece campaign.

The Remodece Project (2006-2008) was carried out in 12 European countries (Belgium, Germany, Greece, Bulgaria, Czech Republic, Portugal, Denmark, Hungary, France, Norway, Italy and Romania).

The Remodece monitoring campaign recorded an average annual electricity consumption per family of 2700 kWh (excluding space and water heating). He also highlighted how e-loads (office and entertainment equipment) account for 22% of household electricity consumption. For refrigeration, most of the household's total electricity consumption is required (28% for refrigerators and freezers). The third largest final consumer of electricity is lighting, with 18% of the total. Standby accounts for around 11% of total consumption, mainly present for office equipment and entertainment devices. The following figure shows the load curves of a typical European family on a typical weekday day (it shows the data taken from the monitoring campaign).

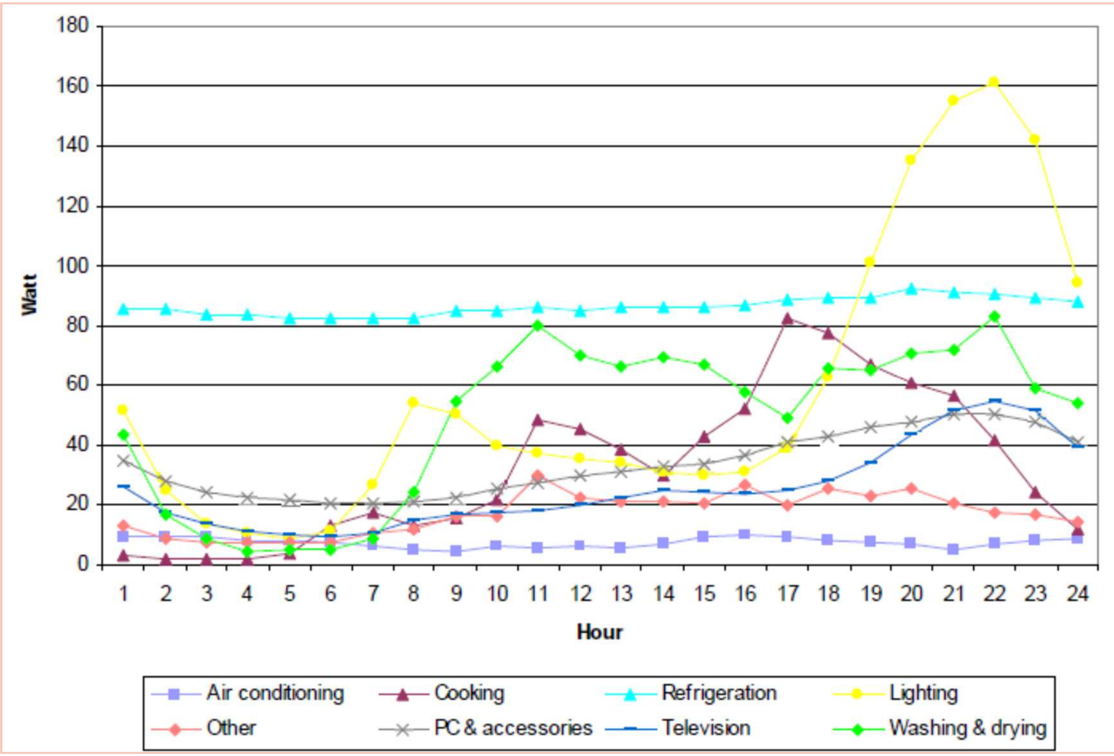


Figure 29. Electricity consumption of household appliances for a typical family on a typical day of the week. Source: Remodece campaign.

The REMODECE project limited itself not only to data collection but also recommended various measures and suggestions to save electricity, through proper selection and operation of household appliances. Certainly, one of the main changes could result from the adoption of Best Practice and Best Available Technology (BAT). Following these precise recommendations, households can reduce electricity consumption by about 48% of total consumption, or about 1300 kWh. This reduction in electricity consumption can result in around 72 million tonnes of avoided CO_2 emissions per year. Speaking at European level

(EU27), the savings potential would amount to around 268 TWh. The following figure shows the annual electricity savings obtained by switching to BAT in a typical family.

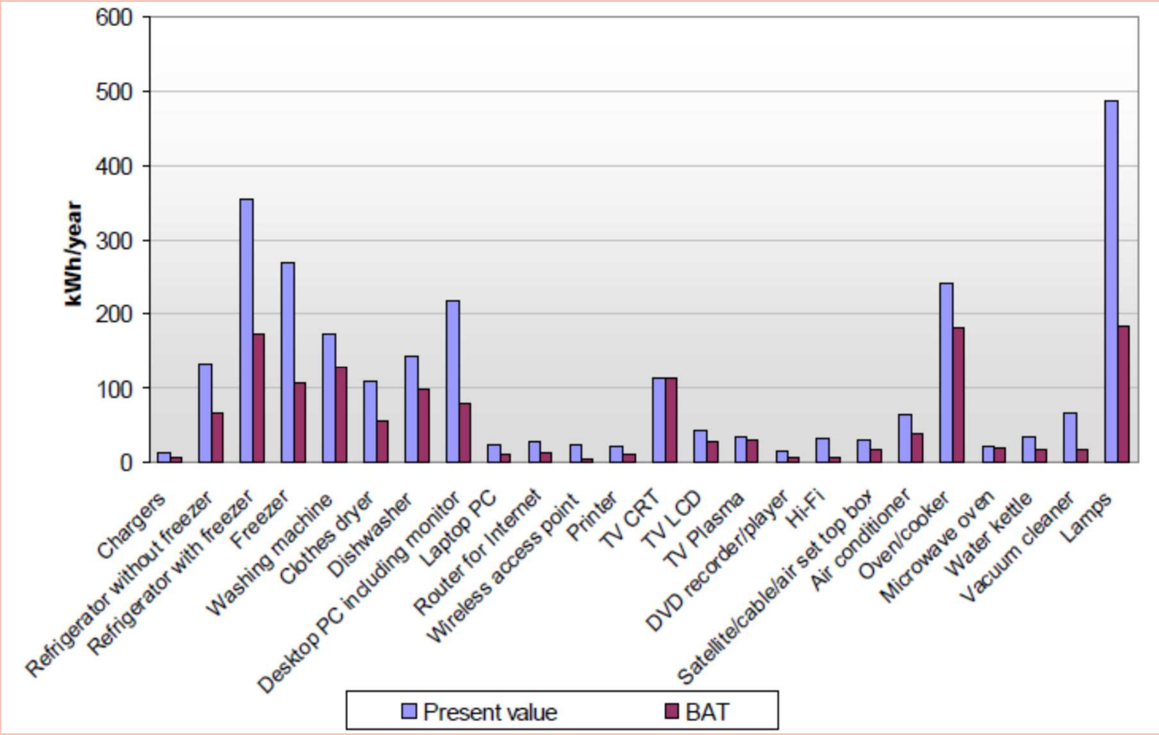
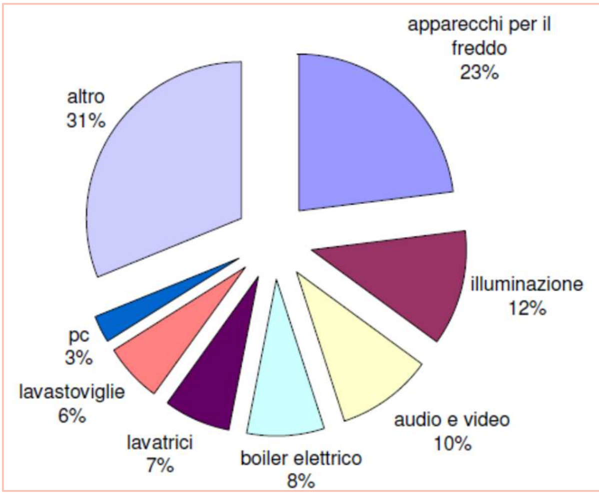


Figure 30. Electricity savings potential per household and appliance, by switching to the BAT. Source: Remodece Campaign.

In order to save electricity, Remodece suggest some steps: replace all compact fluorescent lamps with LED lamps; switching to A + and A ++ devices; reduction of devices left in standby; using washing machines with washing cycles at lower temperatures and at full load; preferring to plasma TVs, LCD TVs; purchasing energy-saving equipment with ECO labeling, using night-time ventilation for free-cooling in the summer; using solar panels, etc. The most important criteria for buying a new domestic appliance result during the campaign is the price, followed by the electricity consumption, the capacity, the comfort of use and less important are mentioned the design and the external dimension.

3.3.3 Micene

Within the European Eureco project, in Italy a monitoring campaign called the Micene project has been organized in 110 dwellings, a project that represents the largest database of this kind in Italy in the domestic sector. This project monitored: lighting, cold appliances, dishwashers and washing machines, audio-visual equipment, electric water heaters, and personal computers. For the monitoring campaign, families with a large number of household appliances have been selected in order to monitor the largest number of devices; for the rest, it has been decided to touch different geographical areas and to alternate metropolitan areas with areas of the province. Almost all houses have a supply contract with a committed power of 3 kW and households are of two people in 9% of cases, 3 in 34%, 4 in 43% and 5 in 14%. The food preservation sector is the one that has improved its performance most effectively following the introduction of the labelling of household appliances. In this sector, it is worth choosing the best model available and in some cases, replacing obsolete equipment, since it represents one of the highest percentages of domestic consumption.



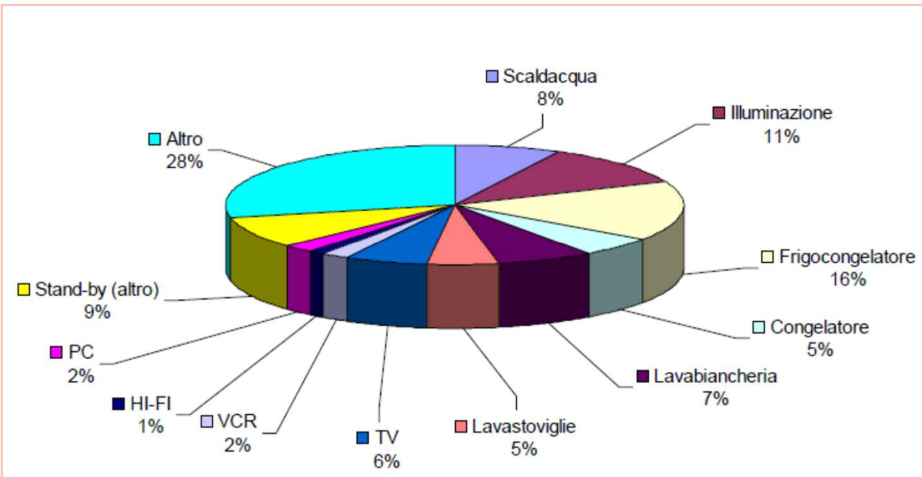


Figure 31. Disaggregation of end-use electrical consumption in monitored dwellings. Micene campaign

Sales data from 2005 of cold appliances [40] show that in some markets class A + appliances are beginning to have an important market penetration at European level; the spread of class A appliances reached 60% of sales, with 9% for the A + class. In all countries, the spread of class

A and A + appliances strongly increased in 2005 compared to previous years. Compared to the markets of France, Spain, Russia, Denmark and Great Britain, the Italian one is the most "virtuous" market in Europe, with 68% of all new models presented in 2007 in class A +/A ++. Also as a result of the results obtained [41] it was, therefore, possible to state that, in the case of freezer cabinets, consumption varies considerably according to age (the newer appliances consume less energy). For cold appliances, the average daily load curves show that there are no sharp peaks, the overall power demand is almost constant in 24 h (with slightly hinted peaks in the evening hours and at lunch hours, resulting from the larger openings from users). As for the Eureco project, also in the Micene project the annual consumption of the washing machines is on average equal to 208 kWh, considering that in Italy about 38% of the monitored devices are aged over eight years. On average, about 280 washing cycles per year are carried out and about 60% of the cycles are carried out at 30-40°, 26% at 60 °, only 6% at cold and the remaining 9% at 90 °. The consumption depends mainly to the temperature of the cycle (as shown in table 7). Therefore, it is possible to reduce drastically your consumption for washing laundry by changing your habits, much more than buying an efficient washing machine, but also by reducing the number of washing cycles. Also for the dishwasher [41] (with an average annual consumption in a sample of 60 appliances, equal to 369 kWh, with an average consumption of 1450 Wh per cycle) the same considerations apply to the washing machine.

Cycle temperature	Energy consumption [Wh]	Cost [€cents]
Cold cycle	149	2,5
Cycle 30° - 40°C	497	9
Cycle 60°C	1097	20
Cycle 90°C	1800	32

Table 7. Consumption and cost of washing machine cycles depending on temperature. Source: Micene campaign.

From the Micene project it appears that, as already seen from previous data, lighting represents a considerable aspect in the domestic consumption sector. The average annual consumption provided by the Micene project for lighting is 375 kWh/year, while ENEL provides an average of 293.81 kWh /year (average from 1986 to 1996) and the International Conference Eedal 2006 370 kWh/year [41].

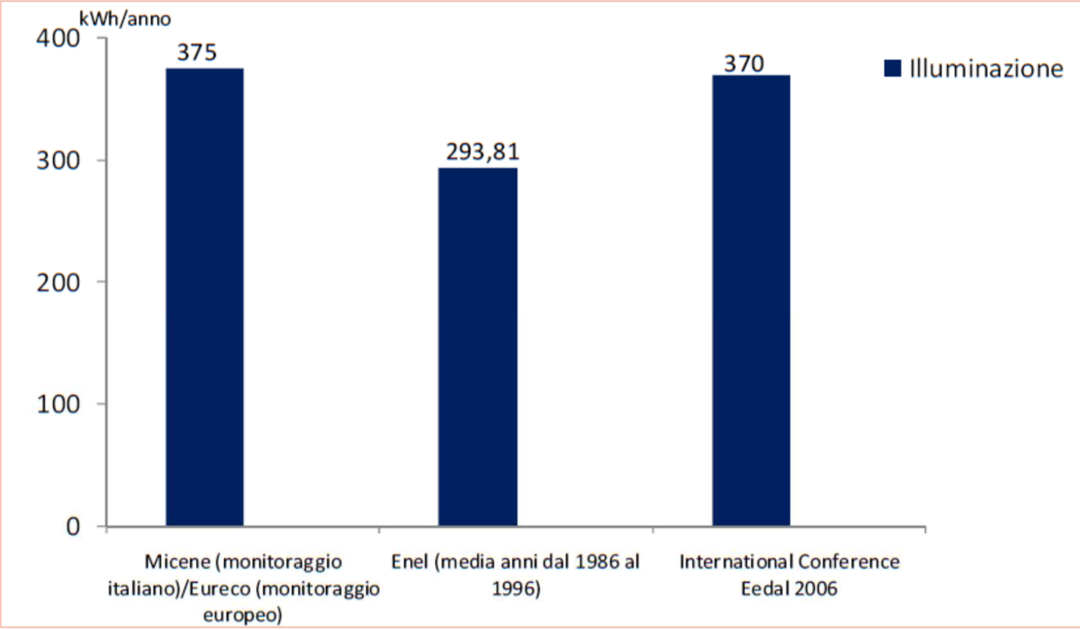


Figure 32. Comparison of the average annual consumption for lighting. Source: Micene campaign.

In the case of audio-visual equipment, overall measurements have been made of the main audio-visual site, usually consisting of a television set, a video recorder and other devices such as a decoder or a PlayStation console. The average power absorbed by an audio-visual site was equal to 160 W in terms of use. The maximum value is 305 W, while the minimum value is 40 W (HI-FI system only). The average annual consumption was analysed for the sites monitored with the Diace device. The average value is 355 kWh/year, while the maximum value is 1000 kWh/year (in a site that includes 2 televisions and a Hi-fi system). The dominant class is that between 200 and 300 kWh/year. The electricity consumption of these devices is reported according to the technology. In this sector are the TV screens that represent the highest electricity consumption (linked to two main types of displays: LCD and plasma).

Chapter 04

4 THE NATIONAL ELECTRICAL SYSTEM IN ITALY

4.1 System structure: from production to end users

In order to ensure that the supply and demand for energy are always in balance, it is necessary to supply the amount of energy required by consumers on the net, moment by moment. The Italian national electricity system articulates in three phases: production, transmission, and distribution (and finally sale) of electricity. The flow of energy travels in a unidirectional way, from the place of production to that of consumption. Transmission lines, power stations and transformation stations are necessary for the management of the whole system: we are talking about a total of over 58 thousand km of lines owned and managed by Terna.

Furthermore, Terna manages the national transmission grid and the electricity flows through the dispatching service, balancing, i.e. the supply and demand of energy 365 days a year, 24 hours a day every day.

Currently, in Italy, the electric market is born as a result of Legislative Decree 16 March 1999, n. 79 (Bersani Decree) as part of the process of transposing the EU directive on the creation of an internal energy market (Directive 96/92 / EC repealed by Directive 2003/54 / EC). The market develops in several sessions managed by the Energy Market Manager (GME)[6]; these sessions take place more than a year before the delivery of electricity up to a few hours before. The most important market session is the Market of the Day Before session ("Mercato del Giorno Prima" MGP)[7], that hosts most of the electricity trading transactions and trades time blocks for the next day.

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[6] GME is a public limited company with the task of organizing and managing the electricity and gas market according to criteria of neutrality, transparency, objectivity and competition among producers, ensuring adequate availability of the power reserve.

[7] The Market of the Day Before (MGP) hosts most of the transactions for the purchase and sale of electricity.
On the MGP, time blocks are exchanged for the next day. The object of negotiation is, therefore, the program for the introduction and/or withdrawal of electricity.
The operators participate by presenting offers in which they indicate the quantity and the maximum / minimum price at which they are willing to buy/sell.
The meeting of the MGP opens at 8:00 of the ninth day before the day of delivery and closes at 12:00 of the day before the day of delivery.
MGP is, therefore, an auction market and not a continuous trading market. Accepted sales offers are valued at the equilibrium price of the area to which they belong (zonal price per hour). This price is determined, for each hour, by the intersection of the demand and supply curve and differs from area to area in the presence of saturated transit limits (system marginal price). Accepted purchase offers are valued at the single national price (PUN) equal to the hourly average of zonal weighted zonal consumption prices.

The platform that manages the purchase and sale of energy is the Italian power exchange (IPEX, Italian Power Exchange). Here, the electricity producers or traders, who make up the offer, sell the energy and suppliers of the free market, the large consumers, the Single Buyer or the traders themselves, buying energy for themselves or energy destined to be supplied to third parties. The Electricity Exchange is not a compulsory market: in fact, the parties can conclude purchase and sale contracts also outside the platform through bilateral contracts (OTC).

In this context, Traders are natural or legal persons who purchase and sell electricity without carrying out production, transmission or distribution activities. It is a "wholesaler" of energy. Today, there are a large number of suppliers on the free market; there are more than 400 companies. The Single Buyer (AU) is very important, because it is a public company belonging to the GSE group (Energy Services Manager), whose main purpose is to guarantee the supply of electricity to customers served in the protected market. With the complete liberalization of the energy market, the consumer can choose the electricity supplier he prefers; however, he may decide not to choose a free market offer and to continue the supply relationship released from the market. The Single Buyer acquires electricity at the most favourable conditions on the market and sells it to customers of the enhanced protection service (i.e. those that do not benefit from the free market).

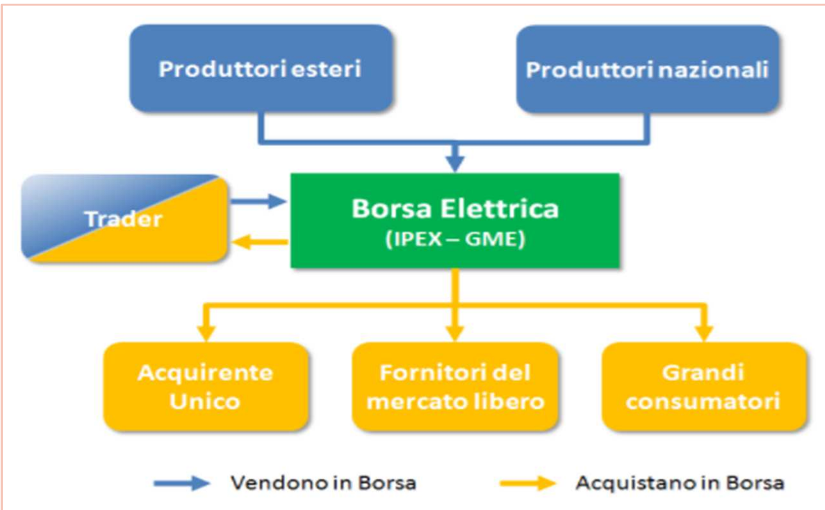

Figure 33. Operators that take part in the Italian Stock Exchange. Source: GME.

The price of energy determined by the electricity market is different according to the zone (zonal price), but the purchase offers are valued at a single national purchase price: the PUN,

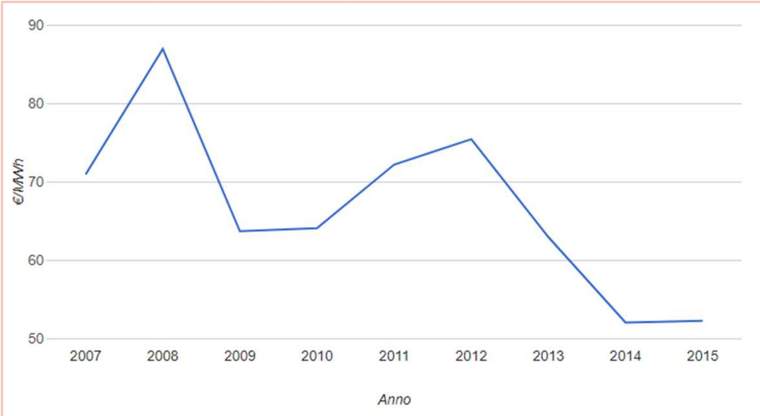

Figure 34. Electricity price trend, annual average values PUN. Source: GME.

which corresponds to the average selling price, weighted with total purchases. The exchange price is defined for each hour of each day on the basis of the match between supply and demand, in other words, only the sales offers are matched, corresponding to purchase offers that are willing to pay a price greater than or equal to the one requested. The PUN is variable every hour of the year with values that tend to be higher at peak times while it has lower values in the base hours.

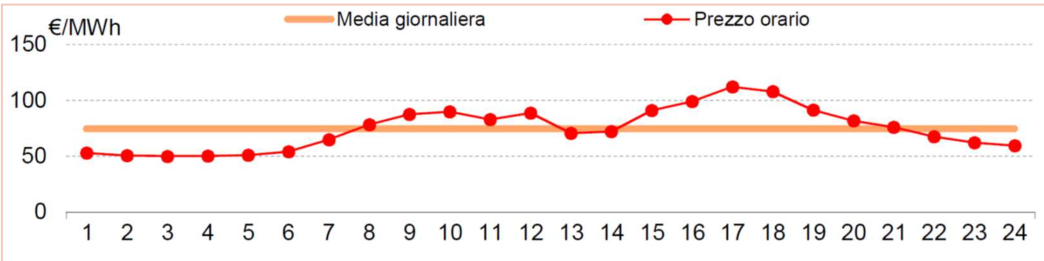

Figure 35. Purchase price, PUN of 11/28/2017. Source: GME

This trend reflects the dynamics of optimal electricity prices, given by the marginal cost of the last plant called to produce.

The plants that come into action first will be those with lower marginal costs (that's why during the base hours the prices are lower) while for power generation during peak hours it will be necessary to put into operation also the other plants with marginal costs more and more (the price during peak hours will, therefore, be higher).

However, the electricity market, which manages the wholesale sale of energy, represents only a part of the energy supply chain that goes from the producer to the consumer. We recall the structure of the Italian electricity supply chain: production, transmission (and dispatching), distribution and sale. The activities of **Production**, **Import**, **Export**, **Purchase** and **Sale** of electricity are free. Therefore, manufacturers, sellers and importers operate in competition. The State manages the Transmission and Dispatching activities and assigns them in concession to the National Transmission Grid Operator (GRTN) to Terna today.

Transmission is the activity of transport and transformation of electricity on the interconnected high voltage (greater than 35 kV) and very high voltage (greater than 150 kV), destined to delivery to customers, distributors and recipients of the self-produced energy.

Dispatching is the management activity of the energy flows on the network, it gives instructions for the coordinated use and operation of the production plants, the transmission network, and auxiliary services.

Distribution is the activity of transport and transformation of electricity on medium voltage distribution networks (higher than 1 kV) and low voltage (up to 1 kV) for delivery to final customers. Many distributors carry out the distribution of electricity under concession.

The supplier (or sales company) deals with the **Retail Sale** or the **Sale of Energy to the Final Customer** by purchasing the energy from the electricity exchange or directly from the producers. (Some suppliers are for example Edison, Enel, Eni, Sorgenia).

There are various types of customers:

- End customer: a natural or legal person who purchases electricity exclusively for his own use.
- Customer wholesaler (or trader): a natural or legal person that buys and sells electricity without carrying out production, transmission and distribution activities.
- Eligible customer: a natural or legal person who has the ability to enter into supply contracts with any manufacturer, distributor or wholesaler, both in Italy and abroad.
- Customer in greater protection: a final customer who is entitled to enter into supply contracts, under conditions defined by the Authority, with the sales company in greater protection that exercises the service in the area where the users are located. (e.g. low voltage domestic customer).

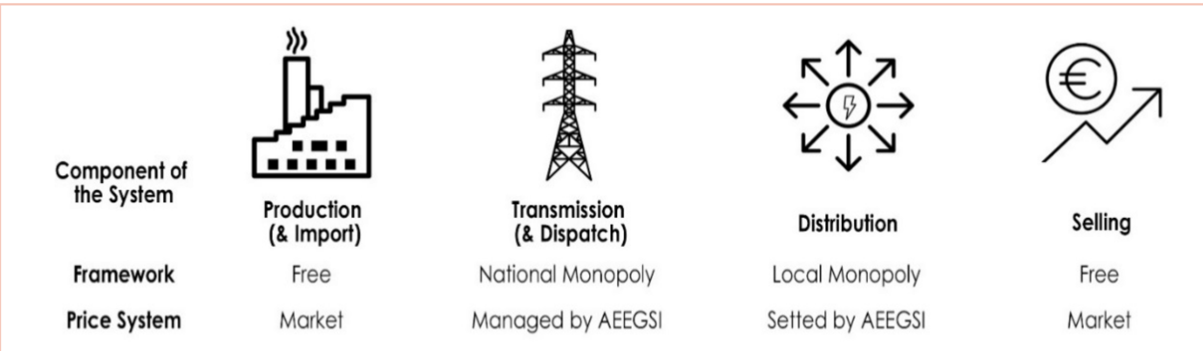

Figure 36. Structure of the Italian electricity system in the liberalized context. Source: the author.

4.2 Toward the liberalization of the Italian electric market

Before discussing the history that led to the liberalization of the electricity market in Italy, it is worth pointing out the difference between the term *Privatization* and *Liberalization* [42].

The term "privatization" refers to transformations of the corporate structure and sees the transfer of ownership of a public company to private individuals.

Therefore, privatization leads to the transition from public to a market economy.

Two phases of the process are distinguished: *formal privatization*, where there is the "legal transformation of the institution" and consists in the "change of the organizational structure from the public body (autonomous company, public body, entity managing state participation) to private (joint-stock company), while remaining under public control, since the State remains the owner of all the shares or the majority package"[8]. *Substantial privatization* is the next phase of the process. It takes place when, through different disposal policies, private individuals are involved in the capital of the privatized company (formerly public). That means "the process of progressive, total disposal of public participation by transferring shares of companies or entire share packages from the State to private entities, thus determining the actual transformation of the entity into a private law body"[9].

The aims pursued through privatization vary according to the needs of the individual State. In Italy, "the choice to privatize public bodies is justified, in addition to the need to meet the needs of the state budget and to reorganize the public debt, from various legal reasons both internationally and internationally."[10].

In Italy, the process of privatization of the electricity sector dates back to the law of 8 August 1992, n. 359 (conversion of Legislative Decree 11 July 1992, No. 333), which ordered the transformation of the public economic entity for electricity (ENEL) into a joint-stock company. In this way, formal privatization took place in Italy (modification of the structural form of the company), while substantial privatization (modification of the ownership structure of the company) was initiated by law 474 of 1994. The term "liberalization", instead, refers to the opening of the market "through the progressive reduction of constraints to its functioning and the removal of barriers to the entry of the State, especially about the performance of economic

[8] Sciascia M., *Diritto delle gestioni pubbliche. Istituzioni di contabilità pubblica*, Milano, Giuffrè Editore, 2013, p. 345.
[9] *Ibidem*.
[10] *Ibidem*.

activities"[11]. The process of liberalization aims to create a market that operates under competitive conditions, i.e. that leads companies and individuals to behave competitively.

The Law of 6 December 1962, n. 1643 (Law of *Nationalization*) led to the development of the well-known ENEL group (National Agency for Electricity) and its subsequent monopolization of the electricity market in Italy. This law unified and put an end to a fragmentation of the electricity market (that caused problems of stability, continuity, and quality of the services provided). About 1250 private electric companies became state-owned and the management has been entrusted to ENEL with the function of "ensuring, with minimum operating costs, the availability of electricity suitable for quantity and price to the needs of a balanced economic development of the country"[12]. ENEL received with the ownership of the activities of production, import and export, transport, transmission, distribution and sale of electricity on the national territory and the production by private individuals was allowed only if aimed at self-consumption. This choice was made since electricity is not an easily storable asset, the demand is subject to temporal and random variations, for transport it is possible to use only the already existing transmission network (the construction of new lines takes time and large investments) and is a good that requires ancillary services essential for the technical functioning of the electricity system and high investment costs, sustainable only with strong economies of scale; for these reasons, the electricity sector was almost a "natural monopoly" that was entrusted precisely to ENEL.

So, from 1962 until 1999, Enel held a monopoly on the electricity market in Italy. Starting from the year of acquisitions (1962) up to 1970 there was a considerable modernization and development of the electricity grid. Following the Chernobyl disaster of 1987 (which stopped using nuclear energy in Italy) and defined the new National Energy Plan (PEN 1988), the aim was to improve the processes of energy transformation, to reduce energy consumption and to improve the environmental compatibility conditions of energy use. Starting in the 1990s, thanks to first positive experiments such as the British one, an opening towards liberalization began to spread throughout Europe; on 16 March 1999, Italy also adopted Directive 96/92/EC concerning "Common rules for the internal electricity market". In fact, since 1991 a progressive process has begun, aimed at liberalization, which sees a change with respect to the previous ENEL monopoly, as on its own there was no certainty that it would be able to satisfy the continuous increase in the demand for electricity. This led to the approval of the Law n. 393/75, which allowed municipalities and provinces to produce electricity by incinerating municipal

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[11] De Vergottini G., La liberalizzazione dei servizi fra Stati e Unione Europea, in "Società Libera", 7° rapporto, Milano, Franco Angeli, 2009, p. 65.
[12] Law n. 1643 of 6 December 1962 "Istituzione dell'Ente nazionale per la energia elettrica e trasferimento ad esso delle imprese esercenti le industrie elettriche".

waste. Then with the Law n. 84/82, the National Committee for Nuclear Energy (CNEN) became the National Committee for Research and Development of Nuclear Energy and Alternative Energies (ENEA). In the same year, with the Law n. 308/82, the production of electricity from renewable sources was liberalized, but without any incentive. Few years later, in 1988, the new PEN has been approved, leading to an opening towards energy conservation and the development of renewable energy sources, despite nuclear energy. The ENEL monopoly finally ends in 1992 with the D.lg. 11 July 1992[13], when it is becoming the ENEL S.p.A, thus passing from having the right to manage the electricity service to having only the concession. The gradual liberalization of Italy has its climax with the "Bersani Decree" [14] (1999) with which Italy has implemented the European Directive n.92/96. With the legislative decree n. 79 of 16 March 1999 (Bersani decree), Italy implemented the community directive 96/92/CE, stating: "The activities of production, import, export, purchase and sale of electricity are free...The transmission and dispatching are reserved to the State and assigned in concession to the operator of the national transmission network ... The activity of distribution of the electrical energy is carried out under the concession regime issued by the Minister of Industry, Trade and Crafts"[15]. This decree actually led to the opening of the electricity market to other operators, which during the previous three decades were monopolistic. Before, a single vertically integrated operator (ENEL) in fact managed all the phases of the electricity system (production, transmission, dispatching, distribution, and sale). Today the National Transmission Grid Operator (GRTN) is a Ltd responsible for the development and promotion of renewable sources. The Bersani decree states that the GRTN "carries out electricity transmission and dispatching activities, including the unified management of the national transmission network ... it has the obligation to connect to the national transmission network all the subjects that request it, without compromising the continuity of the service"[16]. This decree also instituted the Electricity Market Operator (GME) and the Single Buyer (AU). The latter "acts as guarantor of the production capacity necessary to supply the regulated market, the management of contracts and the equal treatment of bound customers."[17]. The decree has ordered that the AU be the GRTN. Instead, GME has in charge the discipline and economic management of the electricity market.

Subsequently, the Marzano Law of 23 August 2004 provides for the reorganization of the energy sector and "intends to promote the effective liberalization of the market, favouring the

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[13] Decree Law of 11 July 1992 "Misure urgenti per il risanamento della finanza pubblica", converted into Law n. 359/1992 on August 8th.
[14] From the name of the then Minister of Industry, Pier Luigi Bersani.
[15] Legislative Decree 16 March 1999, n. 79, "Attuazione della direttiva 96/92/CE recante norme comuni per il mercato interno dell'energia elettrica".
[16] *Ibidem*.
[17] *Ibidem*

competitiveness of the system, avoiding discrimination in access to energy sources and ensuring the low cost of energy offered to customers. It does that not forgetting the improvement of environmental sustainability, in particular regarding the reduction of greenhouse gas emissions and the increase in the use of renewable sources of energy production"[18].

Pursuant to Resolution AEEG 107/2004, all natural or legal persons, whose purchase of electricity is not intended for their domestic use, are considered suitable customers, while, from 1 July 2007, all customers are eligible and free.

[18] Pozzo B., *Le politiche energetiche comunitarie: un'analisi degli incentivi allo sviluppo delle fonti rinnovabili*, Milano, Giuffrè Editore, 2009, p. 82.

Chapter 05

5 OLD AND NEW FORMS OF PRICING OFFERS

5.1 Italian fare

In Italy, there has not yet been a real liberalization of the electricity market, but ENEL took some steps in this direction since it had a monopoly on all phases of the electricity supply chain before the Bersani decree. Those phases are generation, transmission and dispatching. Instead, for the distribution of electricity, the local networks were in concession and active both in the sale and in the distribution. The sale, carried out by the distributor, provided for regulated tariffs. Furthermore, it was not possible for the end customer to choose the supplier. Following the first liberalization, the generation and sales phases are open to competition, while the transmission phase is a natural monopoly entrusted to TERNA, which since November 2005 has owned and operated the network. The transmission and distribution phases have to follow by some rules and the tariffs, established by the AEEGSI, apply uniformly throughout the national territory. The GRTN sold the management of the network, remains in charge of the management, incentive, and development of renewable sources, and becomes GSE (Energy Services Manager). The purchase and sale of electricity take place within the Electricity Exchange, managed by GME according to the system of offers, or through bilateral contracts. Following the (still "partial") liberalization of the electricity market, numerous companies are involved in the generation, such as Enel, Edison, Endesa Italia, ENI Group, Edipower, Tirreno Power, Acea Electrabel, Saras Group, AEM; transmission and dispatching remains in charge of TERNA, owner of more than 90% of the network. ENEL Distribuzione, SET Distribuzione, AEC, SECAB, and some Municipalities carry out the distribution. The companies that deal with the sale are very many. These include EGL, ALPENERGIE, AMGA, ENECO, ENEL Trade and ENIPower and many others. Currently, in Italy, tariffs apply for the supply of electricity in the rooms used for housing. As already introduced in the previous chapters, electricity has a variable cost, determined primarily by the market balance between supply and demand and changes in production costs. In Italy, the Electricity and Gas Authority and the Water System (AEEGSI) for users of the protection market set the reference price of electricity quarterly. Those who choose to move to the free market can instead sign a contract with one of the many suppliers currently operating in the sector with the possibility of obtaining the most suitable economic conditions for their consumption profile. The AEEGSI has established three-time slots in which the price of energy varies according to the time slot during the day.

F1 (peak hours)	Monday to Friday from 8:00 to 19:00
F2 (hours in between)	Monday to Friday from 7.00am to 8.00am and from 7.00pm to 11.00pm
	and Saturday from 07.00 to 23.00
F3 (off-peak hours)	from Monday to Saturday from 23.00 to 7.00 and all hours of Sundays and holidays

Table 8. Time slots in Italy established by the AEEGSI.

During peak hours (F1) electricity costs more, during off-peak hours (F3) energy costs less and in the hours in between (F2), the price is a middle ground between F1 and F3. However, speaking about spending on energy matter, what does this price change depend on? The fundamental factor that implies the change in the price of electricity is the relationship between supply and demand: the more difficult it is to produce energy, the higher will be the price of light in that time slot; on the contrary, when there is little demand (for example, at night), the cost of electricity will be much lower.

Currently, the gap between the cost of daylight and night time light is no longer as large as a few years ago, as the trend of the PUN has changed in the various time slots. The reason why there was a major change was the greater use of renewable energy, which is able to produce more electricity during the day and consequently lowers the price. Starting from these time slots, the rates present in Italy are:

- **One-time-slot Rate:** provides an electricity price that is always the same throughout the day, regardless of when the consumption takes place. This type of tariff still exists in the enhanced protection contract, i.e. the one regulated by the AEEGSI only for users who do not yet have an electronic meter. For these users, the rate is set every quarter for the Authority. On the free market, however, it is possible for all to stipulate a supply contract with a one-time-slot rate. The sellers establish the conditions and the price of these contracts.
- **Two-time-slots Rate:** The Authority as a standard for all families who want to maintain the regime of greater protection and which have the electronic meter introduces this system. This is a tariff that only provides two prices: a higher one for consumption that takes place from Monday to Friday from 8:00 to 19:00 (band F1) and a lower one for consumption that takes place at all other times (bands F2 and F3). The Authority sets prices every quarter. This type of tariff is also available on the free market for all families that have an electronic meter. In this case, the prices are set by the sellers and clearly indicated in the contract.

- **Three-time-slots Rate (o Multi-Time Rate):** provides three-time slots, depending on the time of day and day of the week. The rate is divided into peak hours, hours in between and off-peak hours. The peak range (F1) has the highest electricity price, from Monday to Friday from 8:00 am to 7:00 pm and corresponds to the moment of maximum energy demand. Electricity, on the other hand, costs less in the hours in between (F2), from Monday to Friday, from 7.00am to 8.00am and from 7.00pm to 11.00pm, and Saturday from 7.00am to 11.00pm. The band with the lowest prices is called off-peak (F3) and goes from Monday to Saturday, from midnight to 7.00am and from 11.00pm to 12.00pm, and all hours on Sundays and public holidays. You can choose this rate only if you are a free market customer and you have an electronic counter.

The *One-time-slot rate* is only valid if you have consumption evenly distributed during the day or if you do not want to be worried about having to choose the most convenient time to consume electricity.

The *Two -time-slots rate* and the *Three-time-slots* rate agree to save if consumption is concentrated in the evening and on weekends. The *Three-time slots fare* is particularly convenient if you do not have problems to operate the appliances especially during the night or on holidays. Usually, young couples who spend the whole day away from home and concentrate their consumption on the weekend and in the evening hours choose the Three-time-slots fare. For the elderly and for families with children, on the other hand, a Monorail rate may be much cheaper.

The *Two-time-slots tariff* has been compulsorily introduced in Italy starting from 1 July 2010 for all domestic customers belonging to the "enhanced protection" service.

5.1.1 Electric bill structure

In the current Italian bill, however, the final price that we see to pay is given by the sum of several components and is not the only expense paid for the energy matter, which in fact represents less than half of what is paid in the bill. All the quotas that form the final price are set every three months by the AEEGSI for users of the protection market and are:

- **Spending on energy**: includes all those components related to the activities performed by the seller to supply electricity to the final customer. These include the items relating to the purchase of electricity, its dispatching and retail sales. In detail, it consists in a fixed portion and an energy consumption share, the price of which can be differentiated into time slots for users with electronic meters.

The following components are included in the item "Spending on energy":

- PE: Cost of electricity purchase. It is updated every three months by the Authority and includes compensation for network losses.
- PD: Expenditure for the dispatching service, ie the management of the flow of electricity in the network. Includes compensation for network losses.
- PPE: PE equalization component. It covers the difference between the actual cost of energy and dispatching and the amount paid by customers in the protection market for the same services.
- PCV: Marketing and Sale Price. It covers costs for the commercial management of customers supported by businesses.
- DispBT: PCV equalization component. It covers the difference between the actual marketing amounts paid and the management costs actually granted to protected companies.

- **Spending for transport and management of the meter**: it includes the amounts incurred for electricity transport activities on national transmission networks, local distribution networks and for metering activities, which include also meter management. It consists of a fixed quota, a power quota (dependent on the committed power) and a differentiated energy share for consumption brackets. The following components are included in the item "Expenditure on transport and management of the meter":
  - Tau1, Tau2, Tau3: To cover the costs of distribution, transport and measurement of electricity.
  - UC3: Equalization component, designed to cover the imbalances between the expected distribution and transport costs and the actual costs.
  - UC6: Component to cover loans to companies that manage networks for interventions aimed at improving the quality of services.
- **Expenditure for system charges**: it includes the fees intended to cover the costs related to general interest activities for the electricity system paid by all end users of the electricity service. These include the securing of nuclear power, incentives for renewable sources and the electric bonus (not paid by those who use it). It consists of a fixed quota and an energy quota, which varies proportionally to consumption.

  The following components are included in the item "Spending for system charges":
  - A2: To cover the costs of dismantling abandoned nuclear power plants. A portion of the revenue is allocated to the state budget.

- A3: To cover the recognized incentives for the production of electricity from renewable sources.
- A4: To cover the tariff concessions recognized for the railway sector.
- A5: To cover expenses for research activities in areas of interest for the national electricity system, the results of which are public.
- AE: To cover the benefits for manufacturing companies serviced in medium and high voltage that require high consumption of electricity.
- AS: To cover the energy bonus for domestic customers with lower income.
- UC4: To cover the higher costs of small electrical companies than those operating on the smaller islands.
- UC7: To cover the interventions for the promotion of energy efficiency among end users.
- MCT: Territorial Compensation Measures. Component to cover funding for territories that host nuclear power plants or plants related to the disposal of their fuel. A portion of the revenue is allocated to the state budget.

- **State taxes:** they consist in excise duties, due only to consumption of over 150 kWh / month in the home residence and calculated based on the current consumed, and VAT, equal to 10% for domestic use. Sales companies in the free energy market have the possibility to apply a different price for the energy cost component and therefore can offer more advantageous offers for different consumption profiles. Given the confusion that can create a bill where the real price of energy is masked by other components, from 1 January 2016 the AEEGSI has established that the bills of light must meet a set of criteria mainly aimed at increasing clarity and ease of reading. Among the main novelties we find:
- A more streamlined and modern format;
- Clearer terms;
- Essential items of expenditure well highlighted.

Other three items must instead be indicated, but only if they are invoiced, accompanied by the information necessary to understand the reasons for their application:

- Recalculations;
- Other consignments;
- Social bonus.

It must also be indicated the method of payment, the deadline by which the same must be done and the presence of any instalments.

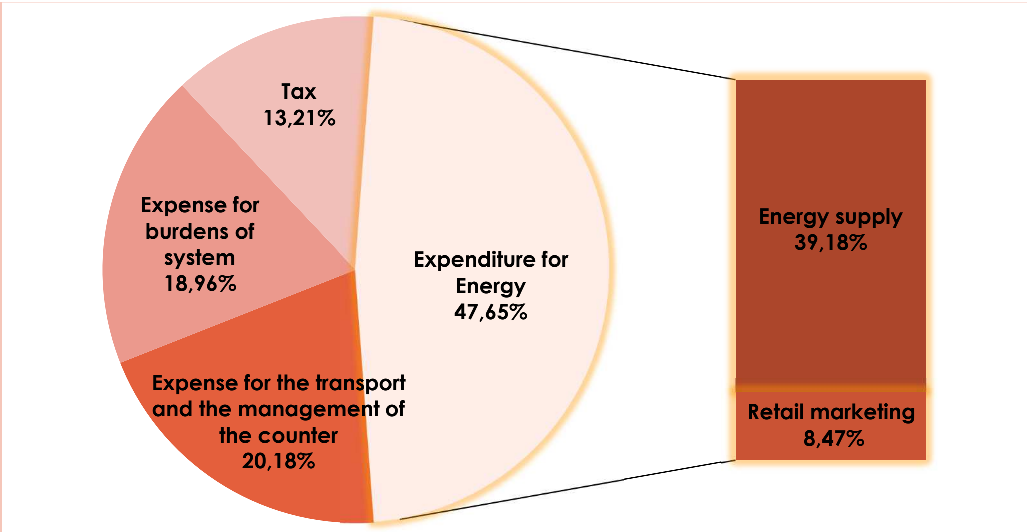


Figure 37. Percentage composition of the price of electricity for typical domestic consumers in Italy. 4th quarter of 2017, Gross price = 19.589 c €/K. Source: AEEGSI.

5.2 Dynamic pricing

The current tariffs illustrated in chapter 5.1 show that in Italy it is simple to charge electricity with options that provide constant prices or with a single price. The disadvantage of these tariffs is that of not being able to encourage customers to shift their demand for electricity and consequently not to reduce stress on infrastructures, especially during peak hours, i.e. when there is a greater demand for electricity. However, other countries apply tariff solutions that allow levelling the "peak-shaving" demand curve and increasing the efficiency of the system, pushing consumers to shift their consumption in certain periods of time when the cost it is undermining and the network is less overloaded. After the consultation phase envisaged by the DCO 36/09[42] (which confirmed the opportunity of the progressive exposure of customers to variable electricity costs over time), the Authority for electricity and gas and the water system (AEEGSI) approved the "Definition of a gradual instrument for application to domestic customers served in greater protection of sales fees differentiated by time slots" with the resolution ARG/elt 22/10. In other words, the introduction in Italy different electricity sales prices depending on the time of consumption, for domestic customers.

So, what pushed Italy to remain, for many years and still today, strongly linked to these tariffs? One of the main reasons is the type of consumption measurement technology, which has remained unchanged over the last 100 years, counting on simple electromechanical meters that had to be read manually; a completely manual reading approach that was carried out no more than once a month. This has pushed suppliers to offer "fixed" tariffs. This lack of granularity in data collection has countered the rise of new tariffs. This obstacle, however, could now almost be bypassed, above all thanks to the "digital revolution" of the last decades [43], which has brought new tools such as the "Smart Meters" (SM). Smart Meters today are more and more widespread all over the world. Some advantages: being able to provide more innovative pricing systems and promoting a more careful management of the demand by users. These SMs, unlike their predecessors, communicate energy consumption data with frequent intervals (e.g. 15 min or 1 hour), thus allowing the provision of tariffs that vary according to the hours of the day. These rates are collectively defined as "Dynamic Pricing". These tariffs related to the real cost of electricity allow the customer to always receive the correct price signal of electricity and to pay only the costs of the energy that is being used. Dynamic Pricing (DP) [44] is an important enabling factor for balancing power supply and demand, that is, the supplier is able to better manage the demand peaks and the user to develop his / her ability to save energy according to of the pricing opportunities proposed and implemented. The DP depends essentially on the following factors: tariff models and response from the end user (awareness / acceptance level).

Dynamic tariffs can be designed in various ways, depending on the pursued objectives and on the structure of the electricity market. The most common categories of dynamic tariffs are four: TOU (Time Of Use), CPP (Critical Peak Pricing), PTR (Peak Time Rebate), RTP (Real Time Pricing).

The DP establishes different electricity prices at different times of day based on the demand, available supply and estimated production costs in advance. For example, the energy consumed during peak hours, when the energy demand on the electricity grid is the highest, will cost a lot more to consumers than it consumes during off-peak hours. These tariffs in fact incentive through costs, to reduce their energy use, in order to reduce the stress of electricity grids. In fact, they introduce a method to fix the price of the most equitable energy, because with the non-dynamic tariffs even those who consume little electricity see their own energy costs increase because of those who create peak moments and their higher costs. Dynamic pricing programs benefit both consumers and energy providers. They reduce peak load, thereby helping utilities, businesses, and residential consumers balance supply and demand; they support utilities in meeting federal regulations; and they can lessen environmental impact.

Improving the industry load factor is one of the main objectives of Dynamic Pricing [45]. This is because electricity cannot be stored in large quantities, so electrical services and electricity generation must be able to provide their service even when the highest peak levels are required. However, when the uses are smaller than the peaks, parts of the structures used to meet the peak loads remain inactive, decreasing the efficiency of the system. The utility's load shape has a parabolic trend - rather than flat - that is, the use of energy varies throughout the days of the year. For example, there will certainly be a higher peak in the morning hours when people are getting ready to go to work, but it falls during the day when no one is at home and there is a peak in the evening when you return home.

Obviously depending on who lives at home there will certainly be variations, but the occupants are not the only reason for these variations; in fact, consumption varies a lot even as the seasons change. By providing a correct signal of the price of electricity, consumers will be able to know in advance when prices are higher (during peak hours) and when they are lower (off-peak hours) and encouraged by dynamic tariffs they can consciously decide to move its consumption during the hours with lower prices, thus reducing the demand in the classic peak hours.

With dynamic pricing programs, money would be saved and expensive investments for new infrastructure would be removed or eliminated. Consumers are treated more equitably and are encouraged not to overload networks and support local distributed generation. In this way, dynamic tariffs make it possible to increase the efficiency of the electricity system at every stage of the value chain.

Many utilities are changing the way they interact with their customers; through two-way communications between the utility and customers, utilities can implement Demand-Response and price programs, thus providing consumers with real-time information on consumption patterns that they have to follow and how to control them, saving energy and reducing energy costs. Several experiments (more than 130) with different forms of dynamic pricing in the US, Europe, Canada, and New Zealand in the last ten years demonstrate that with the new Dynamic Pricing:

- Consumers respond to the price of electricity actively;
- Consumer response varies with the price incentive. The higher the incentive, the greater their demand response;
- Consumer price response also increases with enabling technologies, these help consumers to understand their usage patterns while facilitating their ability to control automatically the function of their major appliances;

- Consumer response continues for many years.

Benefits to the Consumer

- Taking advantage of lower-cost to reduce their energy usage;
- Lower energy rates resulting in an overall reduction of consumers' energy costs;
- High customer engagement, satisfaction, and user experience with tools that deliver insight and control in an easy-to-use customer Web portal.

Benefits to the Utility:

- Reduce peak load, provide environmental benefits through possible emissions reductions, and help utilities to adjust to federal regulations;
- Increase utilities' economic efficiency and asset utilization;
- Increased reliability and security of the system;
- Increase the economic attractiveness of other technologies such as electric vehicles (rechargeable during off-peak hours).
- Facilitate fairness in retail pricing to support those costs;
- Benefit most low-income customers;
- Provide value to utilities in regulated environments.

5.2.1 TOU

TOU rates divide the day into periods of time (time slots) [43] indicating different tariff values for each period. By reflecting the average change in generation costs, the price is higher during peak and lower periods during off-peak hours. In some cases, TOU rates may have a semi-peak period or even two peak periods. This system based on "hourly" tariffs allows correlating the variability of the price paid by the customer to that of the supply costs but, at the same time, represents a form of protection for consumers who are not able to change their habits of consumption.

The awareness on the variability of electricity prices over time allows the customer to plan their electricity consumption in advance, moving them in the periods of time when the general demand for electricity (and therefore also prices) are lower: this favours the levelling of the demand curve (the so-called "peak-shaving") and increases the efficiency of the system. These rates have a simple design and are easy to understand for end customers. They also have the advantage of encouraging the adoption of distributed technologies such as electric vehicles:

electric utilities can in fact define time slots dedicated to recharging in which lower prices are offered. Finally, they do not necessarily require the implementation of advanced measurement infrastructures, still requiring instruments able to record consumption in the different time slots. However, TOU tariffs are not actually "dynamic" because they are not sensitive to the actual price changes of the wholesale electricity market. They are therefore not very flexible to integrate non-programmable renewable sources and manage problematic events in the network. TOU rates do not provide a strong incentive to reduce the load during peak periods.

5.2.2 CPP

With CPP rates, customers pay a constant tariff during all hours of the year except during some "event" days when wholesale prices are higher or when the electricity grid is severely harassed. In these days, during peak periods (fixed or variable) the price increases a lot, while, during the other hours off peak, customers receive a discount on the standard price of the tariff to keep the revenues of the supplier's constant. Customers get to know of a forthcoming "critical event" one day in advance. Like TOU fares, CPPs are easy to understand for customers. They give a strong price signal and provide the incentive for heavy load reductions during peak hours. Furthermore, they have higher prices during only a limited number of hours during the year. The acceptance of this type of fare is limited due to the relatively high price during the critical days. In addition, users, due to the fact of knowing whenever a critical event occurs, consider CPP rates more intrusive than TOU.

5.2.3 PTR

With PTR tariffs, users, compared to a baseline forecast, are paid to reduce their consumption during some critical events. If customers do not participate in the event, then they will pay the existing fare. These rates offer a discount during critical events by not increasing the rates in the remaining hours, so a customer's bill can only decrease in the short term. As a result, PTR rates are more accepted than CPP. The concept is also generally easy to understand for customers, providing an incentive to reduce demand during peak hours, similar to CPP rates.

PTR rates require the preliminary calculation of a baseline consumption profile for each customer, necessary to determine the individual discounts that has to be applied. While in the short term the PTR tariffs are a cost-effective proposal for all participants, it is possible that the tariffs will have to increase to cover the cost of the discounts in the long run. If the prediction of baseline consumption is not accurate, it is probable that the disbursement of the customer discount will exceed expectations and require a long-term recovery. The tariff options presented can also be offered in combination with each other to take advantage of the relative advantages of each. A commonly encountered combination is TOU-CPP. The subdivision into peak and off-peak periods of the TOU type reflect the change in energy costs appropriately while the CPP component reflects the cost of capacity during the most critical seasonal peaks. This combination offers customers greater savings potential, even if its complexity requires a level of awareness and extra customer focus to be effective. The different tariff options can also include seasonal differentiation

5.2.4 RTP

The RTP tariffs are related to the hourly market price of electricity; therefore, they represent the most flexible tariff type for the consumption shift by the user. Depending on the class of customers, participants can be informed of the hourly price trend one hour before or the day before. In general, they are mainly commercial and industrial customers who use this type of tariff. However, some energy utilities in the United States and the European Union (Nordic countries and Spain) offer RTP rates also for residential customers.

The main advantage of RTP tariffs is that they provide the greatest time granularity in transmitting dynamic and accurate price signals to customers willing to comply with these schedule changes. In general, without automated technologies, it is difficult for customers to respond to prices on an hourly basis.

5.2.5 Examples of dynamic pricing in electricity supplies

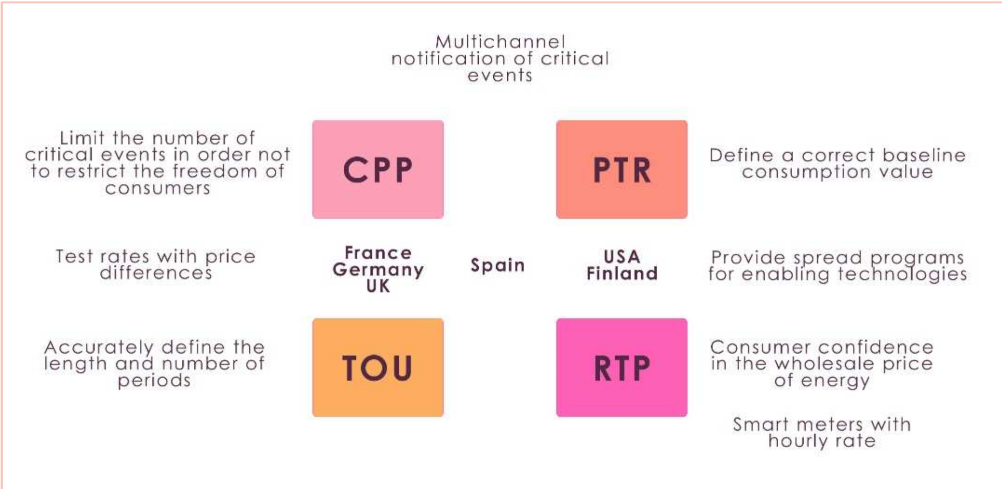


Figure 38. Dynamic Pricing: the different offers. Source: Energy@Home.

From the end user's point of view, tariff options are classified according to a risk/benefit scheme. In general, the options that offer greater benefits (in terms of savings potential), are also the most dangerous (in terms of exposing the customer to the volatility of wholesale electricity markets). User's propensity to risk will determine his choice of an option. The following Figure shows this risk/benefit ratio.

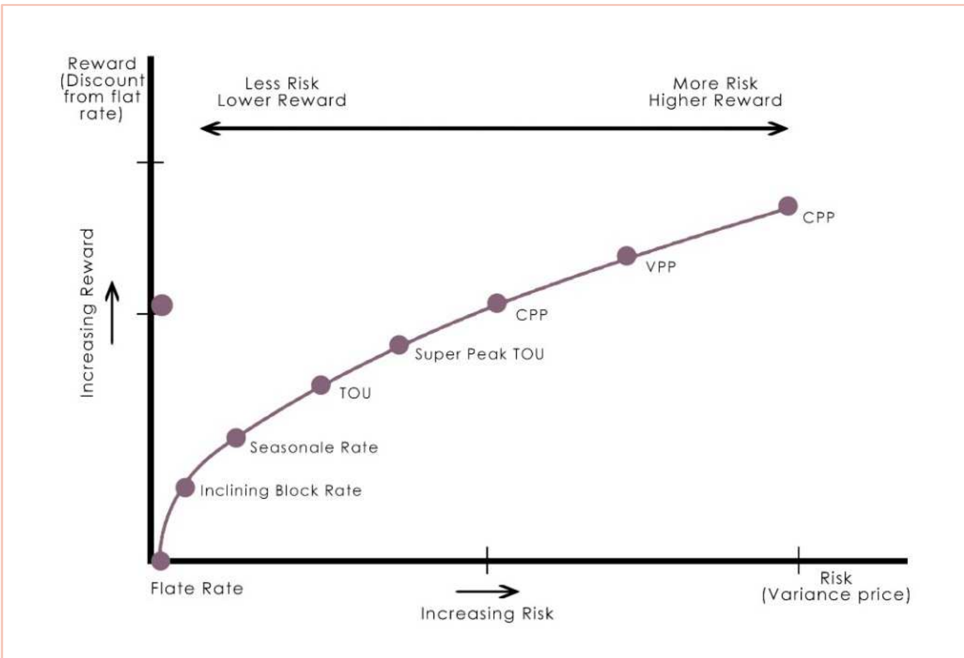


Figure 39. Risk/Benefit ratio in the various dynamic tariffs. Source: Energy@Home.

United Kingdom

The United Kingdom was the first country in Europe to make a first approach to the liberalization of the electricity market [43]. In fact, its reform of the electricity market is an example that all European countries should follow to achieve full liberalization; this model was the inspiration behind the directives of the European Commission.

The UK market has been opened and renovated with the Energy Acts of 1983 and 1989, preceding the first European Directive 96/92 / EC of 1996. The retail electricity market was completely liberalized in 1999. In the UK, seven DSOs distribute 326 TWh of electricity, according to EURELECTRIC's 2010 monitoring data. The CBA (Cost-Benefit Analysis) conducted in Great Britain, on the large-scale dissemination plan of Smart Meters, gave very positive results.

The measurement activity in the United Kingdom is competitive and the supplier is the owner, responsible for the installation of Smart Meters. A central hub gets the role of manager for granting access to metering data. The DCC (Data Communications Company) is the company designated by the OFGEM regulator to manage data and communication infrastructures to support the deployment of smart electricity and gas meters for homes and small businesses in the UK.

Meeting activities	Competitive
Smart meters diffusion	Compulsory
Responsible for installation and management of SM	Supplier
Responsible access to measurement data	Central Hub
Installation costs of the SM	Supplier

Table 9. UK-GB metering market. Source: European Commission - Benchmarking Report 356/2014.

The experimentation of variable tariffs over time in the United Kingdom started already in the '70s with the introduction in 1979 of the "Economy 7" tariff; in this tariff, the electricity that you use during seven hours at night costs less electricity than your use during the day. A variant at the "Economy 7" tariff was created in 2010 and is the "Economy 10" tariff and has the objective of facilitating users who use heating and domestic hot water production systems, with this tariff option in addition to 7 night hours are added three hours discounted rate even in the afternoon Both these options are classic TOU static as the two-hour rate currently in use in Italy, a more interesting dynamic TOU tariff option was tested in 2013 in the United Kingdom, namely: contains three different price ranges, deliberately chosen to have a strong contrast between high and low prices, but planning the tariff so that an average consumer would not have had variations in the cost of his bill, maintaining its standard consumption profile, compared to the flat rate. The values of the price bands were:

- High price = 67.2 pence/kWh
- Average price = 11.76 pence/kWh
- Low price = 3.99 pence/kWh

The standard rate for the non-TOU group was 14.23 pence/kWh. The average price of around 12 pence/kWh was used as a base rate while the high and low prices were used to generate test events of two distinct types, adapted to specific use cases:

- Constraint Management (CM): events aimed at measuring consumer response potential to alleviate network congestion, postponing network expansion and increasing the use of resources already available. In order to incentivize the greatest possible reduction in demand during the peak period, the high price at peak times was combined with a low price for the remaining life of that day.
- Supply Following (SF): they probe the consumer response to simple high or low-price signals of varying duration. The goal of these events was to quantify the potential for response to help the balance between supply and demand. In particular, they aimed to adapt the demand to the generation of intermittent renewable sources. In terms of savings in the bill, users belonging to the TOU tariff group have achieved average savings of around 4% per year.

For the first type of events the response of the users was greater in the case of a high price signal while for the second type the response was greater than the low-price signals.

- **Germany**

Before the liberalization of Germany's national electricity market (which was completely liberalized in 1998 with the Energy Industry Act), each area was served by a single supplier, thus with an almost monopolistic market. According to EURELECTRIC's 2010 monitoring data, there are 896 DSOs in Germany that distribute 511 TWh of electricity. The results of the Cost-Benefit Analysis (CBA) conducted in Germany have shown that in the case of an extensive dissemination of Smart Meters (at least 80% of all consumers by 2020 as requested by the EU) the costs of Intelligent measurement for end users with low annual consumption levels would have been higher than the average savings achievable. The analysis instead encourages the use of smart meters for consumers with an annual consumption of electricity above 6000 kWh, for this reason, in Germany, the plan to replace traditional meters with Smart Meters is limited to about 30 %. The measurement activity in Germany is competitive, the distributor is the owner and responsible for the installation of the Smart Meters, however, the consumer is entitled to the choice of a third party as a metering operator.

Meeting activities	Competitive
Smart meters diffusion	N.A.
Responsible for installation and management of SM	Metering operator (DSO)
Responsible access to measurement data	Metering operator (DSO)
Installation costs of the SM	N.A.

Table 10. Germany metering market. Source: Staff Working Document 188, "Country fiches for electricity smart metering", 2014.

In Germany, there is currently no national plan to spread the Smart Meters because the CBA has given a negative result for a large-scale dissemination. Therefore, the individual energy utilities define the installation of the new meters and the provision of dynamic tariffs. An example is the Stadtwerke Bielefeld, which, as a local energy retailer, offers a TOU electricity tariff consisting of four price levels called "EnerBest Strom Smart". The targets are residential customers and small businesses.

Weekdays are characterized by four price levels:

- Night time band: from 10.15 to 6:15
- Headband from 6:15 to 11:30 and from 17:00 to 19:00
- Peak time from 11:30 to 12:30
- Band from 12:30 to 17:00 and from 19:00 to 22:15

Saturdays and public holidays are characterized by two price levels:

- Night time from 10.15 to 6.15
- Daily range from 6:15 to 10.15pm

According to the utility under favourable conditions, it is possible to achieve annual savings of up to € 150 per year by adopting this tariff scheme (around 10% for a user who consumes between 5,000 and 7,000 kWh/year).

France

In contrast to the British model, there is the liberalization process followed by the French electricity market. France was one of the last European countries to start the reform of the electricity sector, starting from the 2000s, when the law to implement the 1996 directive passed. As a result, this reform has not produced major changes in the French electricity market, which has always undergone a strong State intervention, with a company with a huge market power, EDF (Electricité de France), with over 90% of the share of generation. France began to privatize the national utility on June 29, 2004, encountering strong opposition from the EDF Company; the aim was to open up to 30% of the market to private investors (the lowest level foresaw by the directive). The liberalization process managed by the independent regulatory authority, CRE (Commission de Regulation de l'Electricite), also included the unbundling of the electricity transmission and distribution sectors and the creation of a market platform for energy electricity (Powernext) by the end of 2001 and the possibility for the consumer to choose the electricity retailer. However, the approved unbundling scheme consists only of a form of accounting separation between transmission and generation, essentially maintaining the vertical integration of the electricity sector. According to EURELECTRIC's 2010 monitoring data, in France, there are 158 DSOs that distribute 384 TWh of electricity.

In France, an official CBA was carried out to define the Smart Meters roll-out plan and two scenarios were considered, with different assumptions regarding the growth prospects of electricity tariffs:

Scenario 1: average annual increase in electricity tariffs of 2.3% from 2010 to 2020 and 1.8% after 2020;

Scenario 2: average annual increase in electricity tariffs of 5.75% from 2010 to 2020 and 1.8% after 2020.

The measurement activity in France is regulated and the distributors are the owners and responsible for the installation of the Smart Meters at the end users.

Meeting activities	Regulated
Smart meters diffusion	Obligatory
Responsible for installation and management of SM	DSO
Responsible access to measurement data	DSO
Installation costs of the SM	N.A.

Table 11. France metering market. Source: Staff Working Document 188, "Country fiches for electricity smart metering", 2014.

Very high consumption peaks that have continuously increased over the last 40 years characterize the French electricity system, which leads to further investments in transmission and distribution networks and production plants. In this context, France has set up and tested dynamic tariffs that encourage consumers to reduce their consumption during periods of high demand. The French utility EDF tested "Time" rates since 1989, offering them to residential customers since 1995. This structure is of the TOU type coupled with a CPP pricing structure. The tariff system consists of six price levels, which divide the year into three types of days and each day into two periods. The consumers know the number of days of each type in advance and the type of any day only at the end of the previous day. The price/kWh depends on the type of day of the year. One of the following three "colours" refers to each day:

- Red: less common but more expensive days. In a year only 22 days will be red, all included in the period from November to March. Only weekdays can be defined as "red" - Saturdays, Sundays and holidays are never "red".
- White: 43 days in a year, especially between October and May, with average price levels.
- Blue: cheaper and more common days. There are 300 days in every year. All Sundays are blue days. The colour of each day is announced the night before by 5:30 pm. Customers can find the colour using different methods: check the EDF site, receive an e-mail or text message, or using a special display that can be connected to any power outlet.

On "white" days, consumers have achieved on average a 15% reduction in consumption compared to "blue" days, savings that increase to 45% on "red" days. The resolution of 25th of July of 2013 of the French Authority (CRE) indicates that the transition of a customer from the base rate to the Time option leads to a reduction in the cost of the bill of about 7%. This process implies the transition from a flat rate all option TOU-CPP, limited to 5% for the transition from a TOU option to the TOU-CPP option.

Spain

Spain has adopted a liberalized electricity and gas market model since 1 January 2003. According to EURELECTRIC's 2010 monitoring data, there are 349 DSOs in Spain that distribute 278 TWh of electricity, only three of them are responsible for over 90% of the distributed energy and more than 80% of the retail supply, but the legal and functional separation between the distribution and supply activities is fully implemented.

Spain has not carried out an official CBA (as requested by the European Commission), although it has decided to proceed with a complete roll-out of the Smart Meters with the Royal Decree 1634/2006. This decree indicated that by the 1st of July of 2007, the Spanish regulator would have had to draw up a replacement plan for all Spanish domestic meters with a power contract of less than 15 kW. In 2008, the government approved the plan to replace all residential electromechanical meters (up to 15 kW of contract power) with the new smart electronic meters by the end of 2018.

The measurement activity in Spain is regulated and the distributors are the owners and responsible for the installation of the Smart Meters at the end users.

Meeting activities	Regulated
Smart meters diffusion	Obligatory
Responsible for installation and management of SM	DSO
Responsible access to measurement data	DSO
Installation costs of the SM	End users-Electric bill

Table 12. Spain metering market. Source: Staff Working Document 188, "Country fiches for electricity smart metering", 2014.

In Spain, domestic customers can opt for regulated tariffs from the Spanish CNMC authority (Comisión Nacional de los Mercados y la Competencia) or tariffs offered on the free market. The rate of last resort or TUR (tarifa de último recurso) is a regulated electricity tariff for customers with a contractual power of less than 10 kW. This rate is set automatically for all customers who have not decided to move to the free market.

For both protected and non-protected customers, there is the possibility of choosing flat or hourly rates. The latter is a classic TOU that divides the day into two periods, distinguishing between peak periods (10 hours) and off-peak periods (14 hours). A possible complication of TOU tariffs is seasonal differentiation. In Spain, the length of the periods is constant during the year, but the start and end time of each period change between winter and summer.

Figure 40. Seasonal difference of the TOU tariffs in Spain. Source: http://tarifasgasluz.com

There is also a tariff option called "Supervalle" which introduces a third period at night, from one to seven in the morning, with a further discount on the price of electricity to facilitate the recharging of electric vehicles. The Royal Decree no. 647/2011 established this special tariff. This night-time discount is balanced by an increase in the cost of energy in the hours immediately following in the morning.

Law 24/2013 of the energy sector and Royal Decree 216/2014 have modified the regime of regulated tariffs by introducing the so-called "voluntary price for small consumers" (known by the acronym in Spanish: PVPC) for consumers under 10 kW. With the new PVPC system, consumers receive an hourly RTP pricing based on the results of the Spanish electricity market. The new system started in July 2015, introducing the obligation for electricity distributors to collect timely data relating to the consumption of each customer. In the official forecasts of the Spanish government, this system will be able to assert itself fully only starting from 2018, when all the 28 million Iberian electric customers with contract power within 15 kW will be equipped with Smart Meters.

Finland

After the approval of the Electricity Market Act (386/1995) in 1995, Finland's electricity market was gradually opened up to competition, so since the end of 1998, all electricity users, including private individuals, have been in able to choose their own electricity supplier. The purpose of the reform of the electricity market was to increase the efficiency of operations and to integrate Finland's electricity market into the Scandinavian Nordic market. According to EURELECTRIC's 2010 monitoring data, in Finland, there are 85 DSOs that distribute 60 TWh of electricity. An economic analysis was conducted in 2008 focusing mainly on the potential of demand elasticity, rather than on the evaluation of the costs and economic benefits of the smart meter roll-out. The Finnish industry had voluntarily launched a widespread Smart Meters installation campaign in the early 2000s. The Finnish government followed the European guidelines and set a mandatory installation program for Smart meters for 80% coverage by 2014. At the end of 2013, the Smart meters had already reached the 97% penetration rate. The measurement activity in Finland is regulated by the competent authority and the distributors are the owners and responsible for the installation of the Smart meters at the users.

Meeting activities	Regulated
Smart meters diffusion	Obligatory
Responsible for installation and management of SM	DSO
Responsible access to measurement data	DSO
Installation costs of the SM	End users-Electric bill

Table 13. Finland metering market. Source: Staff Working Document 188, "Country fiches for electricity smart metering", 2014.

In Finland, residential customers can choose between TOU tariffs with variable prices depending on the season or day and night, fixed price rates, and RTP contracts based on the results of the electricity market. The spread of the three types of contract is 80%, 16%, and 4%

respectively. Until Spain's decision to introduce RTP-type pricing from July 2015, the Nordic countries, including Finland, were the only ones to offer hourly rates to residential users in Europe. Unlike Spain, where the system is still in its early stages, in Finland, the tariff system is already quite mature and proposed by some utilities coupled with technological solutions that automate the customer's responsibility. In fact, RTP solutions are more effective if coupled with enabling technologies, because otherwise, the user's response will never be able to follow the hourly granularity. The system offers a very simple way to save on energy costs, but also the ability to monitor household energy consumption. The system promises to achieve savings in the 15% range using energy at the most convenient hours. The price of the system is around € 500, the installation costs around 200 € and there is a monthly fee of 10 €. If you take a saving of 15%, the annual monetary savings are in the range of 300-500 €, in a typical single-family house with electric boiler, with a consequent return on investment of about 2 years.

USA

The US is a pioneering country in the testing of dynamic tariffs and already in the late '70s and early '80s. The Federal Energy Regulatory Commission (FERC) had approved a first wave of experiments. These experiments worked on measuring customer response to simple price changes within the day and/or season. The results were encouraging: customers responded to higher prices during the peak period, reducing energy use and shifting consumption in less expensive periods. However, despite the encouraging results obtained, the experimentation of new dynamic tariffs lost interest over time for three main reasons:

1. The high cost of increasing the number of measures;

2. The peak periods offered in these experiments were considered too large to be accepted by the client;

3. Utilities did not market and promote programs effectively.

The California energy crisis of 2000-2001 has revived the interest in experimenting with the variable tariffs with different pilot projects and subsequent commercialization and the experiences of the past have allowed us to design and promote experimentations more effectively, also driven by the advent of Smart meters, which have solved the problem of the number of measures for data collection. It is interesting to report from the USA the application of PTR tariff schemes. An example is the city of Anaheim, which conducted a dynamic price experiment for the residential sector between June 2005 and October 2005 and saw the participation of 123 clients. This experiment tested a rate with which a discount was offered to customers to reduce their energy consumption (kWh) during some critical periods. The discount amount was 0.35 $/kWh. The discount was applied if consumers reduced energy use compared to a baseline consumption calculated by the utility. The results of the experimentation showed that the group of users to whom the discount had been offered reduced its consumption during the critical event days by about 12%.

An interesting case of commercial application of a PTR tariff concerns the Baltimore Gas and Electricity (BGE) energy utility, which offers its users the possibility to join voluntarily energy efficiency programs, encouraging them to reduce their electricity consumption. Users can choose to join two types of programs:

- Manual: in the days defined as critical if a user reduces his consumption compared to the baseline between 13 and 19 he receives a discount of 1.25 $/kWh.
- Automatic: users use a conditioning system connected to a central system, choosing to adhere to three different programs of automatic consumption reduction.

Depending on the program chosen, they receive a different discount in the bill. Users who choose the automatic program can still further reduce their consumption by receiving in addition the discount provided by the manual program.

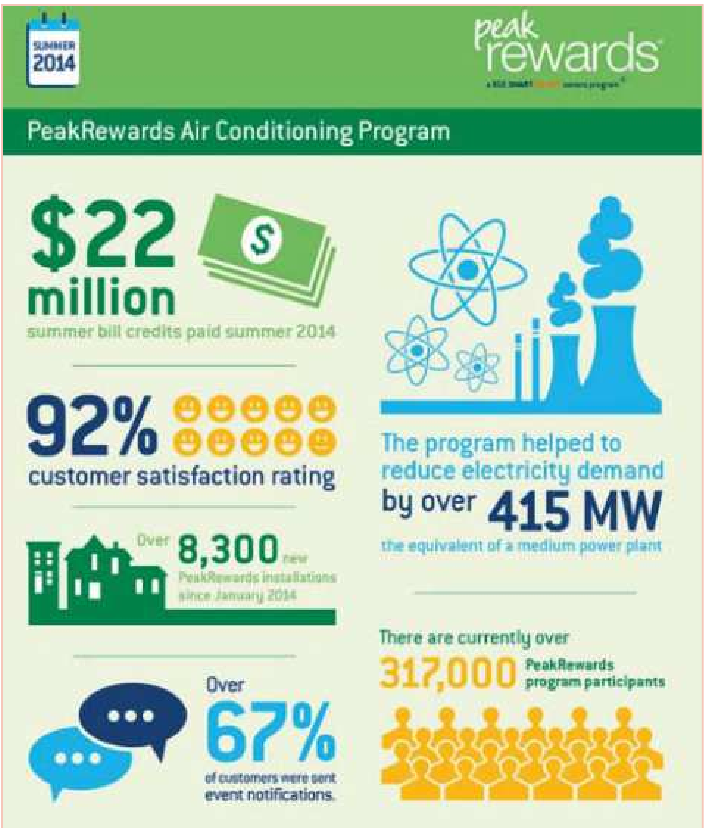


Figure 41. USA program in summer 2014 and the main results of the number of customers involved, degree of satisfaction, discounts applied and effects on the system. Source: Baltimore Gas and Electricity (BGE).

Chapter 06

6 FOR THE UPTAKE OF DYNAMIC PRICING IN ITALY

6.1 Potential barriers

To assess the applicability of the Dynamic Pricing schemes listed in section 4.2, it is necessary to identify potential barriers that could hinder their official entry in all countries, including Italy. Dynamic electricity contracts linked to the wholesale market are in fact currently available only for commercial/residential consumers in some EU countries [46]. Clearly, the advent of even more complex dynamic tariffs will take place in the coming years, also thanks to the use of higher shares of RES for the production of energy. However, there are several challenges to be overcome before you can make these offers available and to make them seem sufficiently attractive to consumers:

- Possible insufficient or no savings possible, due to:
    - The weak price signal to shift consumption: first, prices in the wholesale market may not be high and quite volatile. Secondly, the "energy component" represents only a third of the average retail consumer bill in the EU, in fact, this is masked by other parties on the electricity bill; the remaining 2/3 of the invoice are regulated costs, which include network costs, taxes, and taxes. An ever-increasing tax burden and the costs of electricity-financed policies provide bad signals because they create incentives to switch to other forms of energy, to the detriment of decarbonization targets, and it does not highlight the benefits of dynamic pricing.
    - Consumers limited potential to shift consumption: Nordic countries' experiences are not easily transferable to all EU markets as the displacement potential is relatively high in this region due to higher average consumption, particularly in winter. In countries such as France, where large numbers of retail consumers are equipped with electric heating and DHW, the use of smart meters will enable the development of innovative prices in addition to the current TOU and CPP rates. However, the adoption of such technologies is still uncertain
- The absence of enabling technologies (measurement equipment and related ICT infrastructure): Dynamic pricing is possible as long as smart meters with minimum requirements are available that enable reliable consumption readings at specific time intervals corresponding to market intervals. However, smart meters have already been implemented or are expected in only 14 EU member states. In addition, everything that

requires investments in the IT infrastructure, such as the corresponding data processing and billing procedures and consumption registers, must necessarily be presented and visible. In countries where they have been implemented, smart meters are generally not able to dynamically identify a specific time or set certain hours as critical. Therefore, energy management systems should also be developed to be integrated with the telemetry software, which allows for the creation of multiple tariffs and tariff periods adapted to the different load curves, identifying peak and off-peak periods and opportunities. more suitable savings for consumers.

- High initial cost of smart home equipment: Some pilot projects have shown that consumers engage in the market and adjust their consumption if they have access to advanced information or energy management tools and that, ultimately, only automated solutions They will be interesting for most customers. Otherwise, consumers may find dynamic prices that are too invasive and complex for them, as a result, they will have very slow responses and only partial and limited behavioural changes. As the Internet of Things evolves, home automation, including the smart thermostats and other intelligent equipment in today's home, will also keep the consumer experience going. Customers will continue to be in command, knowing how to manage their equipment and can also make the most of the various dynamic offers without compromising their lifestyle. Recent studies show that there is already a high level of interest among customers regarding the adoption of smart devices even for their own homes, but they do not yet fully convince. The cost is the biggest obstacle to the purchase of such devices.
- Lack of awareness of risks and benefits: Consumers may be interested in dynamic pricing if they have been well informed and if the schemes are designed in an easy to use and understand the way to make savings feasible. Without information on price volatility, or knowing when electricity prices rise or fall, consumers could potentially face significant increases in their bills during certain months. For example, in the case of RTP, with direct exposure to spot prices, customers should be aware that they may one day pay more for their electricity than the rest of the year.

6.2 Practices to facilitates the uptake of dynamic pricing

Foreseeing a future scenario in which there is a growing electrification in all sectors and a further increase also in the contribution of renewable sources, hoping that all this will be accompanied by a growing spread of Smart grids, which will make the network smarter thanks to technologies ICT. In this case, the Smart meters will play a key role, because they will be the means that will make their consumption more transparent, but above all will reduce consumption, thus reducing the load on national networks during peak hours. Certainly, the current tariff schemes need a revision, because today more than ever we are increasingly looking to integrate renewable sources for energy generation. To ensure that these new dynamic tariffs can fully take over the Italian market, consumers must first be encouraged to change their consumption profile, and for example with adequate information on real-time-pricing (RTP) rates. in real time) users can help optimize the use of the national electricity system in order to reduce the costs of electricity in the bill, but also to accommodate the growing contribution from non-programmable renewable sources. From an economic point of view, RTP would appear to be the most effective option, but it is necessary to overcome the non-technological obstacles caused by inadequate legislation and by the lack of appropriate remuneration mechanisms. Therefore, the launch of tariff reform by the Authority is an opportunity to adapt the market rules and the tariff system to the needs of the future energy system. Needless to continue trying to preserve the old system. The new reality of the electricity system will always be less centralized and less fossil, and increasingly distributed and renewable. The same is true of creating the organizational, regulatory and tariff conditions to allow them to develop at best. In this renewal perspective, price differentiation can be an important competitive advantage. Dynamic price offers will emerge more and more and may interest consumers, as long as the price signals of the wholesale markets are strong enough. Retailers could also help overcome customer resistance to smart home devices by offering customized payment plans (e.g. instalments) and bundled service packages. The following measures are necessary to incentivize the appearance of dynamic price offers on the market and their acceptance by customers [46]:

- Open door to innovation, less regulation: Participants in the liberalized market have the freedom to design their offers, including the freedom to decide if and how to offer dynamic price contracts. Where smart meters are present, offering such contracts will be commercially attractive to suppliers. However, the imposition of certain price offers is in conflict with the idea of competitive markets with value propositions linked to consumer preferences. To oblige suppliers to offer specific contracts suited to this type of tariffs and needs should necessarily imply regulation of the market. If, as for the VPSC tariff in Spain, the margins of suppliers within these offers are regulated and set below the cost of the related service, these "regulated dynamic prices" can effectively limit competition by preventing customers from switching to competitive offers or to encourage customers not to switch to regulated offers but to prefer other competitive offers. Furthermore, the IT needs at the provider necessary for the creation of these structures (tariff models, processing of consumption data) would represent the main barrier to entry, which would cause more harm to consumers than benefits, especially if it is not a high demand. for this type of offer or if the functionality of the meters exists only for a small number of customers. Not all suppliers (especially small ones) have already adopted and applied this type of price. They would need to develop IT structures to include this new type of offerings in their product portfolio.

- Emancipation/legitimization through information: Customers should be adequately informed about the opportunities and risks of dynamic price contracts. As these contracts become more common, consumers' awareness and learning will further increase with their participation or the participation of someone they know.
- Having a smart meter: when consumers choose to engage in a dynamic pricing system, but the necessary measurement capabilities are not adequate, they should be entitled to these features. But they must be aware of the measurement prerequisites and may need to bear the cost of a single installation of smart meters, as required by art. 21 of the draft electricity directive. Only in this way is it possible to guarantee the availability of the necessary infrastructure even in countries where the launch of smart meters is not yet planned or completed.
- Better tariff incentives are needed to increase potential savings: to encourage consumers to switch to the electrification of heating, cooling, transportation, and all consumption, there are a need for better price incentives, which justify all of the investments. These incentives, in addition to making the energy component more dynamic in the bill, should also include retail price reform in general. Retailers will be more interested in strengthening the price signal (energy and network) and bringing it back to the customer in a clearer and simpler way. All this to be possible requires such measures:
    - Reducing the levy component by financing the cost of political support through alternative means such as tax credits or cost allocation compared to other fuels: in the Czech Republic, support for RES policy is spread across the state budget (36% in 2015) and taxpayers' electricity. In Germany, the debate on extending the RES (EEG Umlage) contribution to the heating and transport sectors has started.
    - Charging the rest of the "regulated charges", i.e. the costs of policies and costs of the networks, in alternative ways, developing a series of tariff structures with different capacity quotas (kW) and energy-based (kWh) components should be enabled by the competent authorities on the basis of the contractual capacity

and consumption and the contractual models of consumers and prosumer [19]. These regulated tariffs can be communicated with a price, a period of use, peak prices or dynamic options, depending on the consumer's choice - which could further strengthen the signal. With regard to network tariffs, a number of countries have chosen to introduce usage time network (TOU) tariffs with few periods (for example, specific time/limited timetable periods)[20]. The TOU network tariffs apply different predefined prices to pre-defined times of the day or year.

Furthermore, it is questionable whether these dynamic tariffs can be designed to be truly effective, in particular with a lot of decentralized generation that could lead to local congestion and thus large differences across the network.

6.2.1 Demand Response and Demand Side Management

The growing interest in active policies for the management of the demand for energy (demand-side management) and towards actions that can modify the profile (Demand-Response) necessarily implies that the end user, in order to guarantee his comfort, has available energy systems that can guarantee the flexibility of their application. The concept behind Demand Response (DR) is quite simple: the energy supplier encourages the user to reduce his consumption, in correspondence to the load peaks, on demand; on a contractual basis it is specified how and when the supplier can reduce the load; the user subject to the DR can thus modify its electric load profile of its energy consumption as a result of changes in price over time ("market signals") or to signals envisaged by the systems in the presence of critical safety or network loads ("System signals"). The DR technique is already widespread for medium-large consumers, as soon as a large-scale spread of Smart Meters and Smart Grids will be extended, even small users will be able to use them, in particular, residential users, giving rise to new forms of interaction between users and the electricity grid. From this point of view, Europe is supporting and promoting this sector considerably, in relation to the plurality of new stakeholders that can arise with a view to the liberalization of the electricity market; in the USA, significantly later, about 8% (2008) of users subscribe and implement DR programs.

[19] Multiple capacity-based network rates (especially for low-voltage consumers) reflect higher grid costs associated with peak demand and provide incentives for customers to reduce their peak load, resulting in more efficient use of the network. They provide better incentives for more efficient use of energy in general.

[20] See EURELECTRIC paper on Network tariffs, 2016.

Essentially, Smart Metering and bi-directional means of communication that include the user-utility are the enabling factors. In addition, there is an economic convenience on both sides: the consumer saves on his own consumption and the supplier without further investment, aims to better develop his own resources. There will also be a better balance of electricity flows in the network, especially if there is a greater availability of distributed generation, even if not programmable; moreover, the DR mechanism induces a form of energy saving (both on the user and on the supplier side) and consequently a potential for reducing CO_2 emissions.

The actions to modify the user's question are of two types:

- Direct actions, through the remote control of user systems that use energy;
- Indirect actions, through price incentives and/or information on relevant events;

These give rise to the following solutions:

- dynamic price variation ("Dynamic pricing"), in pre-established or entirely variable forms;
- load reduction programs with notification to the end user to reduce consumption during certain periods: the reduction action is currently performed by the user;
- Interrupting contracts ("interruptible contracts") that require a certain amount of load reduction when requested by the supplier: number of reductions per year, economic incentives and time limits for reductions are fixed by contract;
- direct load control programs that allow the supplier to directly control the user systems, through communication links between the operator and the user systems.

It should be noted that, if the loads are similar and manageable with the same parameters (e.g. conditioners) their characteristics are easily superimposable and predictable: in this situation, it is possible to build an aggregation service where the control/management actions are aimed at the aggregate users/systems.

6.2.2 Smart Meters and Smart Metering

The offer of rates that vary over time also plays a fundamental role in justifying investments in enabling technologies such as Smart Meters. Some investments can be justified solely on the basis of savings obtainable by the parties involved in the measurement of electricity, but more and more additional benefits are required to demonstrate that investments in innovative technologies also benefit consumers and for the electrical system. Achieving these benefits, however, requires careful planning, planning and a thorough understanding of the technical, economic and regulatory issues that are emerging in the new international context.

The simplest system for the pricing of electricity certainly would not be a dynamic tariff, but it is based on a constant price, independent of the time and day of consumption; however, this does not encourage customers to change their consumption habits, in particular by reducing their withdrawals during critical times for the network. However, the implementation of a dynamic pricing system requires the installation of a more complex measurement infrastructure that allows separate consumption accounting in the various time intervals [43].

We will try to clarify what "Smart Metering" means by giving some definitions. We will start with the difference between the Smart Meter, i.e. the measurement system of electricity consumption, in the best time for increased functionality, and Smart Metering, which is the complex of features and systems that operate a Smart meter and that allow the achievement of multiple objectives in an automated way [44].

A definition of Smart Metering is given by ESMA, the European Smart Metering Association, which identifies its main features such as:

- Processing, transfer, management and use of power consumption measurement data;
- Automated meter management;
- Bidirectional data communication with meters;
- Provision of significant and timed consumption data to the relevant players in the overall process and to their systems (including end users of energy);
- Support services that increase energy efficiency in energy consumption and energy efficiency of energy systems (generation, transmission, distribution and end-use).

The key feature of Smart Metering is, therefore, the provision of real-time information to the user based on their energy consumption.

Smart Metering is based on a measurement system that allows primarily the user to make/implement decisions pursuing this objective: to control costs; to save money consciously; to know how to save money; to help to be an "active part" of a balanced system energy demand/supply; to use auxiliary energy services, including the ability to manage costs based on dynamic pricing policies. This implies that the end user is aware/responsible/ interested/able to operate: becomes fundamental "customer acceptance" and therefore the taking into account of human factors.

The European Directive 2006/32/EC, art.13 specify the features indicated for Smart Metering; in Italy, Legislative Decree 115/2008 (in particular, article 17) did so. Meter data readings are generally not readily accessible to the user, as they are not easily understandable, they are expressed globally and cumulatively and there is no "historical" information. Combined with feedback support systems, Smart Metering has the following benefits:

- Database of historical data to make comparisons;
- Awareness of their consumption, which could be better managed in the future;
- The possibility of switching from one supplier to another easily;
- The possibility of adapting consumption to the dynamics of tariffs (time) and costs;
- The possibility to install devices for measurements related to the microgeneration without changes on the meters;
- Better management of payments.

Obviously in addition to these positive features, there are also some disadvantages such as:

- Risks of possible violations of privacy and high vulnerability on the part of customers;
- Risk of rising costs (SM introduction and inappropriate use of pricing policies).

In "Demand Response" techniques, energy supply is associated with forms of communication to push or reduce consumption over time based on consumption information, leveraging prices (with clear incentives and tariff schemes) or through limitations (e.g. with load control), with the aim of creating awareness and empowerment.

In order for this process involving Demand Response techniques associated with Smart meters to be effective, the feedback that arrives to the user must absolutely be:

- easy, immediate and continuous;
- the data must be shown with certain characteristics of quality, quantity and clarity;
- the user must be able to interact with them and control them.

Feedback can be distinguished in:

- Indirect feedback, which was processed before reaching the end user and possibly mediated;
- feedback (real time) through a specific display at home or as part of a prepayment program for a specific price.

The new opportunities are linked to the opening of the market for new products and services, made possible by the presence of a "dedicated Gateway" towards the end user. Opportunities are substantially linked to the introduction of "Demand Response" services; these constitute the best perspective and are, as seen, linked to the possibility of when and how end users consume energy. This saving by the user also plays in favour of the retailer. It is noted that dynamic prices make it possible to obtain a first saving; the possibility of controlling loads allows further savings as maximum peak loads can be maximized. This second type of intervention is particularly applicable for heating/refrigeration systems, which represent the largest share of household consumption. MS data can support the European Directive EPBD (Energy Performance of Building Directive - Directive 2002/91/EC). Data from MS can increase the quality of certificates and allow easier quality control.

After talking about Smart Metering and Smart Meter, we must also introduce the concept of Smart Grid, which is the concept of an evolved electrical network. The most important point is the fact that this evolution is not just an optimization of current structures in the face of updating needs for various reasons (demand, new technologies, quality and safety requirements, economic requirements), but it is also and above all a significant revolution compared to a linearity of growth. The revolution consists in two basic aspects, the first of a more technical nature (infrastructural and operational/exercise), the second of a more strategic and market nature:

- Technical aspect: Passage from the passive network (management of flows from the place of production to the place of consumption) to an active network, capable of managing and regulating multiple electric flows that travel in a discontinuous and bidirectional manner. This step is essentially due to:
  - The introduction of distributed generators into the network, mainly small-medium sized production units distributed throughout the territory and connected directly to the user, resulting in a transition from a centralized system to a more decentralized system; in the field of distributed generation, the generators from renewable sources, which will contribute in increasing quantities, according to national and international targets, to the reduction of greenhouse gas emissions, but which, by their nature, produce discontinuously;
  - The end user who passes from consumer to consumer/generator ("prosumer") will be able to manage/limit his consumption by interacting with the system not only in terms of consumption but also in the choice of supplier. The end user tends to play an active role in the operation of the system, realizing the so-called "Demand Side Management" (active demand for electricity).
- Market aspect: Liberalization of the market, with consequences related both to new energy services and new types of players in the market ("virtual power plant" operators), and consequences in additional infrastructures for data exchange, support for

accessibility, security, and controllability. It will then obviously be necessary to define and analyse the possible business models that can be implemented.

The function of energy bidirectionality and active management by the user depends on the availability of adequate data on consumption and delivery by the end user, there can be no actions if there is no knowledge of the data and therefore means of measurement to get them (like Smart meters).

Smart Metering is not a Smart Grid, but it is a fundamental function for the realization of many of the Smart Grid functionalities, which allow considering the target of energy efficiency not only in terms of energy saving by the user but in a broader as related to the evolution of the electricity grid and the market in the sector.

Meters are a part of a larger platform that must allow additional functionality compared to remote reading. It is also to underline that the Smart Metering involves more types of Utilities, while the Smart Grid refers only to electricity.

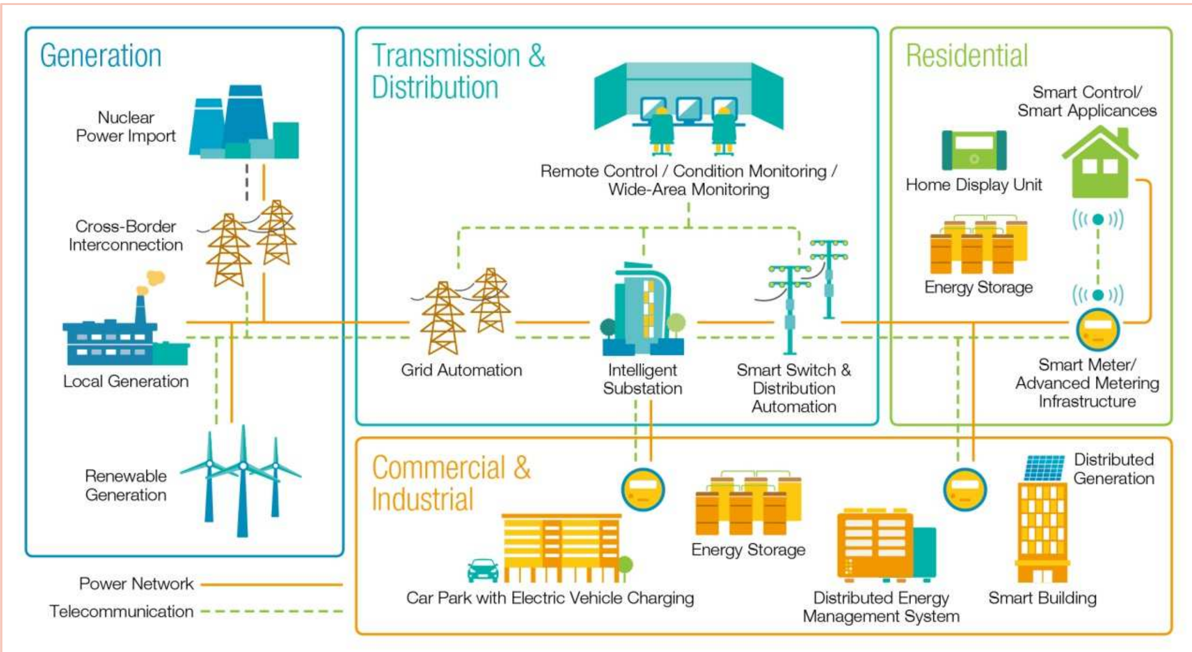


Figure 42. Operating principle of Smart Grid. Source: CLP; https://www.clp.com.hk.

The Third Energy Package, introduced with the Community directives for electricity (Directive 2009/72/EC) and natural gas (Directive 2009/73/EC), obliges the Member States to ensure the implementation of intelligent measurement systems for ensuring long-term consumer benefits. For the electricity sector, the Community objective is to equip these measuring systems by 2020 at least 80% of European consumers positively evaluated in terms of cost-benefit ratio. The directive 2009/72/EC of 13/07/2009 (related to common rules for the internal electricity market and repealing Directive 2003/54/EC) deals with Smart Grids. Specifically, the Directive states that "*the Member States should encourage the modernization of distribution networks, for example through the introduction of smart grids (Smart grids) built to promote decentralized generation and energy efficiency*"[21]. The expression "Mickey Mouse Meters" (counters from Mickey Mouse) is well-known among the officials in Brussels, insinuating that the Smart-meters on the market present a certain asymmetry in the benefits: they mostly cover functions aimed at smart metering, data collection and information on user behaviour for the benefit of electric operators, rather than features that could help consumers save energy.

Brussels financed several beautiful and innovative pilot projects on Smart-grids and the introduction of Dynamic pricing, until it turns out that the results cannot be implemented because they are illegal in the current regulatory framework in the Member States.

[21] Directive: *Direttiva 2009/72/CE del Parlamento Europeo e del Consiglio del 13 luglio 2009 relativa a norme comuni per il mercato interno dell'energia elettrica e che abroga la direttiva 2003/54/CE.*

Chapter 07

7 CASE STUDY: CORTAU HOUSE

7.1 Nearly Zero Energy Building: nZEB

For the first time as a result of the energy crisis of the seventies, buildings with very low energy consumption were assumed, i.e. almost Zero Energy buildings [47], as we know them today, also called NZEB. Officially the term nZEB (Nearly Zero Energy Building) appears for the first time in 2010 in a package of European Directives defined by the acronym EPBD (Energy Performance Building Directions) [27], which continues the Europe 2020 strategy in theme of sustainable development, inviting member states to introduce regulations on the energy performance of buildings. is the art.9 of the EPBD 31/2010 which establishes that all new buildings starting from 31 December 2020 are almost zero energy, while for public buildings the deadline is anticipated as of 31 December 2018. Article 9 of the EPBD directive requires the Member States not only to define a national definition of nZEB but also to actively promote greater market penetration of these buildings. The Member States shall prepare and submit to the European Commission national plans with clear definitions and measures (e.g. financial policies and incentives) for the promotion of nZEBs. These national plans include inter alia interim targets to improve the energy performance of new buildings by 2015 and need to be updated every 3 years. According to the same article (paragraph 5), the EC, by 31 December 2012 and every three years thereafter, evaluates the progress of the countries in increasing the number of nZEB and, if necessary, suggests measures to this effect. In 2015, the evaluation will be conducted for the second time.

Article 2 of the same directive provides the basic concept of nZEB buildings with almost zero energy: "*A building with very high energy performance. Very low or almost zero energy needs should be very significantly covered by energy from renewable sources, including energy from renewable sources produced locally or nearby* ".

However, this does not represent a univocal definition or what characteristics the building should possess, so that each member state is given the transposition of the directive based on local specificities, leaving ample room for personalization.

Therefore, referring to the Italian legislation, the Legislative Decree. 192/2005 (subsequently supplemented and amended by Legislative Decree 311/2006, by Presidential Decree 59/2009, specifically by Decree-Law 63/2013 converted into Law 90/2013 for the urgent transposition of European Directive EPBD 2010/31/CE) emphasize an energy efficiency given by the presence of energy plant components from renewable sources, produced within the site on which the building stands.

The new intervention in the regulatory field has been in force since the 1th of October of 2015, and it is called the 'Minimum Decree' ("Decreto dei Minimi" Gazzetta Ufficiale No. 162 of 15 July 2015) in which the ZEB is defined as a building that meets all the minimum requirements in force, i.e. the new limits provided for by the decree, and which complies with the obligation to integrate renewable sources as required by D.L. 28 of 3 March 2011.

Figure 43. Key years for NZEB in Directive 2010/31/CE. Source: Episcope.

These are the definitions provided by the different Directives and Decrees:

- EC Directive 31/2010 (Recast 2002/91/EC): "*Almost zero energy building*": *building with very high-energy performance. Very low or almost zero energy needs should be very significantly covered by energy from renewable sources, including energy from renewable sources produced locally or nearby*".
- Decree-Law No. 63/2013 (Law 90/2013): "*Almost zero energy building: building with very high energy performance, calculated in accordance with the provisions of this decree, which meets the requirements defined in the decree referred to in Article 4, paragraph 1. Very low or almost zero energy needs are significantly covered by energy from renewable sources, produced within the system boundary (in situ)*".

When it comes to sustainable and high-performance buildings, you can refer to different categories such as Zero Energy Buildings, Net Zero Energy Buildings, and nearly Zero Energy Buildings: ZEB, NZEB, and nZEB [48]. These buildings have both differences and common characteristics.

Common characteristics:

- The thermal energy requirement is reduced as much as reasonably possible (insulation, increase in daylight use, activation of thermal mass, etc.);

- The energy needs of the plants reduced as economically feasible (heat recovery, increase in the efficiency of air conditioning systems, etc.);
- Production of thermal and electrical energy in situ from renewable sources (solar thermal and PV, heat pumps, district heating powered by renewables, biofuels).

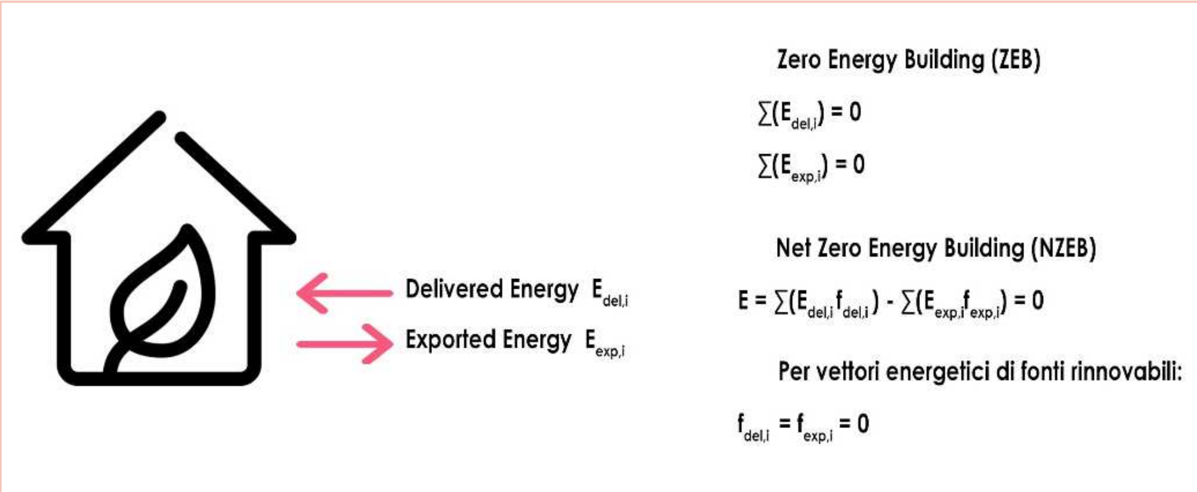


Figure 44. Difference between ZEB and NZEB. Source: the author.

Differences:

- **Zero Energy Building (ZEB):** Building that produces from renewable sources as much energy as it needs to meet its needs, therefore with an annual need for very low energy entirely covered by renewable sources;
- **Net Zero Energy Building (NZEB):** Building connected to a territorial energy infrastructure (electricity grid, gas network, district heating ...) and that in the space of a year presents an algebraic sum of the incoming and outgoing energy flows equal to zero. Usually a building connected to the electricity grid, it exports the excess of electric self-production and imports energy from the network when there is not enough self-production;
- **nearly Zero Energy Building (nZEB):** Building with very high energy performance where very low or almost zero energy needs are significantly covered by energy from renewable sources in situ or nearby. It is also characterized by an optimum level of energy performance, also in terms of costs.

It can be concluded that a nZEB can include an NZEB, while an NZEB may not meet the requirements of nZEB.

Although European technical legislation (prEN ISO / DIS 52000-1: 2015) does not provide a definition of nZEB, it does propose a methodology that takes into consideration:

- Internal environmental conditions;
- The thermal characteristics of the building;
- Air conditioning systems, ACS production, integrated lighting systems, optimal energy management of technical systems;
- Active and other solar systems based on renewable energy sources;
- District heating and District cooling systems (urban or district level).

After considering this, the energy requirements that are considered are:

- The need for useful thermal energy of the building;
- Total primary energy consumption (Energy losses within the assessment boundary are considered directly in the energy calculation delivered to the "delivered energy" building). The primary energy factor considers energy losses outside the boundary of energy evaluation;
- Primary non-renewable energy consumption (without compensation between energy carriers);
- Primary non-renewable energy consumption (with compensation between energy carriers).

Obviously, everything, including these energy requirements, will also strongly depend on certain building requirements such as:

- The quality of the building envelope (e.g. wall insulation, window system performance);
- Options of bioclimatic design (e.g. solar gains, natural lighting);
- Thermal inertia, zoning;
- The quality of the internal environment;
- Prevention of possible negative effects due to insufficient ventilation, such as poor indoor air quality or hygrothermal problems (mold formation).

A nZEB building according to the Decree must also:

- Respect the parameter limit values:
  - Global average coefficient of heat transfer by transmission per unit of dispersing surface (H'T);
  - Equivalent summer solar area per unit of useful area (Asol,est/Asup,utile)
  - Indices of thermal performance useful for heating and cooling (EPH,nd, EPC,nd)
  - Average seasonal efficiency of winter air-conditioning systems (ηH), summer air-conditioning (ηC) and domestic hot water production (ηW);
  - Global energy performance index of the building ($EP_{gl,\ tot}$).
- Cover, using energy produced by plants powered by renewable sources:
  - 50% of the consumption expected for domestic hot water;
  - 50% of the total consumption of domestic hot water, heating, and cooling.

7.2 The residential case study: Cortau House

A relevant example of a nZEB house in Italy is the Cortau House,[49] in which the architectural quality of the construction is combined with high-performing energy solutions. La Cortau House is a residential building located in Northern Italy, in Piedmont in energy class A4. The restructuring has allowed a traditional rural building called "curmà", very widespread in Piedmont, to become a building that uses high-performance energy solutions, valid as an example that can be replicated in all regions. Construction started in March 2014 and ended in January 2016. This building combines high-performance technological systems with the principles of bioclimatic architecture to satisfy an annual energy demand that allows this building to fall within the criteria of a nZEB. The new volume fits below the existing roof that has been retained in its original wooden structure with a tiled roof.

The building is all-electric and supplies its energy demand (for cooling, heating, ventilation and lighting) through self-generation of electricity from a solar photovoltaic system of seven kW_{peak} on the roof. The ventilation system consists of a controlled mechanical ventilation (VMC) with heat recovery unit and dehumidifier, associated to a radiant floor system for heating and cooling in every room (and with electric radiators in all bathrooms). A water-water heat pump guarantees heating, cooling, and production of domestic hot water (DHW). The building uses a strongly insulated envelope and frames with a thermal break aluminium frame and low-e triple panel glass with argon. The building has a large glazed surface greater than the south, compared to the north, to maximize comfort and reduce consumption; also for this purpose, further expedients have been added as deep horizontal projections, which allow maximizing solar gains in winter and reducing overheating in summer.

The technical data of the building is shown in the following paragraph.

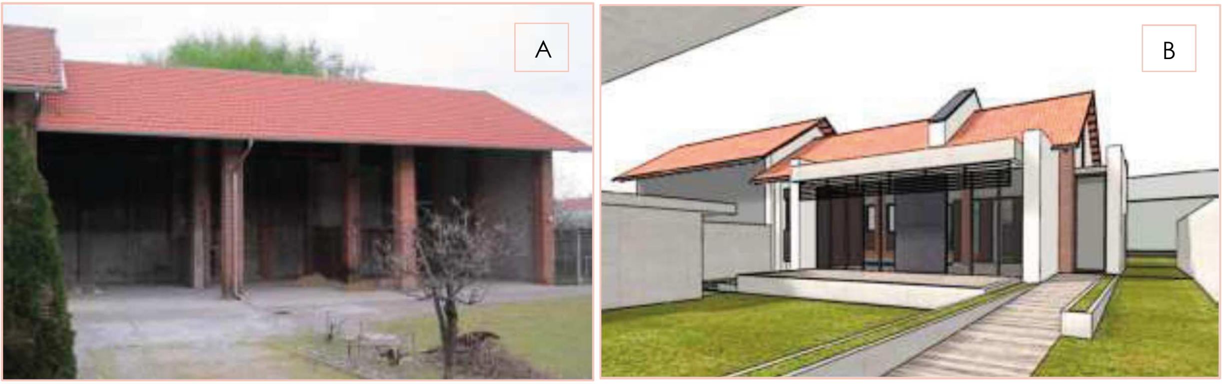


Figure 45. The pre-existing rural building, south front (A) and the current architectural design (B). Source: ingenio.

7.2.1 Technical data and drawings

The building has a total surface of 147 m^2, with a useful surface area of 162.1 m^2 and a heated volume of 736.5 m^2. The building envelope has a reinforced concrete perimeter structure cast in situ, which acts both as a structural element and as a cavity for the plants.

Externally the casing is covered by 16 cm of Rockwool insulation, which allows having a very low thermal transmittance of the wall (U_{wall} = 0.15 W/m^2K). The same insulation (γ = 0.037 W/mK; ρ= 150 Kg/m^3) was also used for the floor and the floor (U_{roof} = 0,15 W/m^2K e U_{floor} = 0,19 W/m^2K). The floor was made with a concrete casting with recycled plastic disposable formwork. The thermal bridge that could have been created between the external masonry walls and the floor was avoided thanks to the insertion of an 8 cm layer of cellular glass insulation, which also acts as a barrier to avoid the phenomenon of rising damp.

The very high-performance fixtures (U_{window} = 0,96 19 W/m^2K) feature an aluminium frame with thermal break and triple low-emissivity glass with interposed argon. Joints and anchoring points were studied between the window frame and the outer insulation layer to avoid the formation of thermal bridges. Still aiming to contain the creation of thermal bridges, the original brick pillars have been preserved as they were, but have been left outside the new heated volume. The internal partitions in plasterboard thanks to a layer of acoustic insulation allow an adequate soundproofing of the rooms. Thanks to these characteristics and to all the design and energy measures implemented, the building is one of the first buildings in Piedmont to reach the energy class A4 with an $EP_{gl,nren}$ (non-renewable global energy performance index) of 11.07 kWh/m^2/y in the energy performance certificate (APE).

Figure 46. Rendering of the final project. Source: GOODFOR.

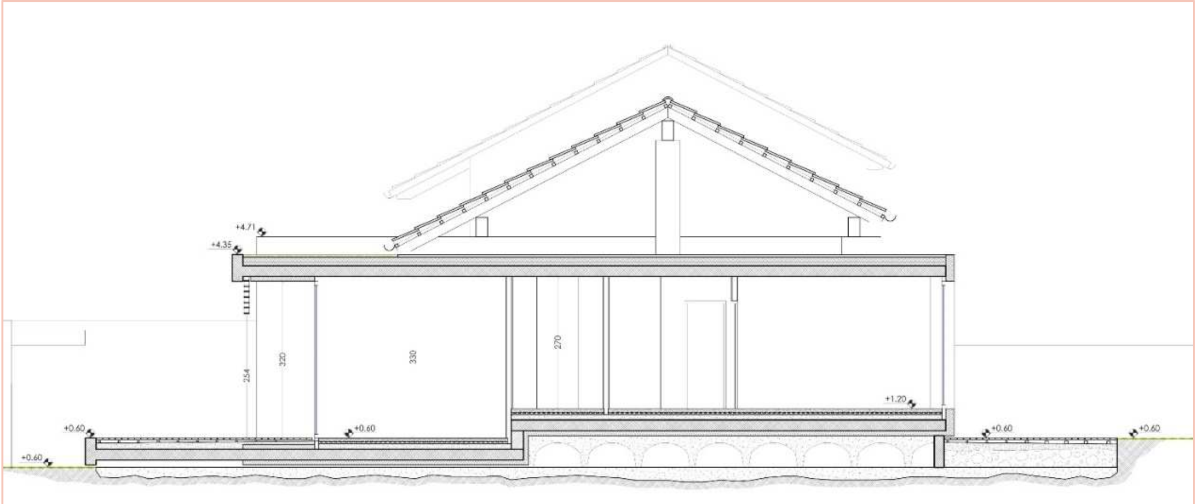


Figure 47. Cortau House transversal section. Source: GOODFOR.

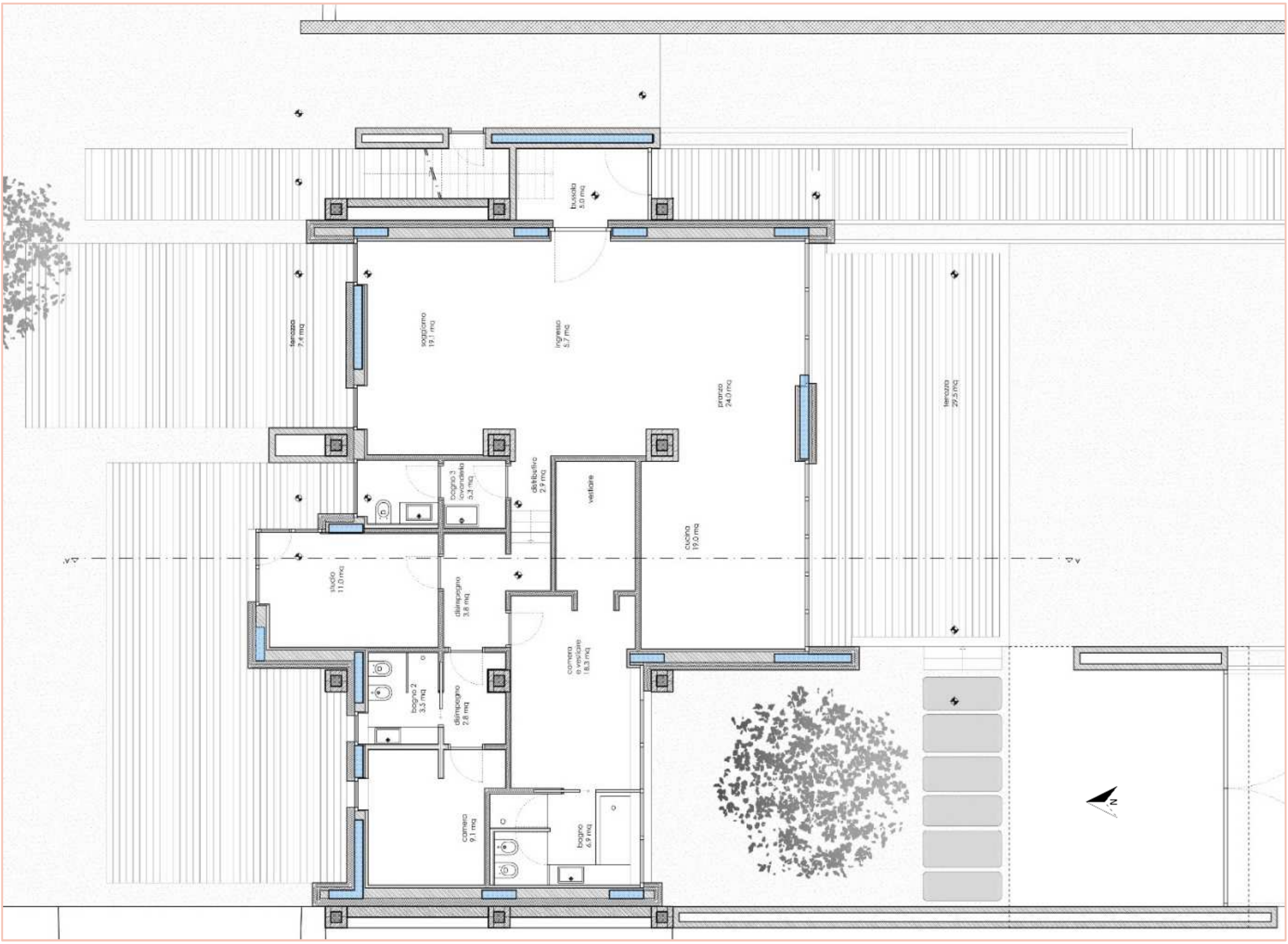


Figure 48. Cortau House plan. Source: GOODFOR.

Cortau House building characteristics		
Location	[-]	Italy
Climatic zone	[-]	E
Building type	[-]	Residential
Construction year	[Year]	2016
Floors	[-]	1
Underground levels	[-]	0
Energy class	[-]	A4
Heated and cooled plan area	[m^2]	162.1
Heated and cooled building volume	[m^3]	736.5
Dispersant surface	[m^2]	636.33
S/V	[-]	0.8640
Energy systems	[-]	-Cooling and Heating
		-DHW
		-CMV

Transparent component			
Type of component	[-]	Triple pane glazing 33_15_4_15_33	U [W/m^2K]
Solar transmittance	[-]	0.6	0,96
Solar Heat Gain Coefficient	[-]	0.68	

External wall	Thickness [cm]	Conductivity [W/mK]	Density [kg/m^3]	Specific heat [J/kgK]	U [W/m^2K]
Gypsum/plasterboard	3	0,16	950	840	0,148
Perforated brick	25	0,25	1800	840	
Insulation	20	0,37	150	1030	
External coating	0,1	45000	7680	420	

Floor	Thickness [cm]	Conductivity [W/mK]	Density [kg/m^3]	Specific heat [J/kgK]	U [W/m^2K]
Flooring	1	0,06	200	1300	0,192
Screed	5	0,15	400	840	
Screed + radiant panel	5	0,15	400	840	
Insulation	12	0,037	150	1030	
Concrete	15	1,13	2000	1000	
Weak mixed concrete	15	1,7	2200	840	
Gravel	25	0,36	1840	840	

Roof	Thickness [cm]	Conductivity [W/mK]	Density [kg/m^3]	Specific heat [J/kgK]	U [W/m^{2}K]
Gypsum/plasterboard	3	0,16	950	840	0,155
Concrete	25	1,13	2000	1000	
Insulation	20	0,037	150	1030	
Screed	5	0,15	400	840	
Tiles	1	0,056	380	1000	

Table 14. characteristics of the components of the opaque and transparent envelope. Source: the author.

Chapter 08

8 SIMULATED SCENARIOS

8.1 Operating methods

In the previous chapter (7.2) all the technical and physical characteristics of the building that will be used as a case study for the simulation have been defined: Cortau House.

The tool used for the simulations is the IDA Indoor Climate and Energy software (IDA ICE), version 4.7.1, of the EQUA Simulation AB. IDA ICE is a program that allows you to simulate dynamic scenarios, used in many countries by engineering and construction companies, professional firms, institutions, research centres, Universities for the energy design of buildings. This dynamic simulation software allows, through a graphical interface, to build your own geometric model on which the calculation will be performed.

IDA ICE is used for energy projects of high-performance buildings, energy diagnosis (consumption simulation and energy performance), LEED certification, the design of ventilation systems, heating, renewable sources. With the IDA ICE simulation in every single environment you can get as results:

- Air temperature and perceived temperature;
- Air temperature at floor and ceiling;
- Temperature and heat fluxes on individual surfaces;
- Thermal balance;
- Thermohygrometric wellbeing according to Fanger indices (PPD, PMV) and according to the Comfort Class of the EN 15251 standard;
- Indoor air quality through air changes/hour, CO2 level, humidity;
- Air flows and controlled mechanical ventilation (VMC);
- Dispersion of heat flows through the air, the enclosure, the walls;
- Solar lighting and shading control.

In this study, the data related to uses, costs and comfort would be gathered at the end of the simulation, taking into consideration both the different rates and the different inhabitants' types.

These simulations were carried out dynamically, i.e.: the boundary conditions are considered variable at every instant and in each calculation period, the system is changing its state to respond to the variation of external stress. The calculation, assuming hourly data taken from climatic files, is conducted in all cases hour by hour, except in the case in which one wishes to analyse the temperature ramp, where one day is simulated for each minute.

Instead, if it was a steady-state simulation, all the boundary conditions would be considered constant over time for the entire calculation period. The calculation would be conducted as usual monthly, assuming average data over this period.

The starting point was to model the building on the IDA ICE software, thanks to the DWG import of the CAD file of the executive project. For all the simulated cases the plant has been divided into 10 thermal "zones" that correspond to the rooms of the residence:

- Kitchen+Lunchroom
- Living room+Entrance
- Room 1+Wardrobe
- Room2
- Bathroom1
- Bathroom2
- Bathroom+Laundry
- Studio
- Hallway
- Corridor

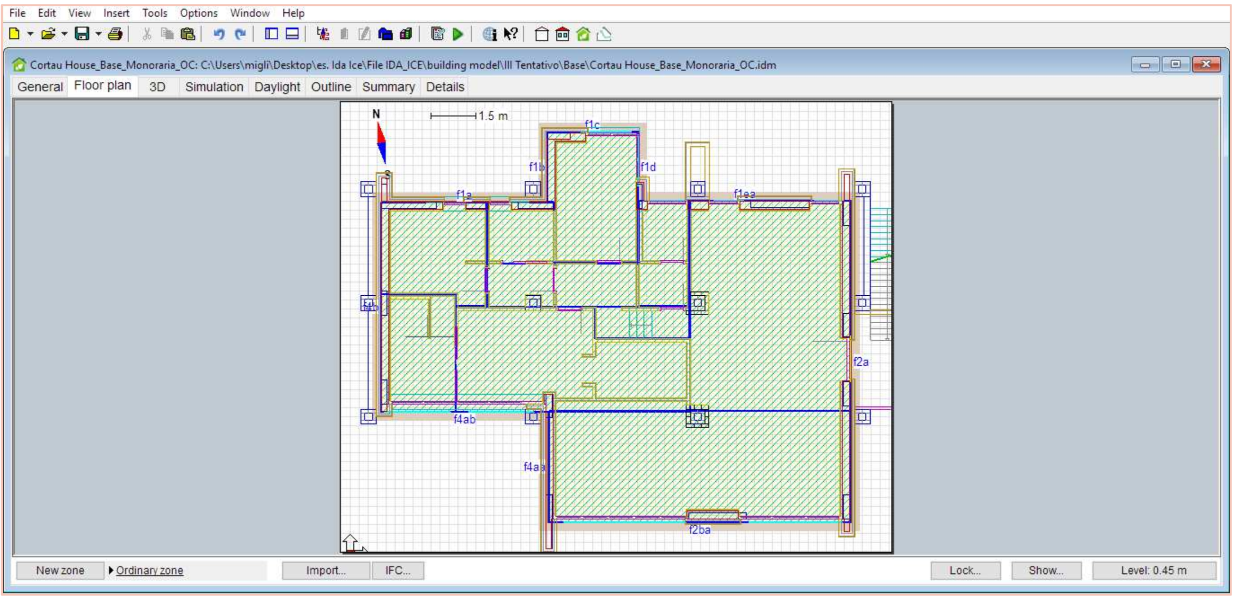


Figure 49. Cortau House thermal zones in model IDA ICE.

In each room all sources considered as "Internal Contributions" are included, which are:

- Occupants;
- Equipments;
- Lights.

For the occupants, three different types were analysed [22]:

- Young Couple (YC), 2 people;
- Family (FAM), 4 people;
- Old Couple (OC), 2 people.

These are the three most representative types, shown in the graph below (from ISTAT 2010 data) that will help us to understand how consumption also varies depending on who occupies the houses, as it varies the time that the occupants spend within them.

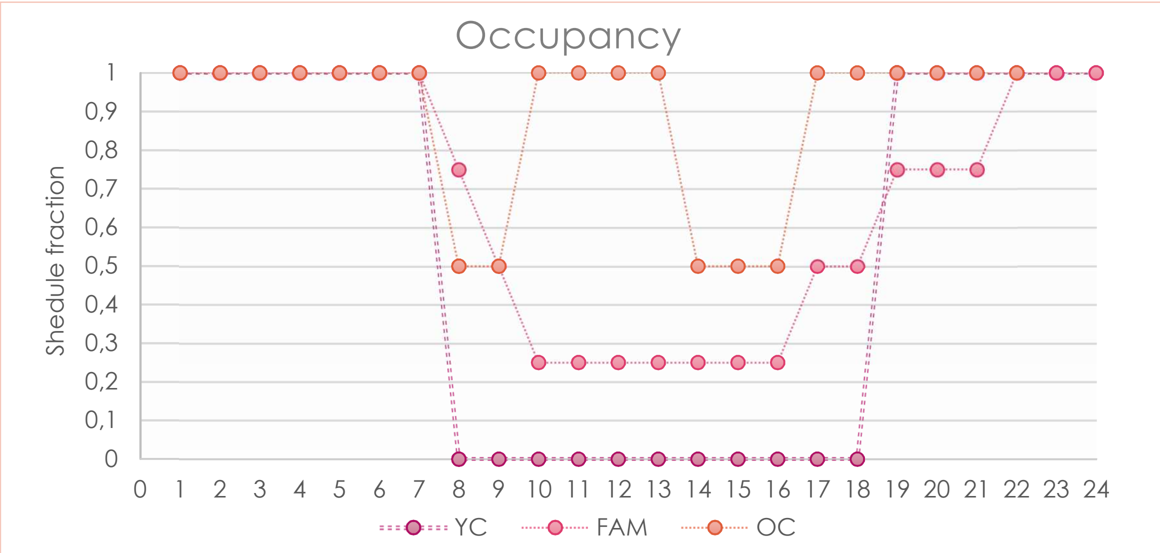


Figure 50. Schedule variation for household composition by occupancy in one Weekday.

The profile of the Young Couple with two people is assumed to consume less than the other profiles because they go out in the morning to go to work and go back home in the evening (8-18), just the moment in which they will have the highest power densities (21- 23). The profile referred to the Family is assumed to be four people and refers to the base employment schedules (DOEc), but modified to consider the possible fractions for four people (e.g. 0.25 = 1 person; 0.5 = 2 people; 0, 75 = 3 people, 1 = 4 people).

For the Old Couple, it is supposed to stay often in the house, leaving it only a few hours in the morning and in the afternoon; they should also consume more during lunch hours (from 11 to 14) and in the early evening hours (19-21).

[22] V. M. Barthelmes, C. Becchio, and S. P. Corgnati, "Occupant behavior lifestyles in a residential nearly zero energy building: Effect on energy use and thermal comfort," *Sci. Technol. Built Environ.*, vol. 22, no. 7, pp. 960–975, 2016.

From the documents from the definitive project of the Cortau House, data concerning the heating/cooling system with radiant panels were also obtained; the table below shows the data entered in the IDA ICE model.

Zone/Room	Cooling power [W]	Heating power [W]	Controller
Kitchen+Lunchroom	1681,5	3501,6	PI
Living room+Entrance	1681,05	3500,6	PI
Room 1+Wardrobe	706,05	1473,6	PI
Room2	328,1	684,7	PI
Bathroom1	0	957,5	PI
Batroom2	0	446,9	PI
Bathroom+Laundry	0	578,6	PI
Studio	378,6	790,5	PI
Hallway	214,6	448,2	PI
Corridor	-	-	-
Total	**4989,9**	**12382,2**	

Table 15. Radiant panel for heating and cooling entered in all models of Ida Ice.

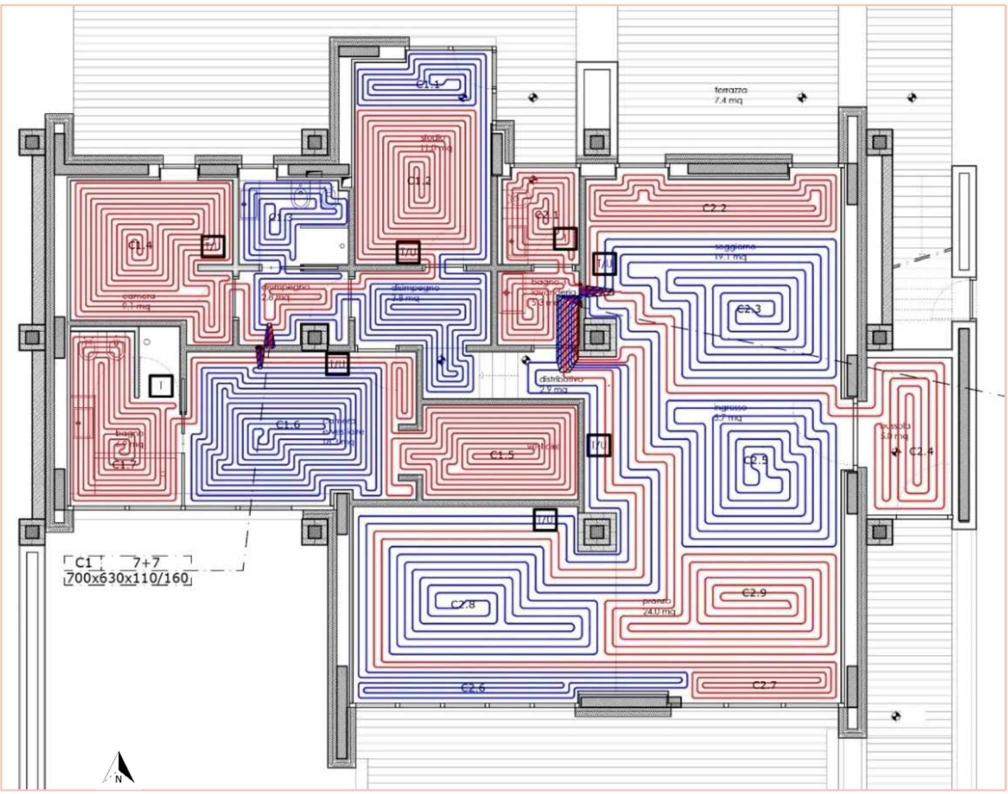


Figure 51. Indicative scheme of radiant plant. Source: Irtech, Rhoss.

With regard to the schedules used for load profiles and powers of Equipment and Lighting, the data deriving from the Micene project (eERG 2004) [36] were taken as a reference; the average powers installed per room type (Figure below) and the average daily lighting load curves of the various rooms were used, as shown in the example below (of the kitchen).

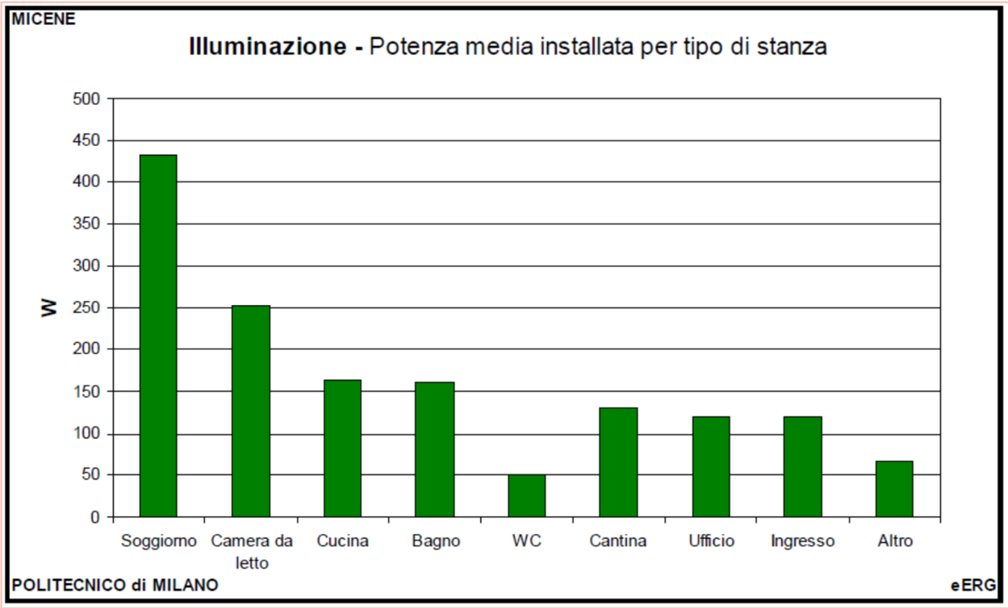


Figure 52. Lighting - Installed power by room type. Source: Micene Project.

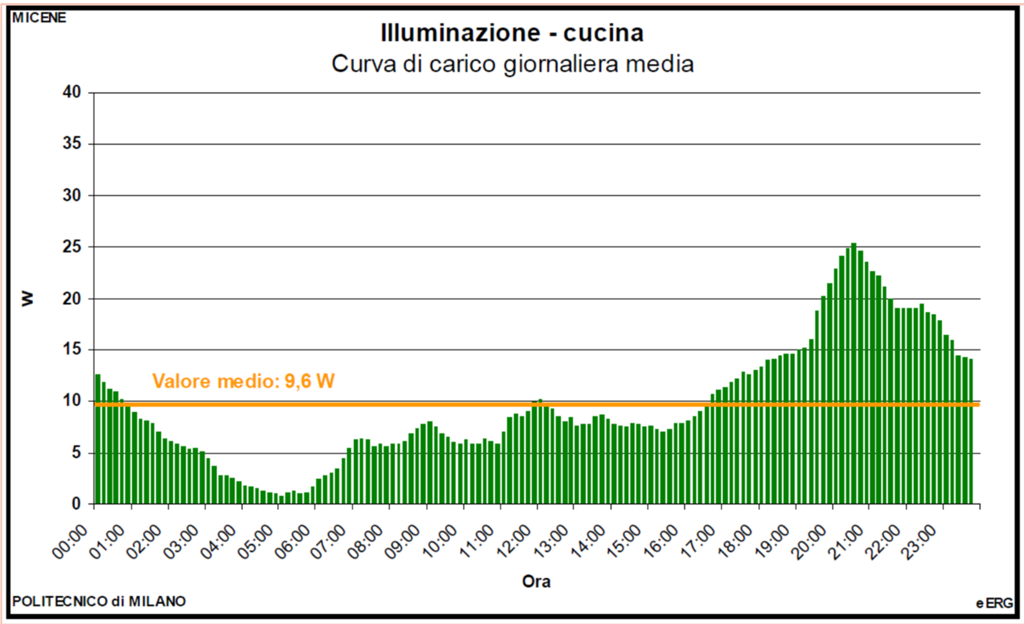


Figure 53. Lighting - Average daily load curve for the kitchen. Source: Micene Project.

The table below shows the values entered for the simulations of the different scenarios.

Zone/Room	Lighting				
	W	Mean W	W/m²	Yearly Total kWh	kWh/m²/y
Kitchen+Lunchroom	160	91,91	4,27	805,15	21,5
Living room+Entrance	400	229,8	10,68	2012,9	53,76
Room 1+Wardrobe	250	143,6	10,4	1258	52,33
Room2	250	143,6	22,4	1258	112,7
Bathroom1	150	86,17	15,35	754,83	77,27
Batroom2	100	57,45	21,9	503,22	110,2
Bathroom+Laundry	150	86,17	25,21	754,83	126,8
Studio	120	68,93	9,288	603,6	46,74
Hallway	80	45,95	11	402,57	55,33
Corridor	50	28,72	14,89	251,61	74,93
Total	**1710**	**982,3**	**145,388**	**8604,71**	**731,56**

Table 16. Lighting included in the models of Ida Ice.

As regard to electronic devices and their powers, these were also taken as reference by the Mycene monitoring campaign (eERG 2004) [36]; the following Equipment has been reported in the model, in addition to lighting equipment, in the different areas of the house:

Zone/Room	Equipments		
	Type	Mean W	W/m²
Kitchen+Lunchroom	Refrigerator Dishwasher Oven	65 20,058 9,245	3,509
Living room+Entrance	Television HI-FI	8,09 4,625	0,5876
Room 1+Wardrobe	-	-	-
Room2	Computer	5,25	1,25
Bathroom1	-	-	-
Batroom2	-	-	-
Bathroom+Laundry	Washing machine	11,96	4,789
Studio	Computer	5,25	1,084
Hallway	-	-	-
Corridor	-	-	-
Total		**129,48**	**11,2196**

Table 17. Equipment included in the models of Ida Ice.

Once all the schedules of the load curves of the devices deriving from the Micene project were analysed and included in the Base Scenario, alternative scenarios were hypothesized in which it was assumed to be able to move the domestic loads of some household appliances, based on the different tariffs taken into account.

To evaluate which loads could or could not be translated, certain exclusion criteria were taken into consideration:

- Continuity of operation of the equipment: for example, the refrigerator or freezer cabinet, the alarm and monitoring systems and the care appliances, are not considered temporally movable.
- Appliances whose use depends on exogenous variables: for example, air conditioning, electric heating, lighting, are not considered temporally movable.
- Electronic devices whose use is strongly linked to domestic or social life cycles: for example, consumer electronics and information technologies are considered only partially movable over time.

Therefore, they are considered temporary transferable by exclusion:

- Washing machines and dishwashers: the possibility of temporal translation is generally high and is considered particularly high for the most recently designed equipment equipped with the cycle start time programming function;
- Hair dryers, small tools, iron, vacuum cleaners and appliances belonging to the IT equipment category are considered temporally transferable, albeit with some limitations (but which was decided not to include in the model due to lack of accurate/reliable data).

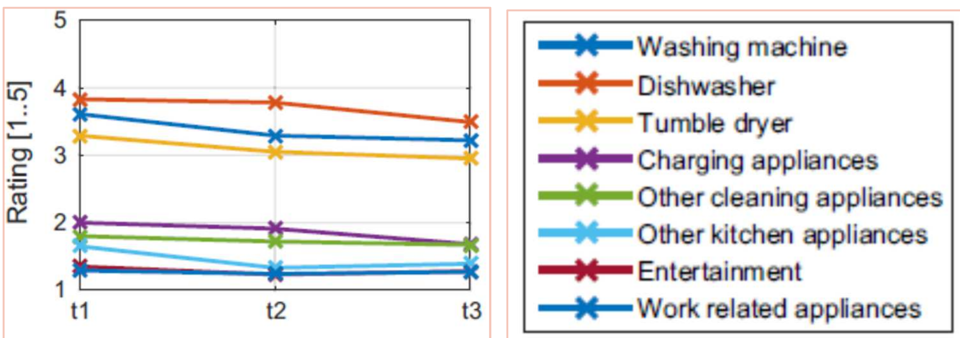


Figure 54. Example for Equipments moveable for the load shift. Padova University.

Therefore, the dishwasher and washing schedules will change, compared to those taken by the Micene project, and will be used for the Second (Demand Response) and the third Scenario (Dynamic Pricing).

The thesis develops three different types of scenarios:

- I Scenario: Basic;
- II Scenario: Demand Response;
- III Scenario: Dynamic Pricing (Advance + Comfort).

In these three different scenarios, the applied tariffs, the shifted loads and the heat pump schedules will vary according to the rate present in the simulation. All scenarios will obviously be simulated for each of the types of occupants.

Scenarios		Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
I	BASIC	YC (2 People) OC (2 People) FAM (4 People)	One-time slot	Micene Schedules	Micene Schedules	Basic	80 l/p
			Two-time slots				
			Three-time slots				
II	DEMAND RESPONSE (DR)	YC (2 People) OC (2 People) FAM (4 People)	One-time slot	Micene Schedules + Washing machine DR + Dishwasher DR	Micene Schedules	Demand Response	80 l/p
			Two-time slots				
			Three-time slots				
III	DYNAMIC PRICING (DP Advance)	YC (2 People) OC (2 People) FAM (4 People)	TOU4	Micene Schedules + Washing machine TOU4 + Dishwasher TOU4	Micene Schedules	Dynamic Pricing (Tou4 and Tou4Peak)	80 l/p
			TOU4Peak	Micene Schedules + Washing machine TOU4P + Dishwasher TOU4P			
	DYNAMIC PRICING (DP Comfort)	YC (2 People) OC (2 People) FAM (4 People)	TOU4	Micene Schedules + Washing machine TOU4 + Dishwasher TOU4	Micene Schedules	Comfort (Tou4 and Tou4Peak)	80 l/p
			TOU4Peak	Micene Schedules + Washing machine TOU4P + Dishwasher TOU4P			

Table 18. Summary of the variables of scenarios.

The table below shows the types of charging used in the simulated scenarios, i.e. the time bands and the prices of both the tariffs present in Italy and the two dynamic tariffs analysed (Tou4 and Tou4Peak), which refer to a study carried out by Energy @Home[23].

[23] R. Lanati F., Gelmini A, "*Impatti del Dynamic pricing applicato ai consumatori elettrici residenziali*". 2016.

Italy Time bands	
F0	Same price all day and all hours
F1 (Peak hours)	Monday-Friday 8:00 - 19:00
F2 (Average hours)	Monday-Friday 7:00 - 8:00 19:00 - 23:00 Saturday 7:00 - 23:00
F3 (Out Peak hours)	Monday - Saturday 23:00 - 7:00 Sunday&Holidays h.24

Table 19. Current rates in Italy and used in simulations. Source: Servizio Elettrico Nazionale.

Dynamic Rate		
TOU4 Workdays	+	17:00 - 22:00
	±	07:00 - 17:00
		22:00 - 24:00
	-	24:00 - 7:00
TOU4Peak Workdays	+	19:00 - 23:00
	±	07:00 - 19:00
		23:00 - 1:00
	-	1:00 - 7:00
TOU4 - TOU4Peak Weekdays&Holidays	+	17:00 - 23:00
	±	07:00 - 17:00 23:00 - 24:00
	-	24:00 - 7:00

Table 20. Dynamic rates used in the simulations. Source: Energy@Home.

Rates Typology €/kWh		
One-Time slot	F0	0,0768 €
Two-Time slots	F1	0,08426 €
	F2, F3	0,07321 €
Three-time slots	F1	0,07923 €
	F2, F3	0,07805 €
	F3	0,06476 €

Dynamic Rates (TOU4&TOU4Peak)	Workdays & Weekends	+	0,0633 €
		±	0,0521 €
		-	0,0439 €

Table 21. Current rates and Dynamic tariffs used in the different scenarios (days-h and €/kWh).

It can be noted that the dynamic tariffs are more advantageous at an economic level than the current Italian ones; this price difference should certainly encourage users to move towards a dynamic rate, but the latter have slots that may seem more "restrictive" and that could discourage users.

The results of the simulations of all the scenarios will be reported in each chapter:

A first table shows the results relating to the consumption of appliances in all the zones, unique for all types of occupants and for all the tariffs of the scenario considered. Subsequently, the consumption of Delivered Energy (Lighting, Electric Cooling, HVAC aux, Electric Heating, Equipment, PV production) and System Energy (Zone Heating, Zone Cooling, AHU heating, AHU cooling, DHW) are analysed through pie charts. for each occupant, which clarify in which percentage the different systems affect the total annual consumption.

Regarding the costs related to the different tariffs applied in the three scenarios, two different graphs are shown: the first bar graphs showing, for each occupant, all the various systems with their consumption related to System energy, useful to understand how each affects the total costs differently. A second chart shows instead of the total costs of the scenario, in relation to the three occupants with the different tariffs applied.

The following chapters show all three scenarios and their results in detail.

8.2 First scenario: Basic (Micene schedules)

Scenarios		Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
I	BASIC	YC (2 People) OC (2 People) FAM (4 People)	One-time slot Two-time slots Three-time slots	Micene Schedules	Micene Schedules	Basic	80 l/p

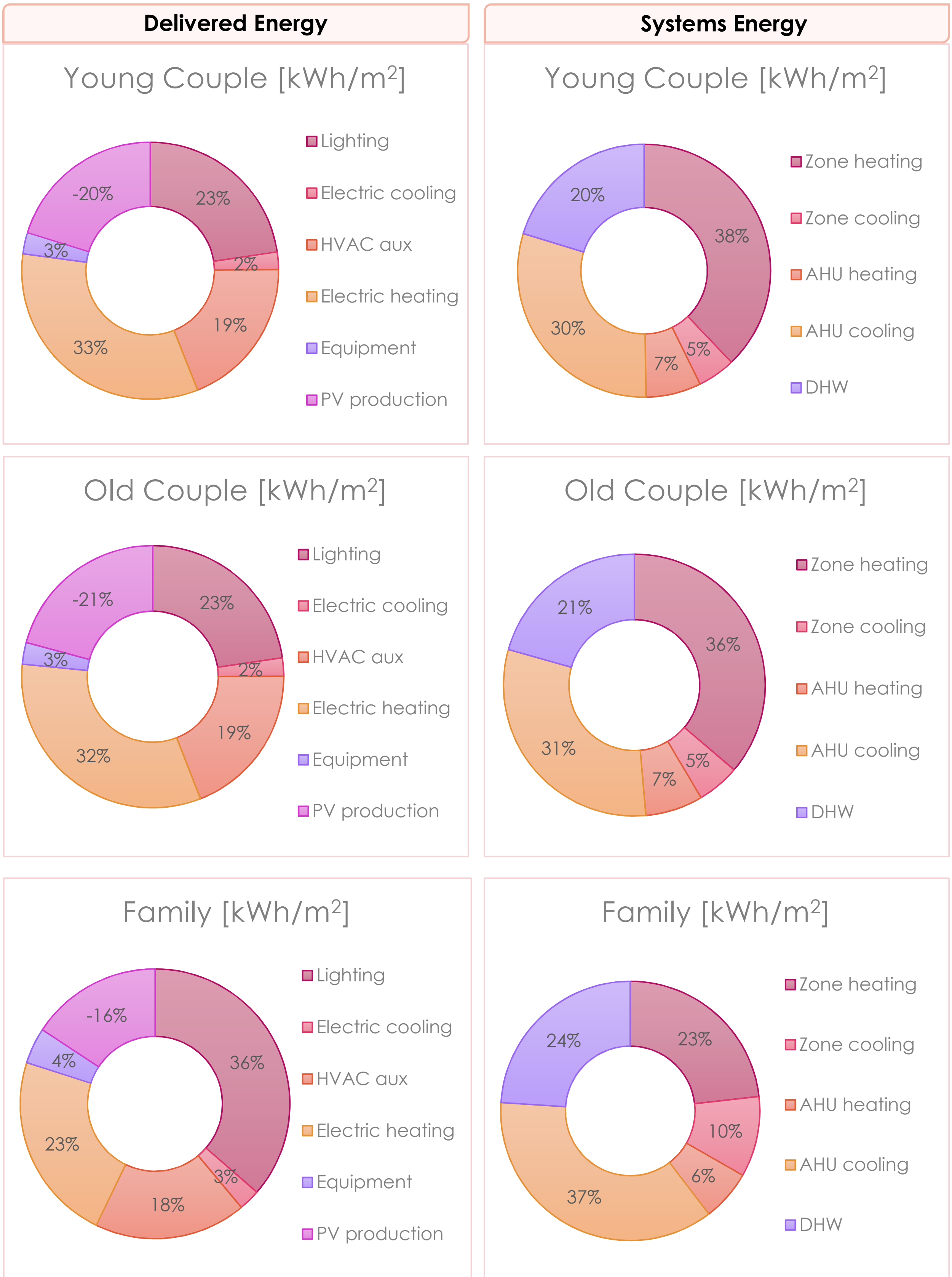
The first Basic scenario considers the current Italian tariffs: One-time slot, Two-time slots, and Three-time slots.

In this first scenario, for all three occupants and for the three tariffs, the schedules for the lighting of the Micene Project will be used (Table 16); the Micene project schedules seen in the previous chapter are always used for the devices (Table 17). In this case, the Heat Pump provides continuous operation from h 7 to 20 for Cooling and from h 6 to 24 for Heating.

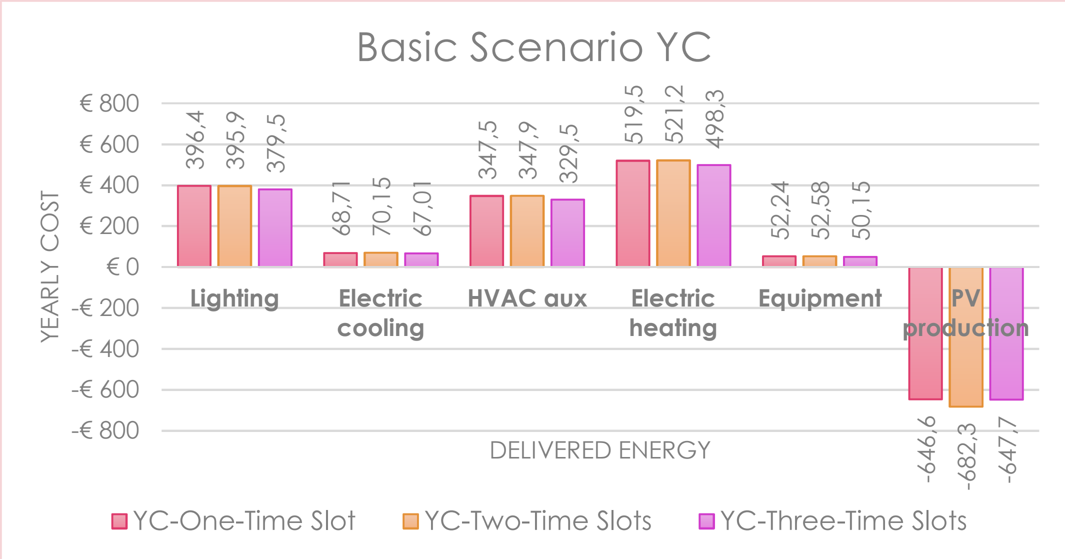
BASIC				
Zone/Room	Equipments			
	Type	Mean W	kWh/m²/y	Yearly Tot kWh
Kitchen+Lunchroom	Refrigerator Dishwasher Oven	65 9,245 20,058	22,06	826,1
Living room+Entrance	Television HI-FI	8,09 4,625	2,976	111,42
Room 1+Wardrobe	-	-	-	-
Room2	Computer	5,25	4,121	45,99
Bathroom1	-	-	-	-
Batroom2	-	-	-	-
Bathroom+Laundry	Washing machine	11,96	17,61	104,78
Studio	Computer	5,25	3,56	45,99
Hallway	-	-	-	-
Corridor	-	-	-	-
Total	**-**	**129,478**	**50,327**	**1134,28**

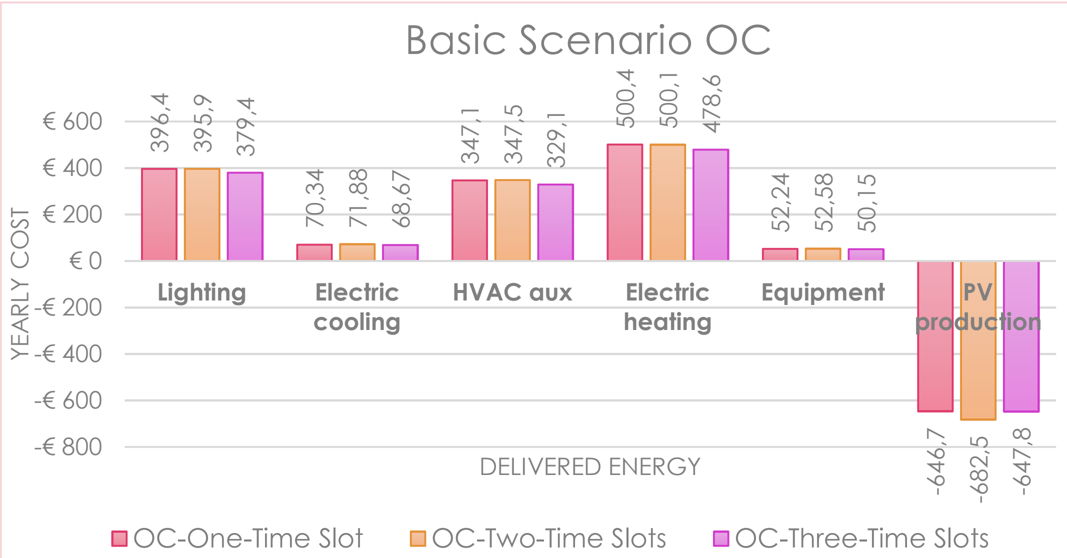
Table 22. Consumption results of the equipment for all the occupants and for all the tariffs.

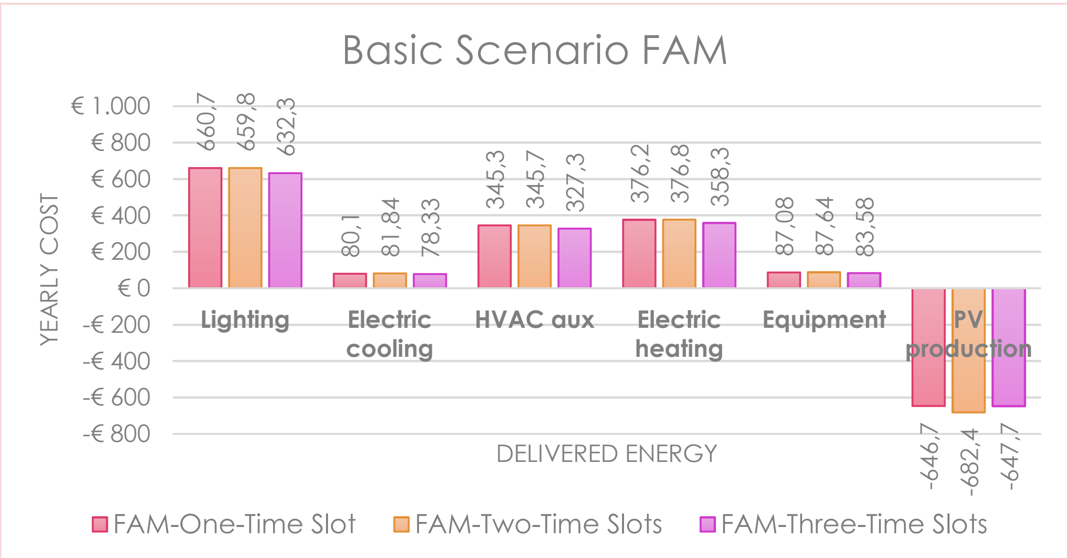
The consumption related to System Energy and Delivered Energy, for each occupant, as a percentage are shown in the pie charts below.



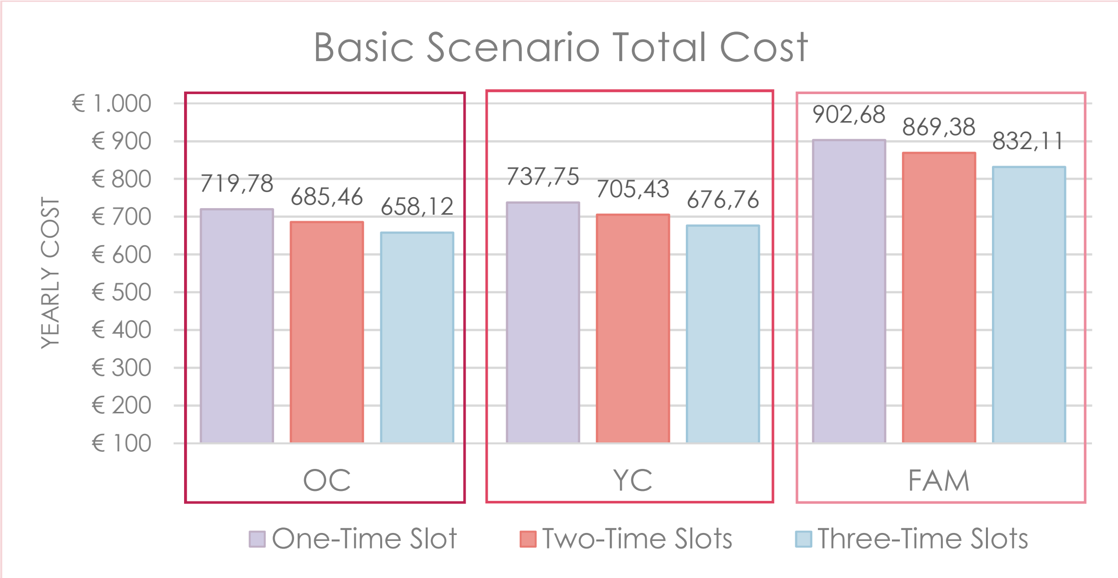
Graphics 1. Consumption of the Delivered Energy (on the Left) and System energy (on the Right) for the different occupants, Scenario Basic.







Graphics 2. Annual costs of the different occupants distributed by type of consumption, Scenario Basic.



Graphic 3. Total Annual costs of the different occupants, Scenario Basic.

Thanks to the graphs illustrated above, the following considerations can be made for this scenario: Graph 1 shows that the greater consumption for Old Couple and Young Couple for Delivered Energy concerns Heating, followed by Lighting, HVAC, Equipments and finally Cooling; only the Family consumes more for Lighting and then for Heating. While about to the System Energy the occupants have obtained different results: Old Couple and Young Couple use more for Heating, followed by AHU Cooling, DHW, AHU Heating and Cooling; the family instead consumes more for AHU Cooling, then for DHW, Heating, Cooling and AHU Heating. It is also noted that for all the share of consumption for AHU Cooling is actually high, in the case of the Family even more than Heating.

Regarding costs, graphs 2 and 3 show that, for all three occupants, the tariff Three-time slots are proved to be the most convenient, followed by the tariff Two-time slots and, finally, the tariff One-time slot.

In general, this scenario proved to be economically more advantageous for the Old Couple with the Three-time slots rate, followed by the Young Couple. For the Family, it is not very advantageous with any of the three simulated fares in the scenario.

8.3 Second scenario: Demand Response

The second scenario is the one that takes into consideration:

Scenarios		Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
II	DEMAND RESPONSE (DR)	YC (2 People) OC (2 People) FAM (4 People)	One-time slot Two-time slots Three-time slots	Micene Schedules + Washing machine DR + Dishwasher DR	Micene Schedules	Demand Response	80 l/p

The second scenario Demand Response considers the current Italian tariffs (as the first scenario): One-time slot, Two-time slots, and Three-time slots.

In this scenario, the Micene schedules for lighting are still used for all three occupants and for the three tariffs (Table 16); the Micene schedules are again used for the appliances (Table 17), but unlike the first scenario, the load curves for washing machines and dishwashers have also been modified, as well as the operation of the heat pump, referring to the different types of rates used and in the presence of occupants at home. Therefore, their operation was fully loaded at the most convenient hours of the day.

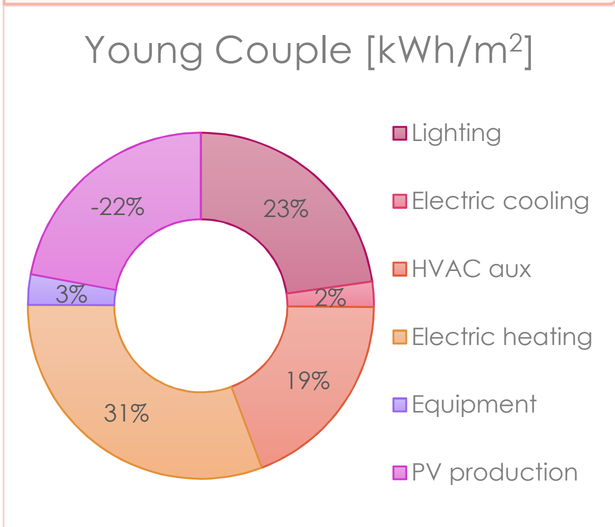
DEMAND RESPONSE				
Zone/Room	Equipments			
	Type	Mean W	kWh/m²/y	Yearly Tot kWh
Kitchen+Lunchroom	Refrigerator Dishwasher Oven	65 15,75 20,058	21,05	788,398
Living room+Entrance	Television HI-FI	8,09 4,625	2,976	111,416
Room 1+Wardrobe	-	-	-	-
Room2	Computer	5,2	4,121	45,99
Bathroom1	-	-	-	-
Batroom2	-	-	-	-
Bathroom+Laundry	Washing machine	9,077	13,36	79,514
Studio	Computer	5,2	3,56	45,99
Hallway	-	-	-	-
Corridor	-	-	-	-
Total	**-**	**133**	**45,067**	**1071,308**

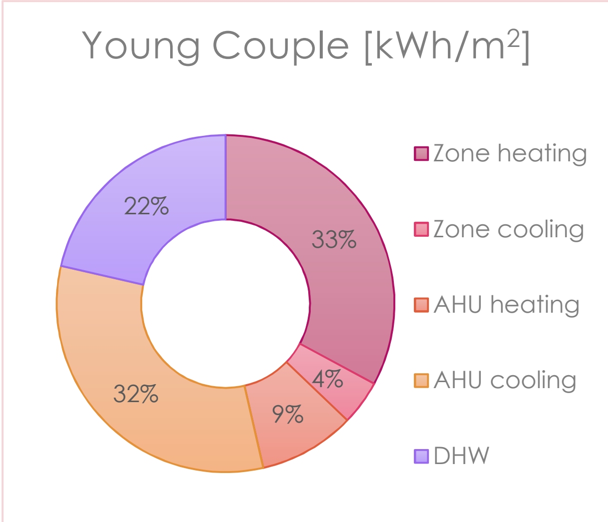
Table 23. Consumption results of the equipment for all the occupants and for all the tariffs.

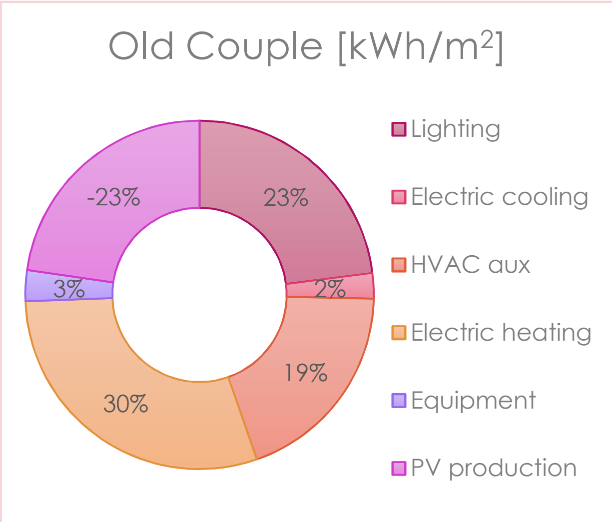
Below are shown in the pie charts the consumption related to System Energy and Delivered Energy, for each occupant, as a percentage; bar charts, for each occupant.

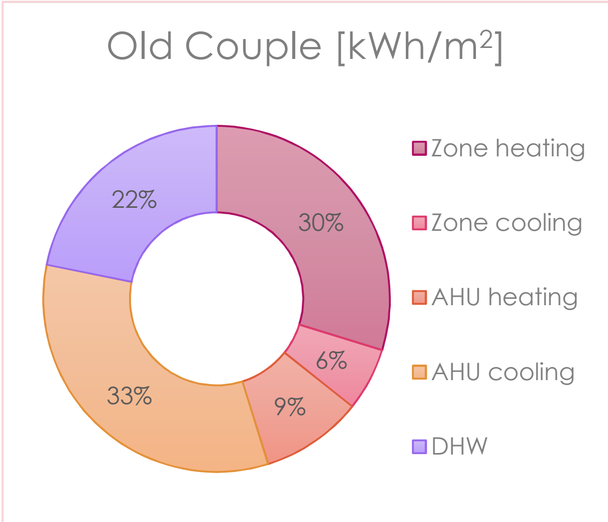
Below are the graphs relating to the costs of the different rates for each occupant.

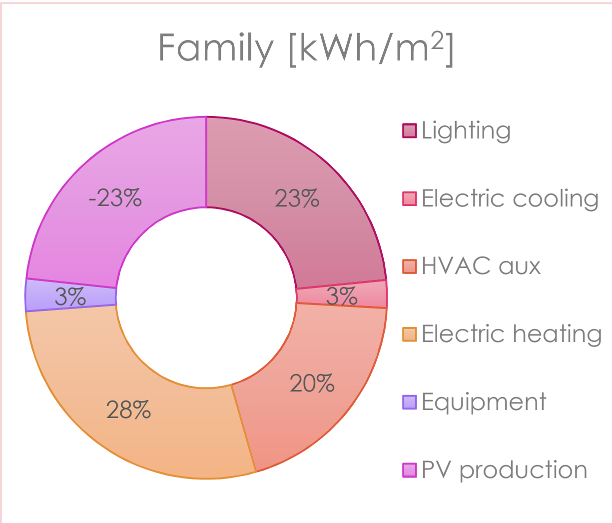
Delivered Energy | **Systems Energy**

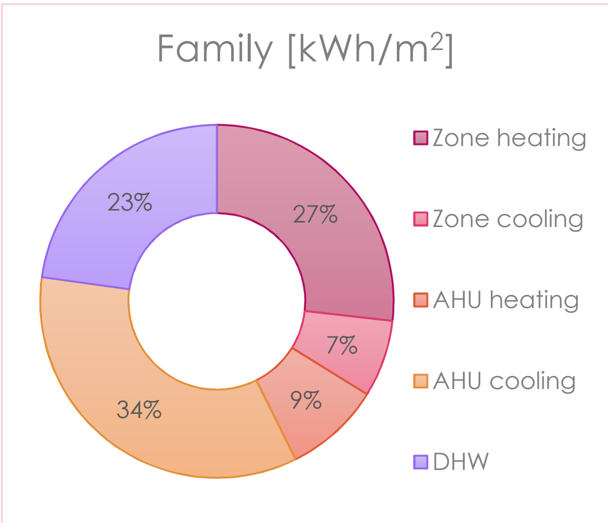




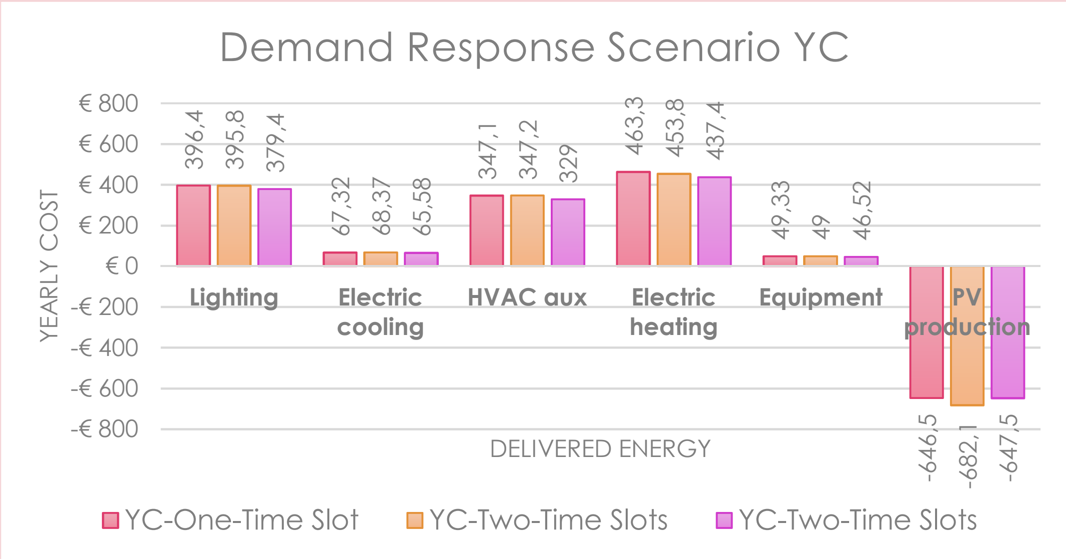


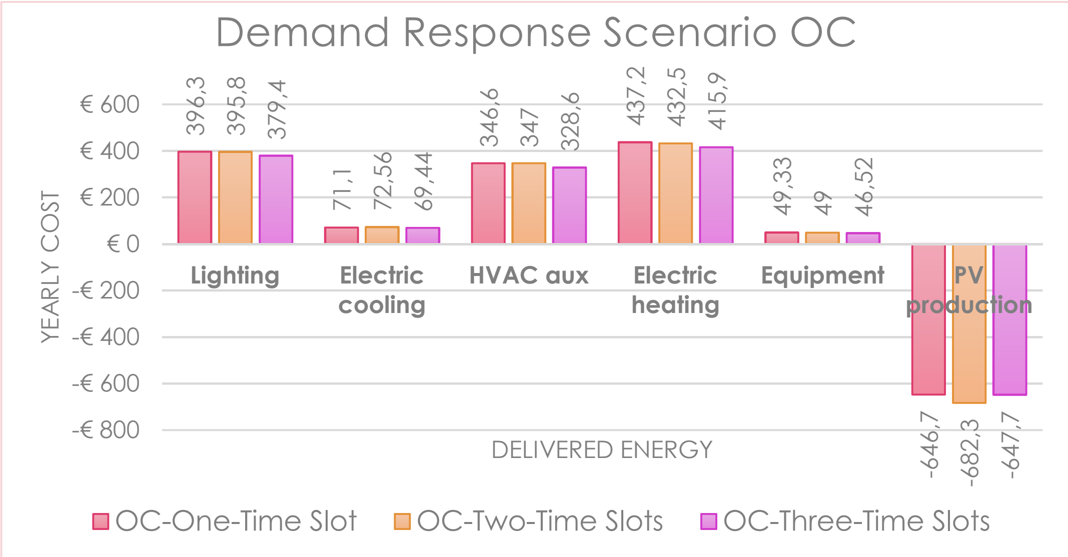


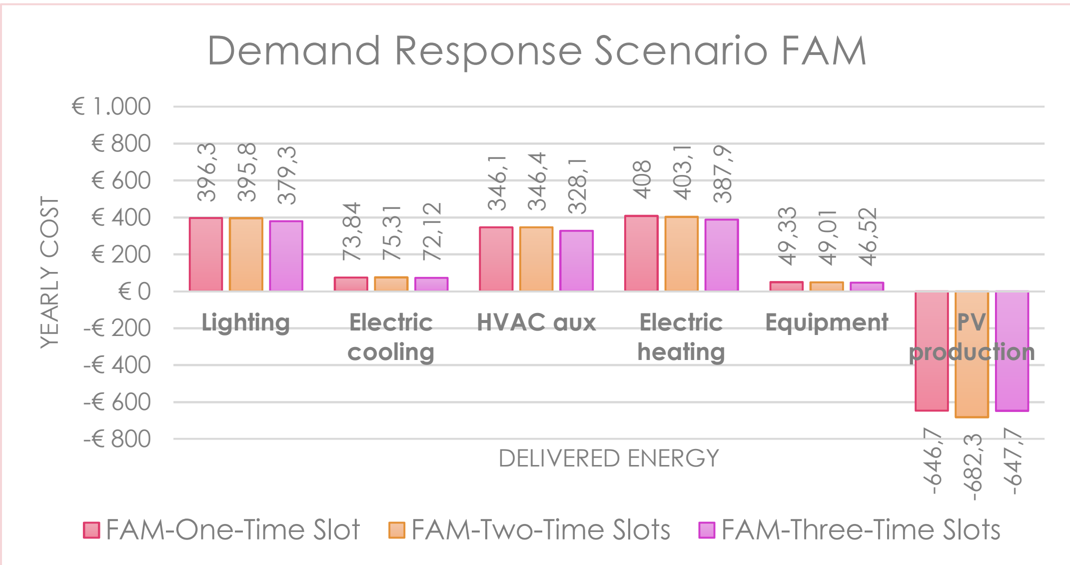




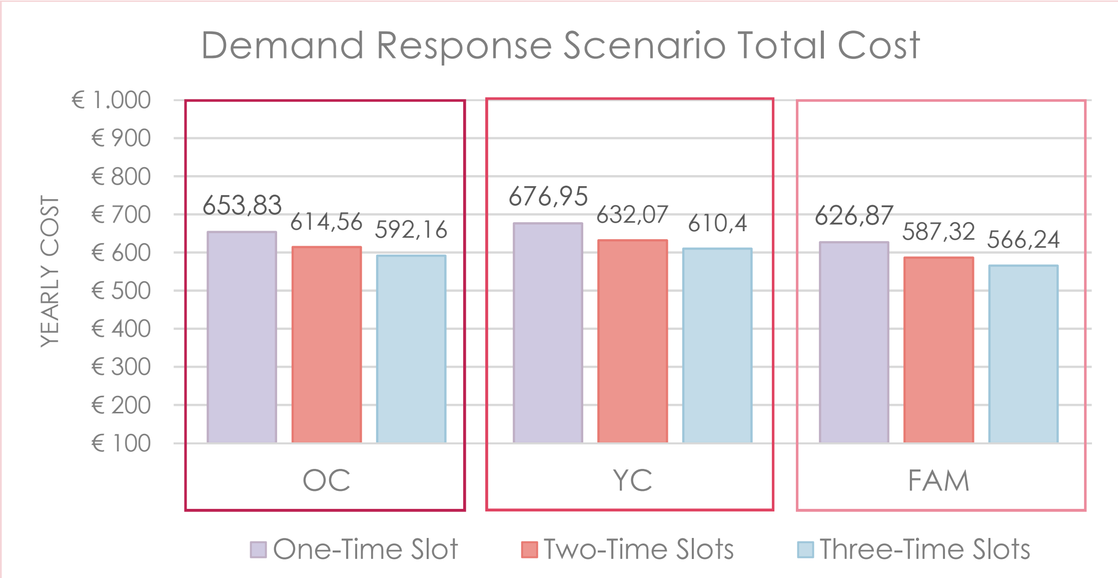
Graphics 4. Consumption of the Delivered Energy (on the Left) and System energy (on the Right) for the different occupants, Scenario DR.







Graphics 5. Annual costs of the different occupants distributed by type of consumption, Scenario DR.



Graphics 6. Total annual costs of all rates in the Demand Response scenario, for different occupants.

Thanks to the graphs illustrated above, it is possible to make the following considerations for this scenario: as for the first scenario (Basic) from Graph 4 can be seen that the greatest consumption of all occupants for Delivered Energy regards Heating, followed by Lighting, HVAC, Equipment and finally Cooling. While regarding System Energy the occupants have obtained different results: only the Young Couple consumes more for Heating, followed by AHU Cooling, DHW, AHU Heating and Cooling; the Old Couple family instead consume no more as the first scenario (where they were in order for AHU Cooling, then for DHW, Heating, Cooling and AHU Heating), but the most consumption they always have for AHU Cooling, but it is time followed by Heating and then from DHW, then for AHU Heating and finally for Cooling.

About costs, graphs 5 and 6 show that, for all three occupants, the Three-time slots tariff proves to be the most cost-effective, followed by the Two-time slots tariff and finally the One-time slot tariff. Just like in the Base scenario.

Among the different occupants, in general, this scenario proved to be economically more advantageous for the Family with the Three-time slots tariff, followed by the Old Couple; it is not very advantageous for the Young Couple instead. Unlike the first Base scenario, it can already be seen that in any case, the costs of the annual consumption of electricity in all the tariffs are much lower than those obtained in the base scenario. This is certainly due to the substantial difference for the times and the methods of ignition of the Heat Pump and of the washing machine and dishwasher, which in this scenario have been modulated both based on the tariffs and on the basis of the occupants' presence.

8.4 Third scenario: Dynamic Pricing

The third scenario is the one that takes into consideration:

Scenarios		Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
III	DYNAMIC PRICING (DP Advance)	YC (2 People) OC (2 People) FAM (4 People)	TOU4	Micene Schedules + Washing machine DP + Dishwasher DP	Micene Schedules	Dynamic Pricing	80 l/p
			TOU4Peak				
	DYNAMIC PRICING (DP Comfort)	YC (2 People) OC (2 People) FAM (4 People)	TOU4	Micene Schedules + Washing machine TOU4 + Dishwasher TOU4	Micene Schedules	Comfort	80 l/p
			TOU4Peak	Micene Schedules + Washing machine TOU4P + Dishwasher TOU4P			

The third Dynamic Pricing scenario no longer considers the current Italian tariffs (such as the first and second scenarios, i.e. One-time slots, Two-time slots and Three-time slots), but applies two different dynamic rates: TOU4 and TOU4 Peak, which were taken as a reference by the study conducted by Energy@Home [43].

In this scenario, for all three occupants and for the tariffs, the schedules for the lighting of the Micene Project are still used (Table 16); for the appliances, the schedules of the Micene project are used as before (Table 17), but as in the second scenario, the load curves for washing machine and dishwashers have been modulated and the operation of the Heat Pump, this time referring to the bands of the other two dynamic tariffs used in this scenario.

This rough scenario (DP) is in turn divided into two parts: DP Advance (Chapter 8.4.1) and DP Comfort (Section 8.4.2). Both the first and the second show the modified load curves for washing machines and dishwashers, designed to combine the occupants' presence with the price trend of the two dynamic tariffs (TOU4 and TOU4 Peak). The difference between the two scenarios is represented by the Heat Pump, which in the first case has a linear trend (as in the first 2 scenarios), always modelled on the basis of the two dynamic tariffs; in the second case instead, the Heat Pump has a more sinuous and has been designed to ensure that the occupants always have a feeling of comfort, to keep 20 ° C in winter and 26 ° in summer. With this last scenario, in addition to data on consumption and costs, it will be noted (for a building like the Cortau House, i.e. a nZEB), how long it takes the operative temperature to decrease by 1 ° C, in a living area and in an area night, during a working day and a public holiday, both in summer and in winter.

Regarding the two scenarios of the Dynamic Pricing, the results related to the consumes of the Equipments are shown below, divided into two types of rates: TOU4 and TOU4 Peak.

DYNAMIC PRICING: TOU 4				
Zone/Room	Equipments			
	Type	Mean W	kWh/m²/y	Yearly Tot kWh
Kitchen+Lunchroom	Refrigerator Dishwasher Oven	65 11,458 9,24	19,89	744,724
Living room+Entrance	Television HI-FI	8,09 4,625	2,976	111,416
Room 1+Wardrobe	-	-	-	-
Room2	Computer	5,2	4,121	45,99
Bathroom1	-	-	-	-
Batroom2	-	-	-	-
Bathroom+Laundry	Washing machine	10,03	14,77	87,87
Studio	Computer	5,2	3,56	45,99
Hallway	-	-	-	-
Corridor	-	-	-	-
Total	**-**	**118,843**	**45,317**	**1035,99**

DYNAMIC PRICING: TOU4 Peak				
Zone/Room	Equipments			
	Type	Mean W	kWh/m²/y	Yearly Tot kWh
Kitchen+Lunchroom	Refrigerator Dishwasher Oven	65 11,458 9,24	20,05	750,758
Living room+Entrance	Television HI-FI	8,09 4,625	2,976	111,416
Room 1+Wardrobe	-	-	-	-
Room2	Computer	5,2	4,121	45,99
Bathroom1	-	-	-	-
Batroom2	-	-	-	-
Bathroom+Laundry	Washing machine	9,079	13,36	79,53
Studio	Computer	5,2	3,56	45,99
Hallway	-	-	-	-
Corridor	-	-	-	-
Total	**-**	**117,892**	**44,067**	**1033,684**

Table 24. Consumption results of the equipment for all the occupants and for the tariffs TOU4 and TOU4 Peak, Scenario DP.

8.4.1 Heat Pump Dynamic Pricing: Advance

The first case of the third scenario is the one that takes into consideration:

	Scenarios	Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
III	DYNAMIC PRICING (DP Advance)	YC (2 People) OC (2 People) FAM (4 People)	TOU4	Micene Schedules + Washing machine TOU4 + Dishwasher TOU4	Micene Schedules	Dynamic Pricing (Tou4 and Tou4Peak)	80 l/p
			TOU4Peak	Micene Schedules + Washing machine TOU4P + Dishwasher TOU4P			

The first case analysed is the Advance scenario of the third Dynamic Pricing scenario

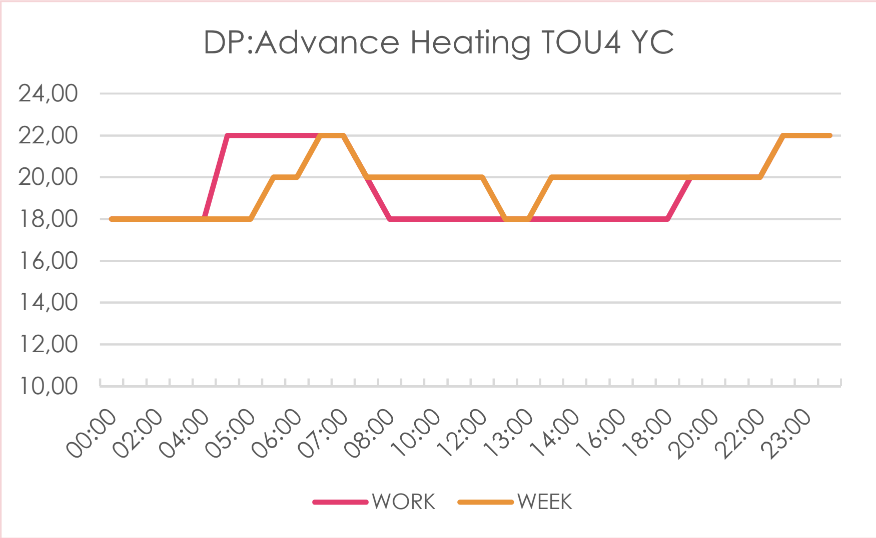
In this case, the schedules for the lighting of the Micene Project are used for all three occupants and for the two tariffs (Table 16); for the appliances, the schedules of the Micene project are used (Table 17), here the load curves for washing machine and dishwashers and also the functioning of the Heat Pump have been modified compared to those of the Micene Project referring to the different prices of the tariff bands , trying to combine the presence of the occupants with the trend of the bands of the two dynamic tariffs (TOU4 and TOU4 Peak). In this case the Heat Pump has a linear trend (as in the first 2 scenarios), but modelled according to the different bands of the two dynamic tariffs. Below the Graphics from Graphics 7 to 10 show an example of functioning of the Heat Pump for Heating and for Cooling, modelled on IDA ICE, in the case of the Young Couple, for the two dynamic tariffs, TOU4 and TOU4 Peak.

The table below shows the periods for switching the Heat Pump on and off both for heating and cooling.

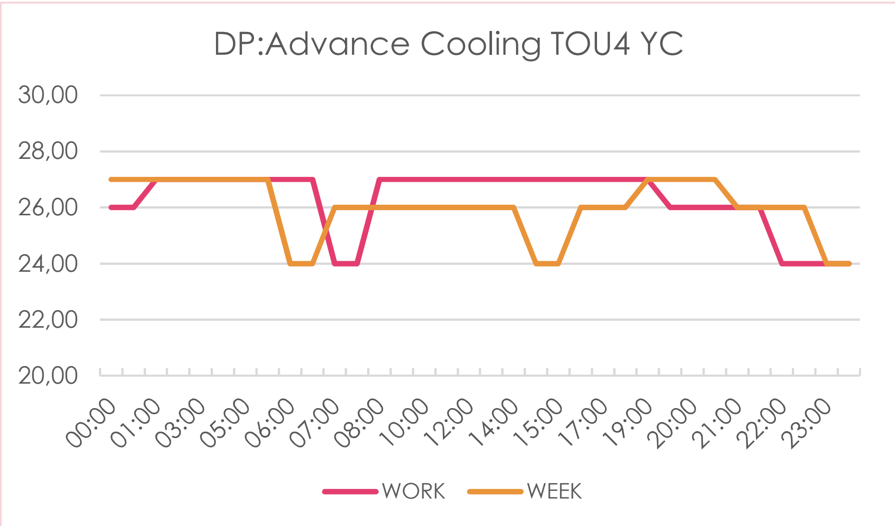
Heating	Workdays	Weekends
Start date	15/10/2017	
End date	15/04/2017	

Cooling	Workdays	Weekends
Start date	30/04/2017	
End date	30/09/2017	

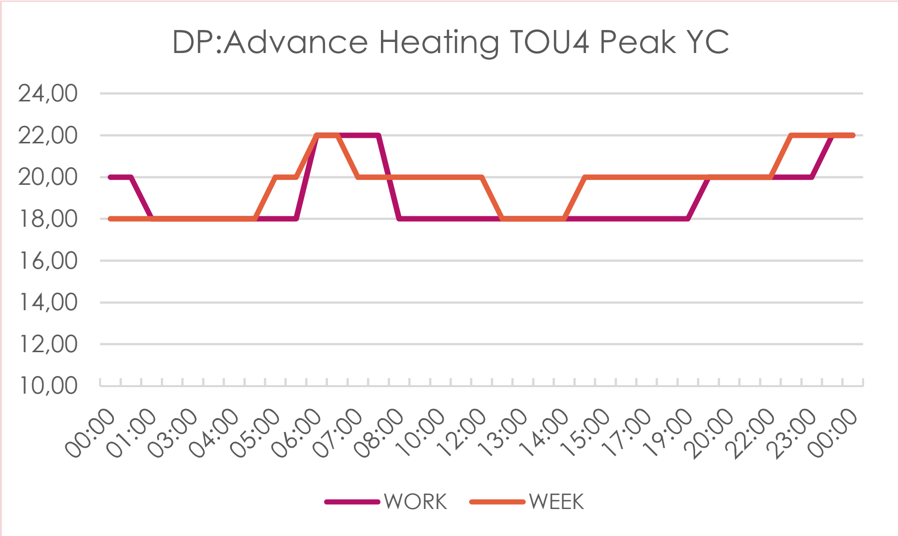
Table 25. Switching on and off for the Heat Pump, used in all scenarios.



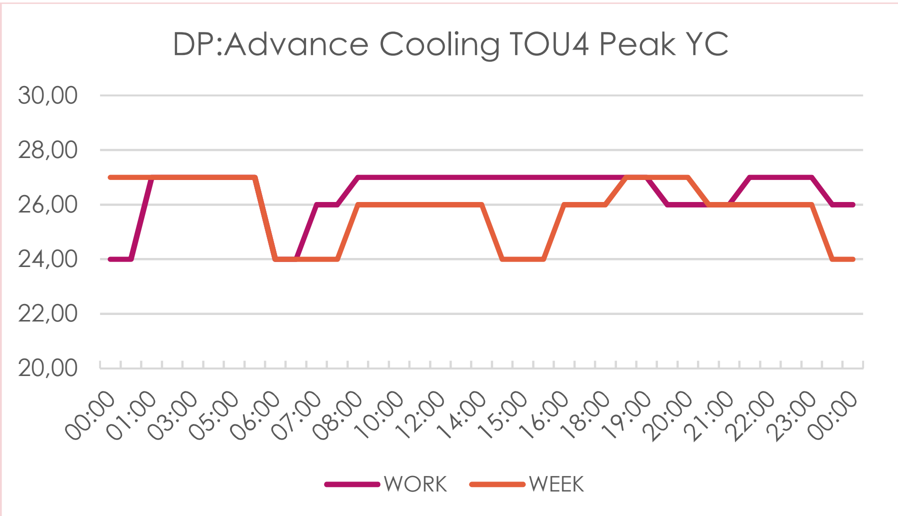
Graphic 7. Heat Pump DP: Heating TOU4 Advance Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE.



Graphic 8. Heat Pump DP: Cooling TOU4 Advance Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE

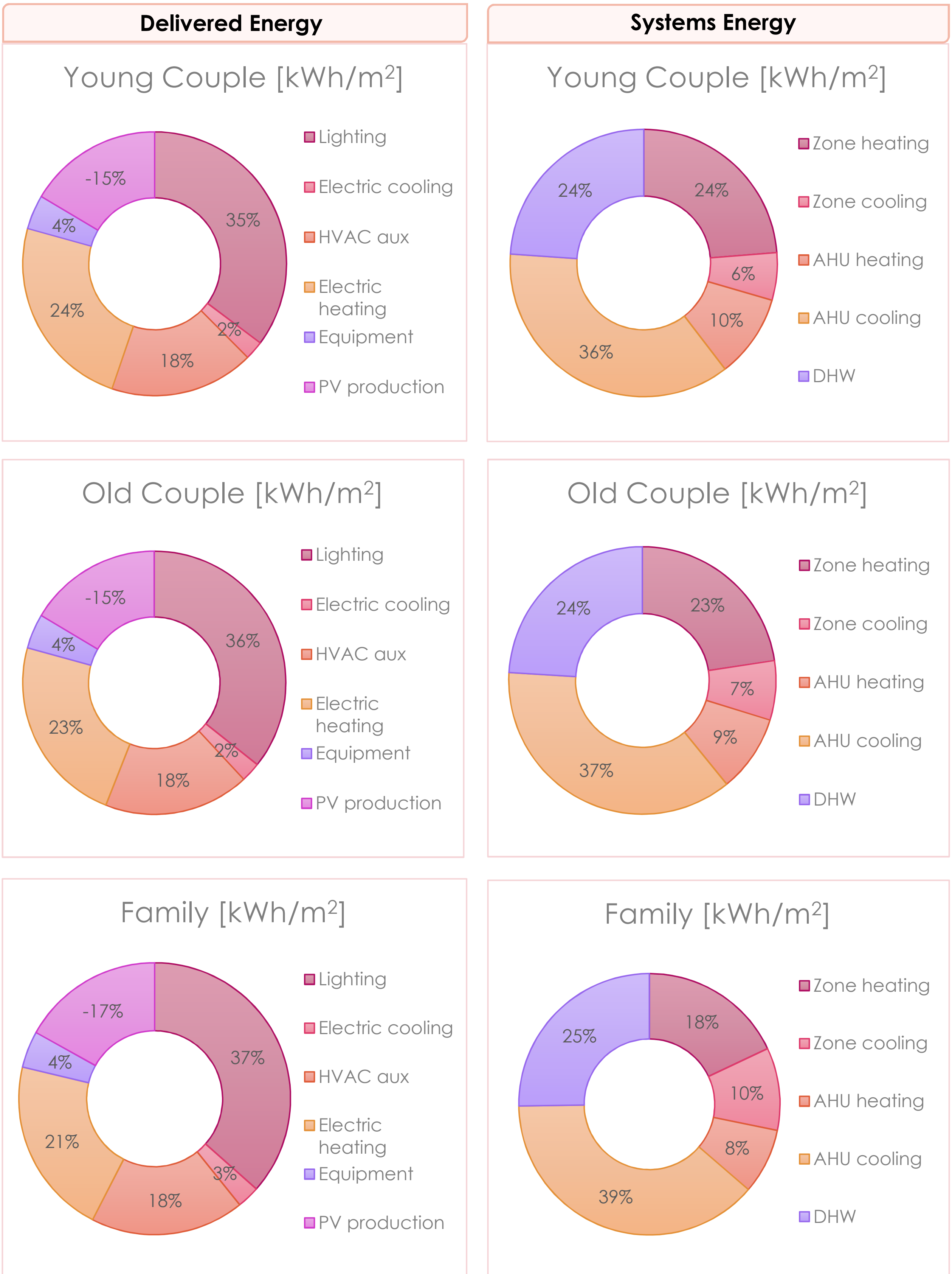


Graphic 9. Heat Pump DP: Heating TOU4Peak Advance Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE

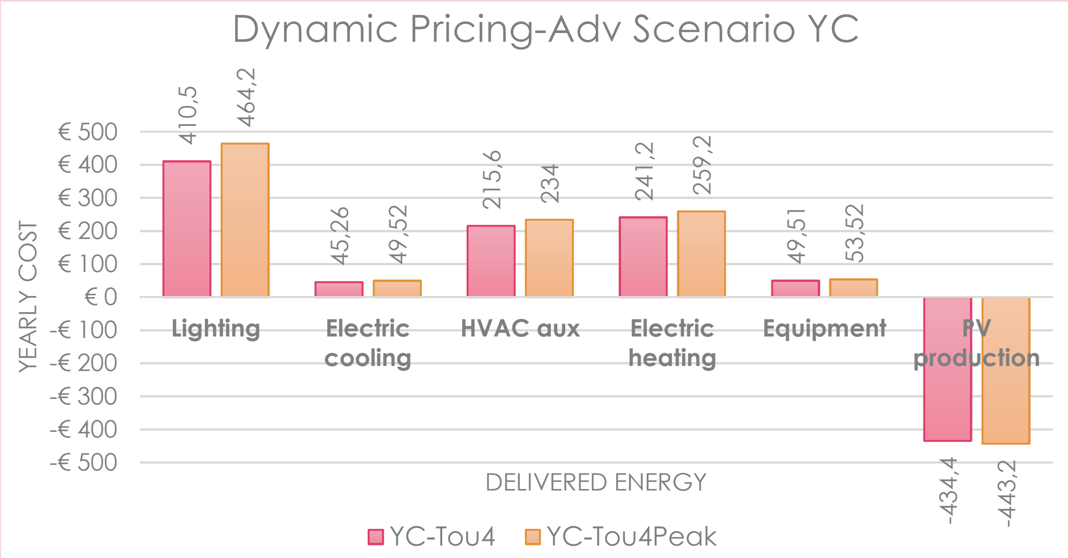


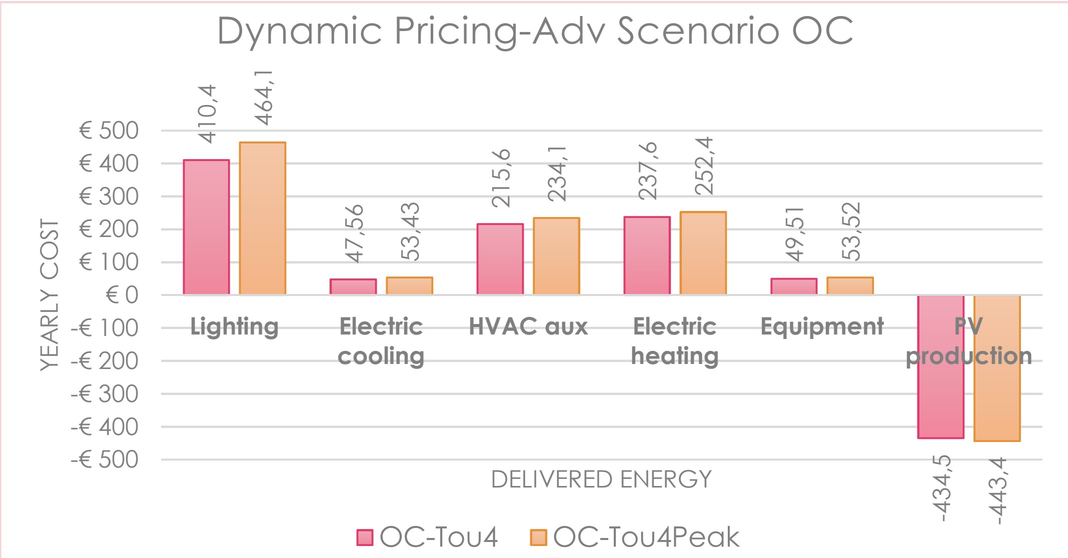
Graphic 10. Heat Pump DP: Cooling TOU4Peak Advance Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE

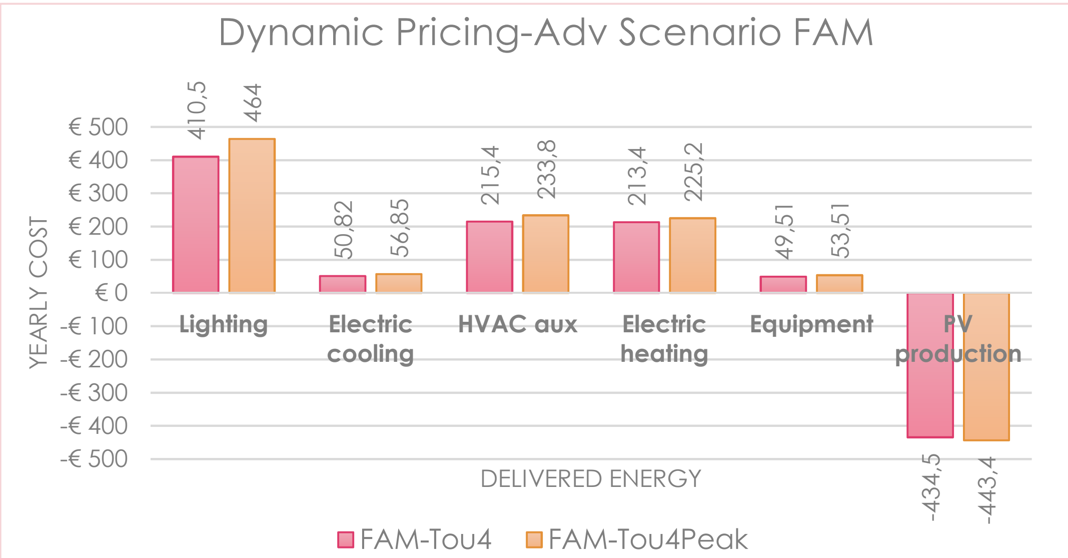
The graphs relating to consumption and costs for the various occupants related to this scenario are shown below.



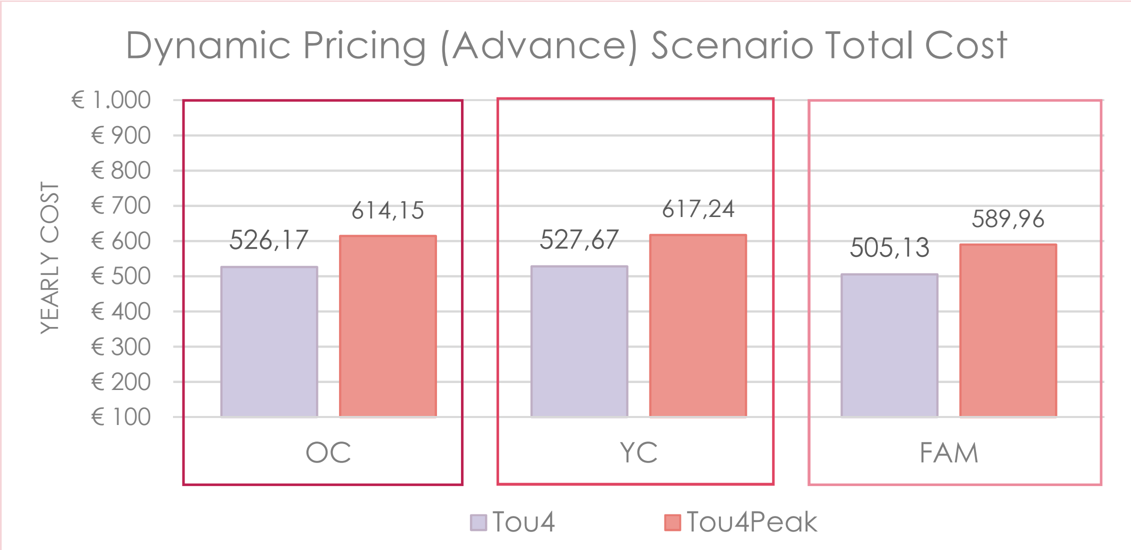
Graphics 11. Consumption of the Delivered Energy (on the Left) and System energy (on the Right) for the different occupants, Scenario DP Advance.







Graphics 12. Annual costs of the different occupants distributed by type of consumption, Scenario DP Advance.



Graphic 13. Total annual costs of all rates in the Dynamic Pricing-Advance scenario, for different occupants.

Thanks to the graphs illustrated above, it is possible to make the following considerations for this scenario: unlike the first and second scenarios, from graphs 11 we can see that the greatest consumption of all occupants for Delivered Energy concerns first Lighting and then Heating, followed by HVAC, Equipment and finally Cooling. Unlike the other two scenarios, here for the consumption of System Energy, the occupants have obtained the same result: the higher consumption is for AHU Cooling, then for DHW, Heating, Cooling and AHU Heating.

About costs, the graphs 12 and 13 show that, for all three occupants, the most convenient tariff is TOU4, followed by the TOU4 Peak.

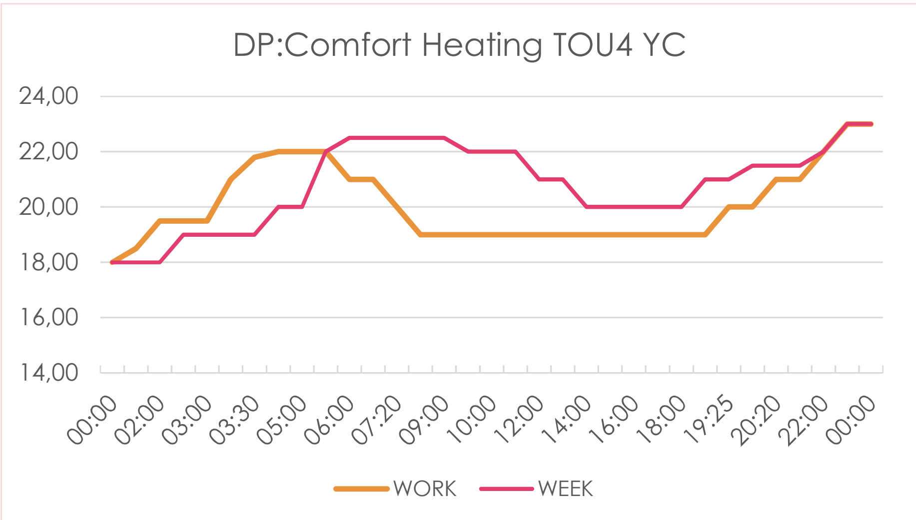
Among the different occupants, in general, this scenario proved to be economically more advantageous for the Family, considering both the TOU4 and TOU4 Peak fare, followed by the Old Couple; they are less advantageous for the Young Couple. Anyway, in this case the costs of annual electricity consumption in all rates are lower than in the second scenario (DR) and above all compared to the first scenario (Basic). This is certainly due to the further difference for the timing and the modes of ignition of the Heat Pump and washing machine and dishwashers, which in this scenario have been modulated both based on rates and according to the occupants, but this time following the dynamic tariffs.

8.4.2 Heat Pump Dynamic Pricing: Comfort

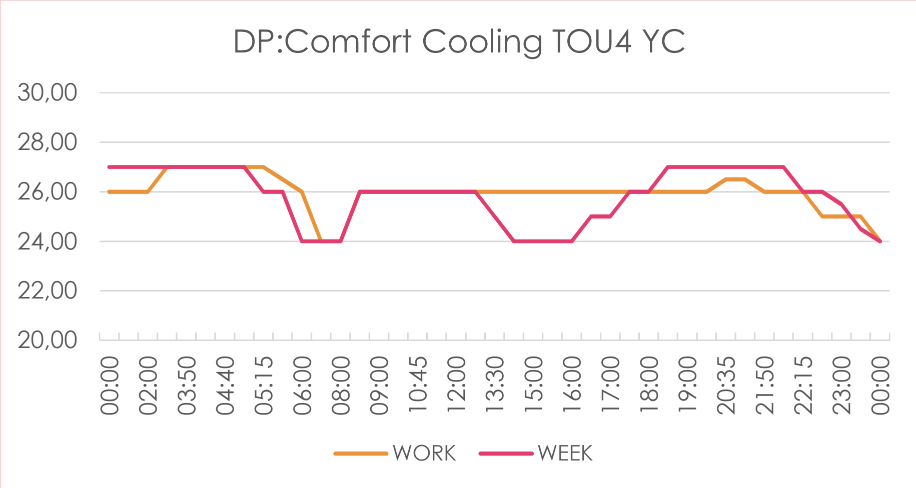
Of the third Dynamic Pricing scenario, the second case analysed is Comfort.

	Scenarios	Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
III	DYNAMIC PRICING (DP Comfort)	YC (2 People) OC (2 People) FAM (4 People)	TOU4	Micene Schedules + Washing machine TOU4 + Dishwasher TOU4	Micene Schedules	Comfort (Tou4 and Tou4Peak)	80 l/p
			TOU4Peak	Micene Schedules + Washing machine TOU4P + Dishwasher TOU4P			

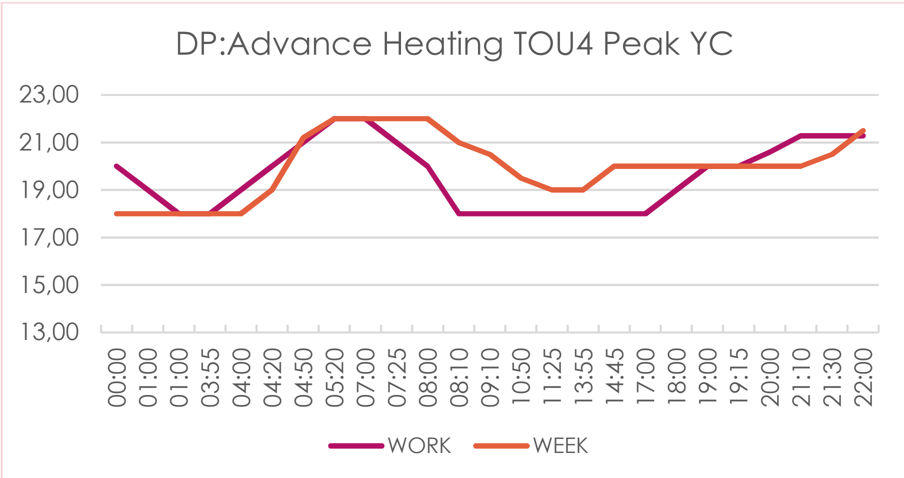
In this case, as mentioned above, the schedules for the lighting of the Micene Project are used for all three occupants and for the two tariffs (Table 16); for the appliances, as in all the scenarios, the schedules of the Micene project (Table 17) are used, here the load curves for washing machine and dishwashers and also the functioning of the Heat Pump have been modified compared to those of the Micene Project, referring to the bands of the two rates, always thinking of combining the presence of the occupants with the trend of the dynamic tariffs (TOU4 and TOU4 Peak). In this case, the Heat Pump has a less linear trend (as in the first 2 scenarios and in the DP: Advance). Below the Graphics (from 14 to 17) show an example of Heat Pump for Heating and Cooling, modelled on IDA ICE, in the case of the Young Couple, for the two dynamic rates, TOU4 and TOU4 Peak. We note the non-linear trend, aimed at maintaining the optimal temperature and comfort required inside the rooms, in summer, and in winter.



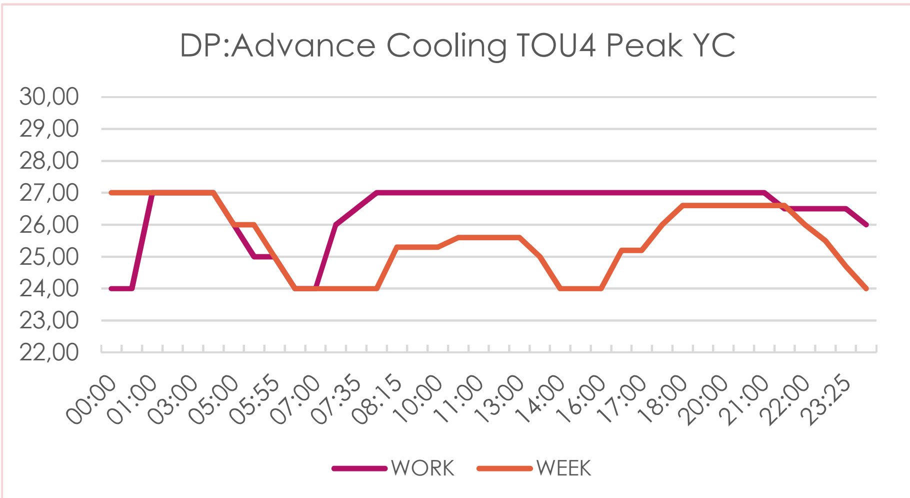
Graphic 14. Heat Pump DP: Heating TOU4 Comfort Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE



Graphic 15. Heat Pump DP: Cooling TOU4 Comfort Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE

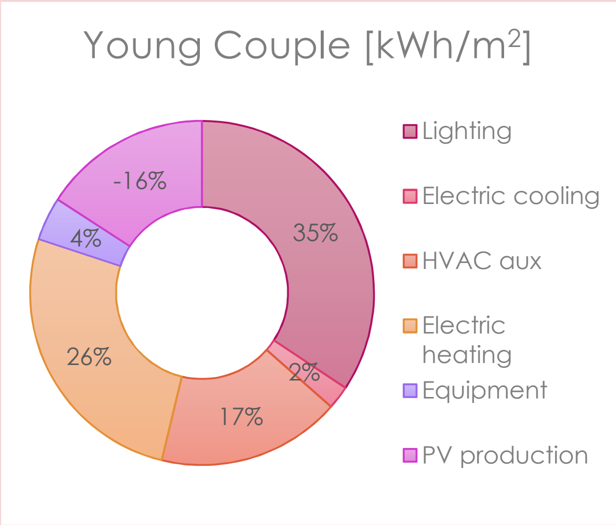


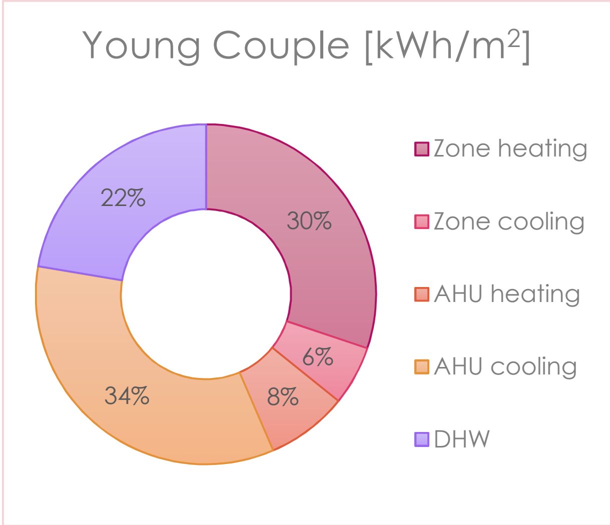
Graphic 16. Heat Pump DP: Heating TOU4Peak Comfort Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE.

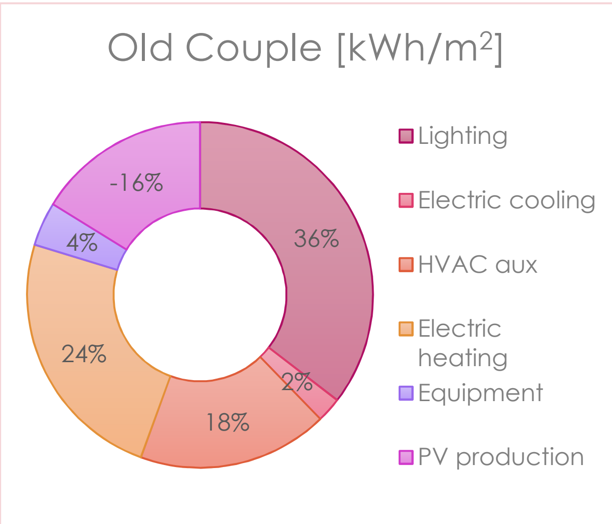


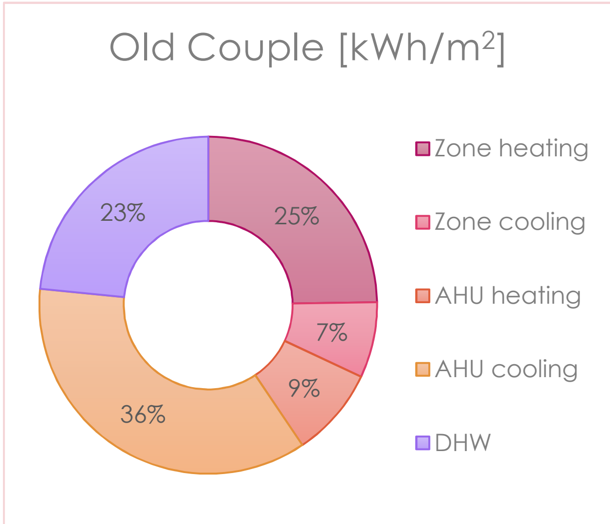
Graphic 17. Heat Pump DP: Cooling TOU4Peak Comfort Young Couple (for Workdays and Weekends-Holydays). Source: IDA ICE.

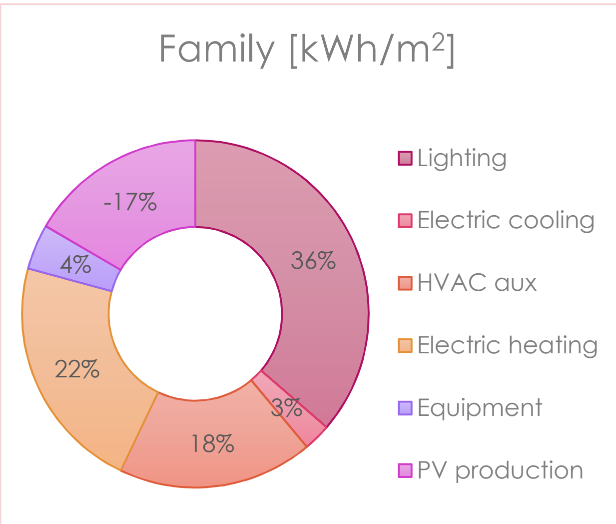
Delivered Energy	Systems Energy

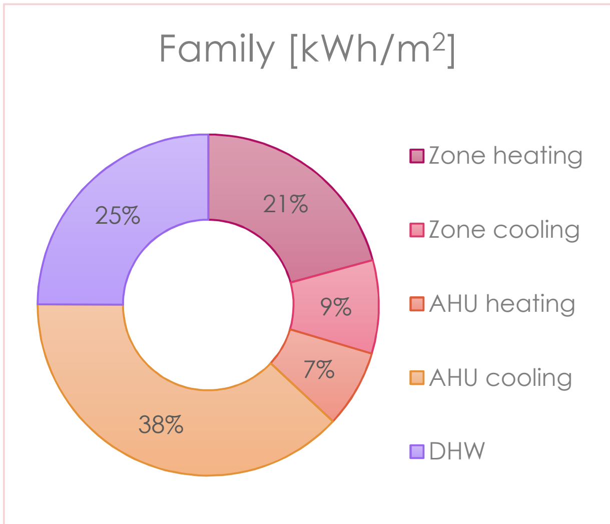




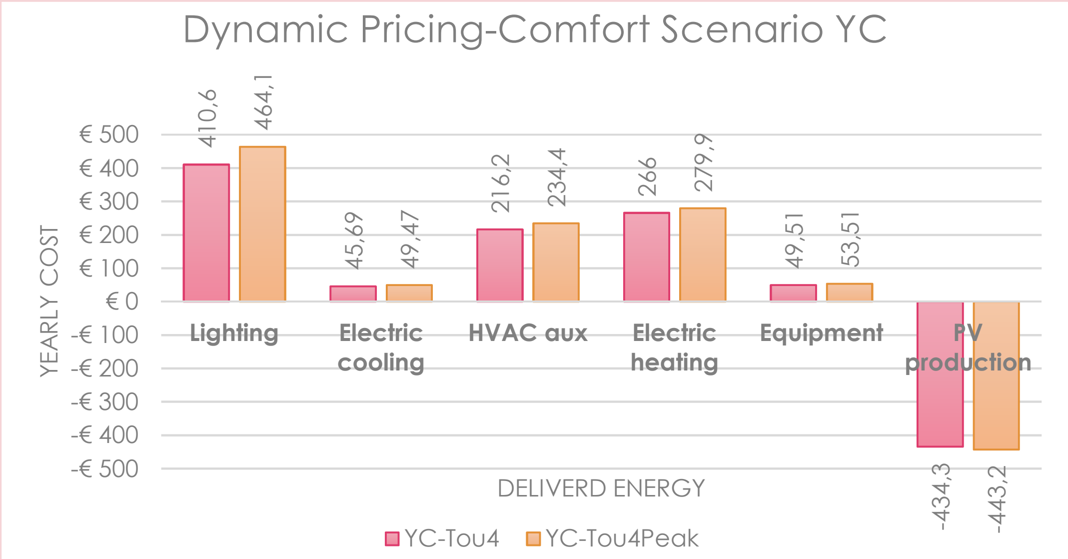


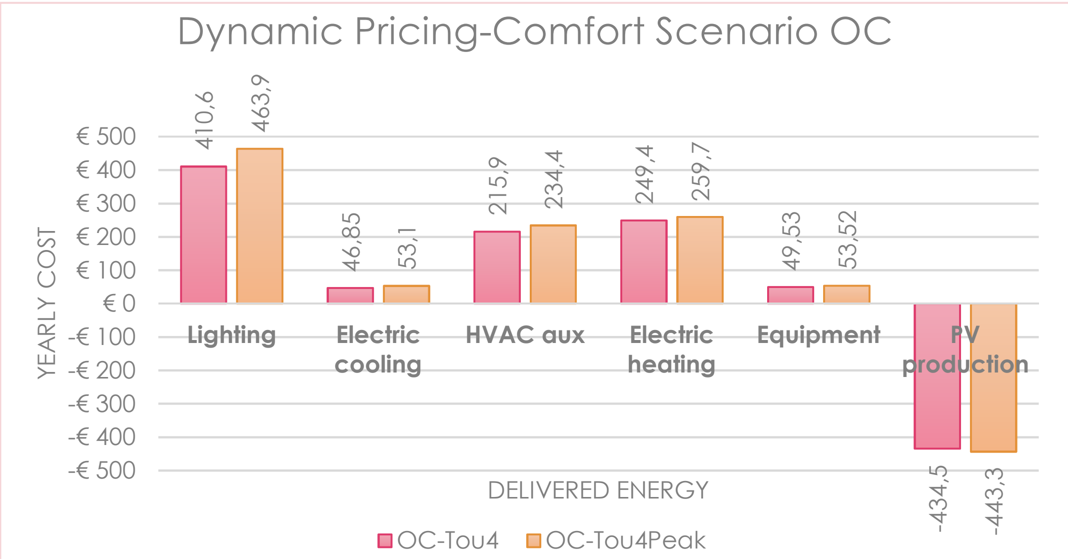


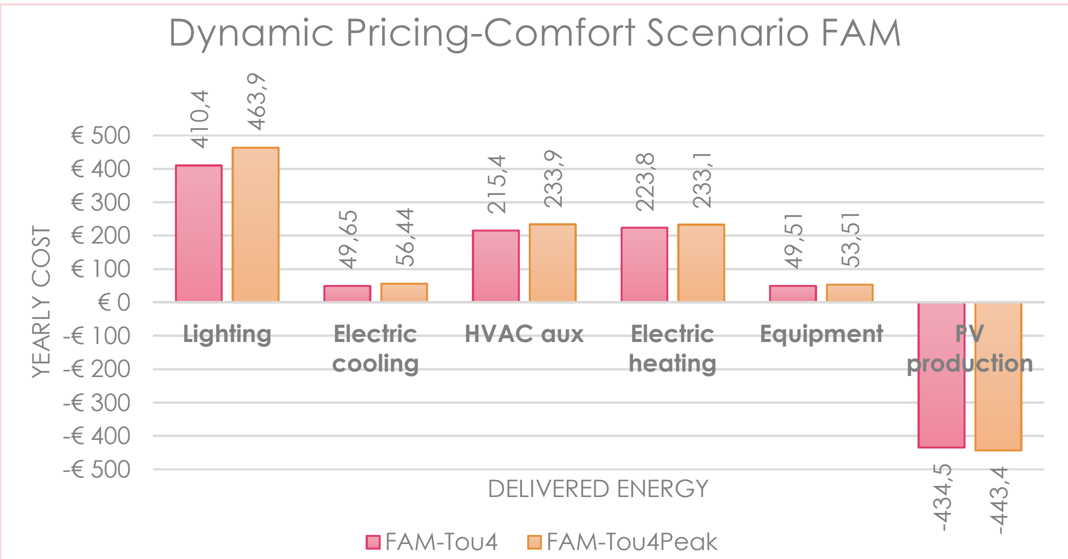




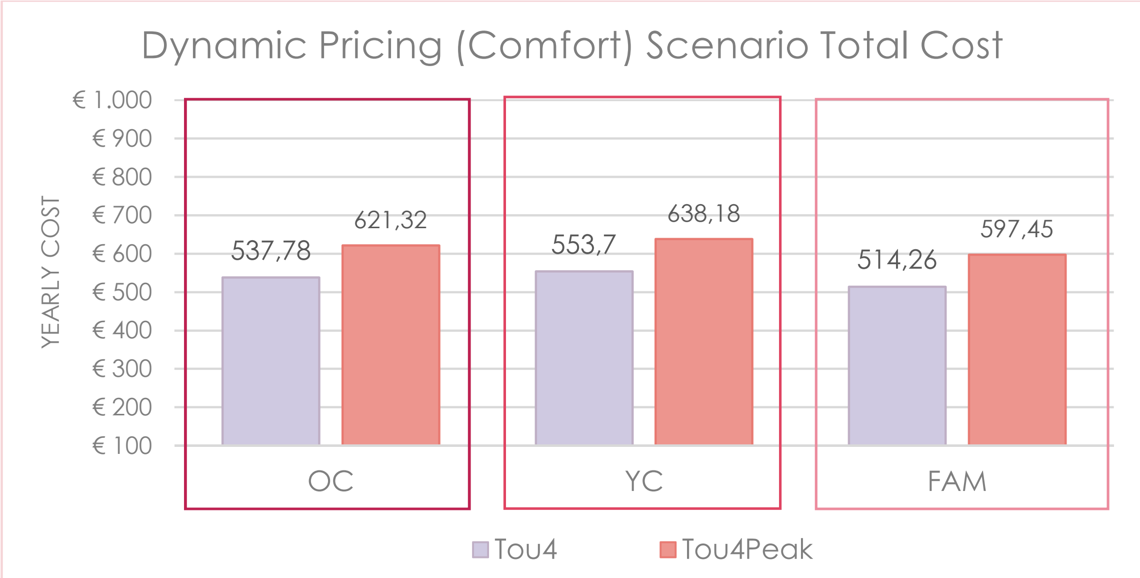
Graphics 18. Consumption of the Delivered Energy (on the Left) and System energy (on the Right) for the different occupants, Scenario 3 Comfort.







Graphics 19. Annual costs of the different occupants distributed by type of consumption, Scenario 3 Comfort.



Graphic 20. Total annual costs of all rates in the Dynamic Pricing-Comfort scenario, for different occupants.

Thanks to the graphs illustrated above, it is possible to make the following considerations for this scenario: unlike the first and second scenarios, Graph 18 shows that the greatest consumption of all occupants for Delivered Energy is equal to that of the DP: Advance scenario, with higher consumption related to Lighting and then Heating, followed by HVAC, Equipment and finally Cooling. Unlike the previous scenario, here for the consumption of System Energy, the Family has obtained the highest consumption of AHU Cooling, then for DHW, Heating, Cooling and AHU Heating; instead for the Yong Couple and the Old Couple the most consumed regards AHU Cooling, followed by Heating, DHW, AHU Heating and finally Cooling.

Regarding costs, graphs 19 and 20 show that, for all three occupants, the most convenient tariff is TOU4, followed by the TOU4 Peak (as in the DP: Advance case). Among the different occupants, in general, this scenario proved to be economically more advantageous for the Old Couple, considering both the TOU4 and TOU4 Peak fare, followed by the Family; they are less advantageous for the Young Couple, but still with low costs. Compared to the previous scenario (DP: Adv), this is slightly more expensive, but still more economically advantageous compared to the second scenario (DR) and even more than the first scenario (Basic). This is always due to the substantial difference in the times and methods of ignition of the Heat Pump and washing machine and dishwasher, which also in this scenario have been modulated both based on prices and rates, but also according to the occupants, following of the dynamic tariffs in this case (Comfort) as in the previous one (Advance).

8.4.2.1 Temperature ramp

	Scenarios	Occupants	Rate	Equipments	Lighting	Heat Pump	DHW
III	DYNAMIC PRICING (DP Comfort)	YC (2 People)	TOU4	Micene Schedules + Washing machine DP + Dishwasher DP	Micene Schedules	Comfort (Tou4)	80 l/p

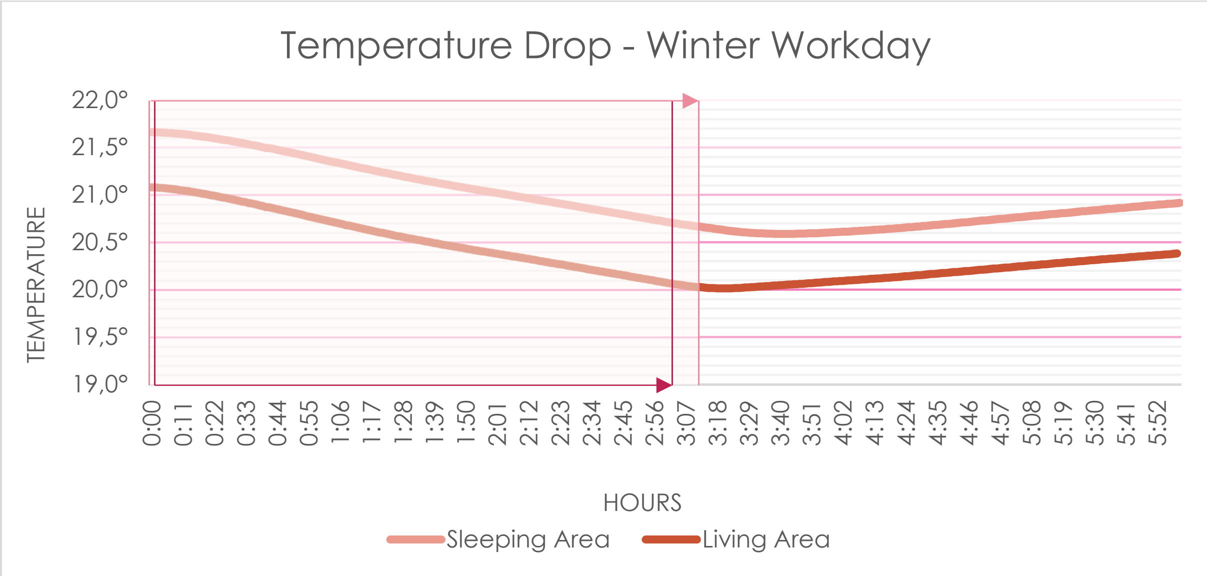
This chapter shows the results concerning the second case of the third scenario: Dynamic Pricing Comfort; this was designed to be able to see the effects on the internal temperature of a high-performance building like the Cortau House and not a traditional building.

In particular, with the operating mode of the Heat Pump shown in chapter 8.4.2, with a non-linear trend, we want to ascertain how long the operative temperature of the internal areas of the house uses to lower by 1 ° C.

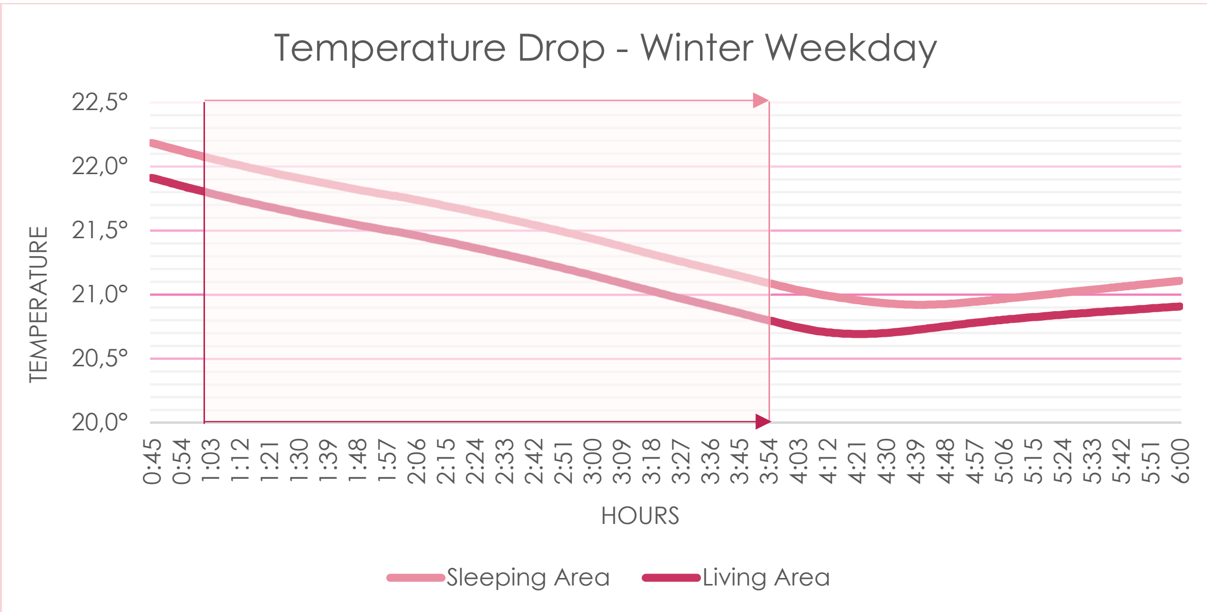
The following graphs show the temperature ramp for Workdays and Weekdays in winter and for Workdays and Weekdays in summer, each followed by a table which details, for the sleeping area and the living area, how many hours the operative temperature takes to lower by 1 ° C.

If in a traditional building the operative temperature for lowering of 1 ° C takes about 40 minutes, in this building the shortest time it takes is 2:54 h (in the case of winter in Weekdays), and about 3 h always winter but in Workdays in both areas; we also understand that the Cortau House is in effect a nZEB if we refer to the temperature ramp that covers the summer, which takes about 5 hours during the Workdays and about 6 hours during the Weekdays in both areas.

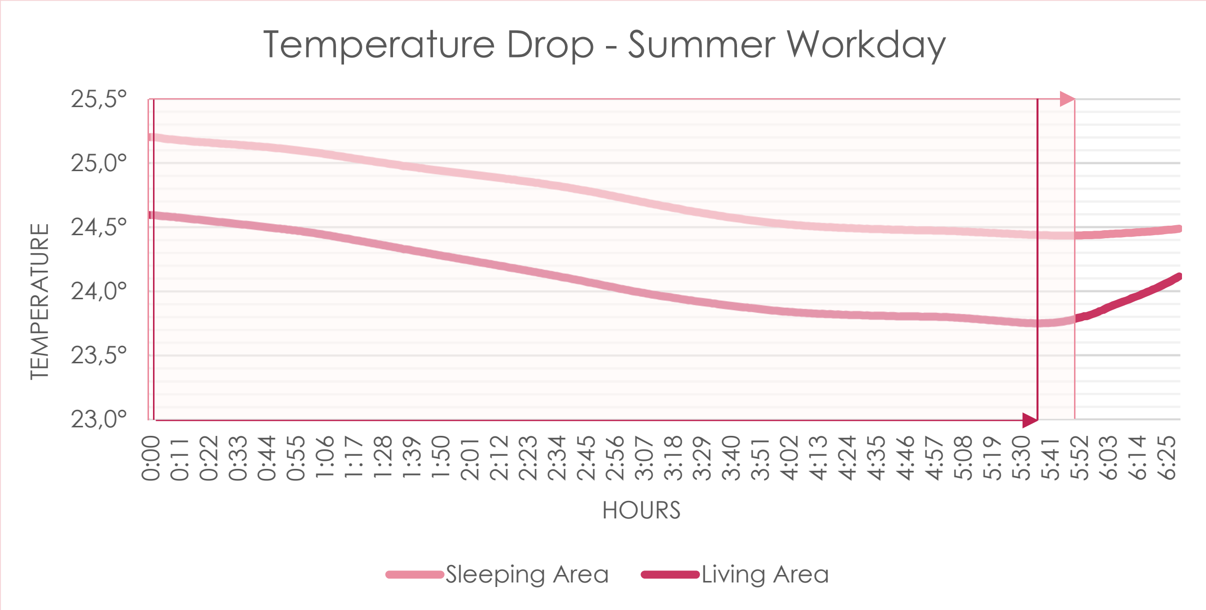
The most significant result was obtained during the Summer Weekdays, where the operative temperature to lower 1 ° C in the Living Area takes 5:59 h and in the Sleeping Area 6:05 h.



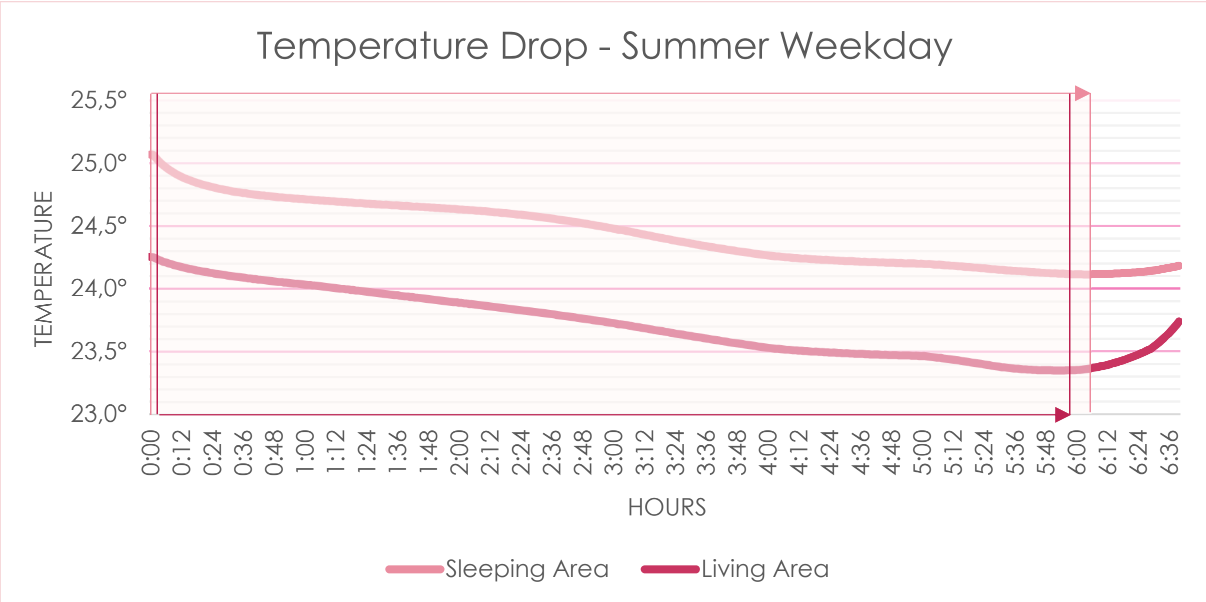
Zone	Hours	°C	Time to reduce	Zone	Hours	°C	Time to reduce
Sleeping Area	00:00	21,66°	03:13 h	Living Area	00:00	21,08°	03:00 h
	03:13	20,66°			03:00	20,08°	



Zone	Hours	°C	Time to reduce	Zone	Hours	°C	Time to reduce
Sleeping Area	01:00	20,9°	02:54 h	Living Area	01:00	21,8°	02:54 h
	03:54	19,9°			03:54	20,8°	



Zone	Hours	°C	Time to reduce	Zone	Hours	°C	Time to reduce
Sleeping Area	00:00	20,9°	**05:51 h**	Living Area	00:00	20,7°	**05:37 h**
	05:51	19,9°			05:37	19,7°	



Zone	Hours	°C	Time to reduce	Zone	Hours	°C	Time to reduce
Sleeping Area	00:00	25,06°	**06:05 h**	Living Area	00:00	24,25°	**05:59 h**
	06:05	24,1°			05:59	23,35°	

Chapter 09

9 CONCLUSION

9.1 To sum up

This research, conducted on the case study Cortau House, has allowed comparing electricity consumption and economic convenience between different rates, three current Italian tariffs (One-Time slot, Two-Time slots, and Three-Time slots) and two dynamic rates (TOU4 and TOU4 Peak) for three types of different occupants. Before being able to start with the simulation of the case study, a careful literary review was necessary regarding the traditional consumption of the residential sector and its appliances; the research also focused on the study of the national electrical system present in Italy, with its tariffs, and on the analysis of the various dynamic tariffs.

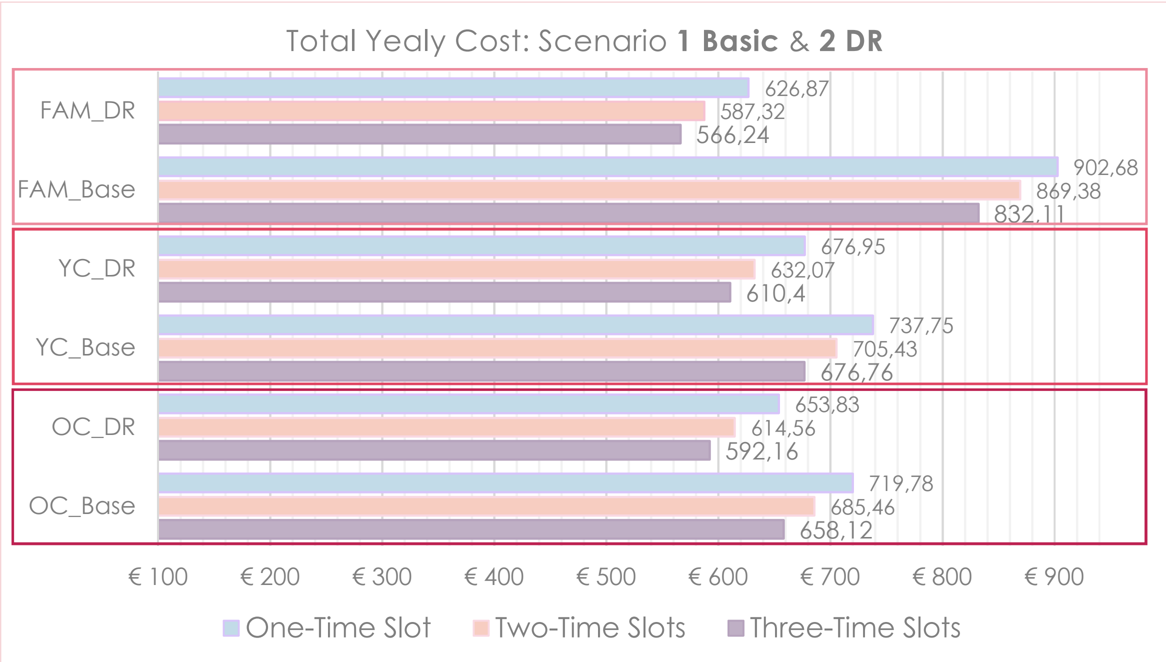
This research represents a first attempt to simulate the actual consumption of a high-performance building like the Cortau House, which, thanks to its physical and technological properties, distinguishes itself from the consumption of any other traditional building. The innovative part of the work carried out concerned not only the analysis of the consumption of the case study related to the rates already in place in Italy, but also an analysis on the variation in consumption compared to dynamic tariffs, not yet present in Italy but already effectively applied abroad.

The methodological approach first identified three main categories of occupants for which the simulations would be carried out: Young Couple, Old Couple and Family. The final objective was, for each of these occupants, to simulate three different scenarios to verify the various costs and consumption, applying the different rates mentioned above: Basic Scenario, Demand Response Scenario and Dynamic Pricing Scenario (divided into Advance and Comfort).

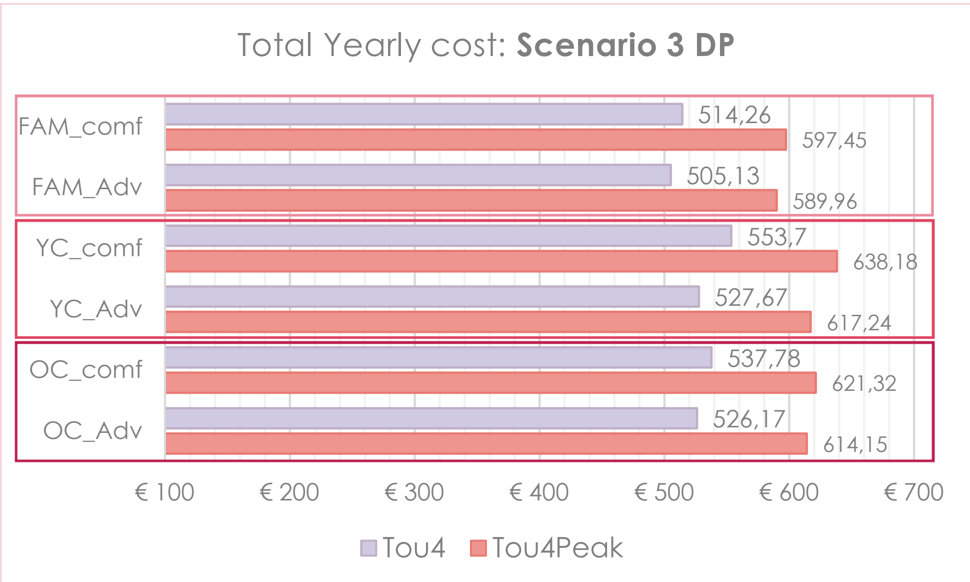
The results of this analysis led to the following conclusions, also shown below in the graphs and tables: at the economic level for the first two scenarios (Basic and DR) where the three Italian tariffs were applied (One-Time slot, Two-Time slots, and Three-Time slots), the Three-Time slots are the most convenient and, among the two Three-Time slots, the scenario of the DR scenario, rather than the Scenario Basic, is more convenient for each of the occupants, in particular the lower costs are for the Family in the DR scenario. Regarding the costs but for scenario 3 (DP) where two dynamic tariffs are applied (TOU4 and TOU4 Peak) the most advantageous tariff is the TOU4 tariff, both in the Advance and Comfort scenario, but between the two cases of the third scenario the most economic results in the DP scenario: Advance for all three occupants.

In this third scenario (DP) the cheaper costs are generally obtained between all 3 simulated scenarios and in this the Family is the type of occupant with the lower costs; the Family in the DP: Advance scenario with the TOU4 tariff is the one with the lowest costs among all the scenarios.

The chart 21 below shows the total costs of the three Italian tariffs for scenario 1 Basic and 2 Demand Response, while chart 22 includes the annual costs of the Dynamic Pricing scenario with the two dynamic tariffs.



Graphic 21. Total annual costs in the Basic Scenario and in the Demand Response Scenario.



Graphic 22. Total annual costs in the Dynamic Pricing: Advance and Comfort.

So excellent results and greater economic savings can be obtained by combining a type of dynamic pricing, which has lower prices than the current Italian rates, associated with the use of household appliances depending on the most convenient tariffs and the operation of the Heat Pump considering activating it only according to the presence of the occupants and especially in the most convenient hours of the day.

All the tariffs of the Scenarios with the relative costs for the three different occupants are shown below, from the most expensive to the most convenient; the next table, instead, shows a saving percentage comparing all the rates with the most expensive rate, i.e. the One-Time Slot tariff of the Scenario Basic.

Cost effectiveness	Family
One-Time Slot-Basic	902,68 €
Two-Time Slots-Basic	869,38 €
Three-Time Slots-Basic	832,11 €
One-Time Slot-DR	626,87 €
TOU4Peak-Comfort	597,45 €
TOU4Peak-Advance	589,96 €
Two-Time Slots-DR	587,32 €
Three-Time Slots-DR	566,24 €
TOU4-Comfort	514,26 €
TOU4-Advance	**505,13 €**

Cost effectiveness	Old Couple
One-Time Slot-Basic	719,78 €
Two-Time Slots-Basic	685,46 €
Three-Time Slots-Basic	658,12 €
One-Time Slot-DR	653,83 €
TOU4Peak-Comfort	621,32 €
Two-Time Slots-DR	614,56 €
TOU4Peak-Advance	614,50 €
Three-Time Slots-DR	592,16 €
TOU4-Comfort	537,78 €
TOU4-Advance	**526,17 €**

Cost effectiveness	Young Couple
One-Time Slot-Basic	737,75 €
Two-Time Slots-Basic	705,43 €
One-Time Slot-DR	676,95 €
Three-Time Slots-Basic	676,76 €
TOU4Peak-Comfort	638,18 €
Two-Time Slots-DR	632,07 €
TOU4Peak-Advance	617,24 €
Three-Time Slots-DR	610,40 €
TOU4-Comfort	553,70 €
TOU4-Advance	**527,67 €**

Cost effectiveness	Family
One-Time Slot-Basic	100%
Two-Time Slots-Basic	-4%
Three-Time Slots-Basic	-8%
One-Time Slot-DR	-31%
TOU4Peak-Comfort	-34%
TOU4Peak-Advance	<u>-35%</u>
Two-Time Slots-DR	<u>-35%</u>
Three-Time Slots-DR	-37%
TOU4-Comfort	-43%
TOU4-Advance	**-44%**

Cost effectiveness	Old Couple
One-Time Slot-Basic	100%
Two-Time Slots-Basic	-5%
Three-Time Slots-Basic	-9%
One-Time Slot-DR	-9%
TOU4Peak-Comfort	-14%
Two-Time Slots-DR	<u>-15%</u>
TOU4Peak-Advance	<u>-15%</u>
Three-Time Slots-DR	-18%
TOU4-Comfort	-25%
TOU4-Advance	**-27%**

Cost effectiveness	Young Couple
One-Time Slot-Basic	100%
Two-Time Slots-Basic	-4%
One-Time Slot-DR	<u>-8%</u>
Three-Time Slots-Basic	<u>-8%</u>
TOU4Peak-Comfort	-13%
Two-Time Slots-DR	-14%
TOU4Peak-Advance	-16%
Three-Time Slots-DR	-17%
TOU4-Comfort	-25%
TOU4-Advance	**-28%**

As far as consumption is concerned, this research work has confirmed, as already seen in the chapters relating to the consumption research of traditional residential buildings, that the highest energy consumption is mainly used for air conditioning (in particular heating) and for the lighting in all three simulated scenarios.

Taking, in particular, the analysis of the three scenarios, it emerged that the consumption of more kWh/m²/y concerns the Basic scenario, followed by similar consumption for the Dynamic Pricing scenario with the Tou4 tariff and the Demand Response scenario, while lower consumption has in the Dynamic Pricing scenario with Tou4 Peak tariff. Below are the tables that summarize consumption.

SYSTEM ENERGY

Consumption: from the highest to the lowest			
I	Zone heating	+	BASIC (OC, YC) DEMAND RESPONSE (YC)
II	AHU cooling		
III	DHW		
IV	AHU heating		
V	Zone cooling	-	

Consumption: from the highest to the lowest			
I	AHU cooling	+	BASIC (FAM) DYNAMIC PRICING: Adv (YC, OC, FAM) DYNAMIC PRICING: Comf (FAM)
II	DHW		
III	Zone heating		
IV	Zone cooling		
V	AHU heating	-	

Consumption: from the highest to the lowest			
I	AHU cooling	+	DEMAND RESPONSE (OC, FAM) DYNAMIC PRICING: Comf (OC, YC)
II	Zone heating		
III	DHW		
IV	AHU heating		
V	Zone cooling	-	

DELIVERED ENERGY

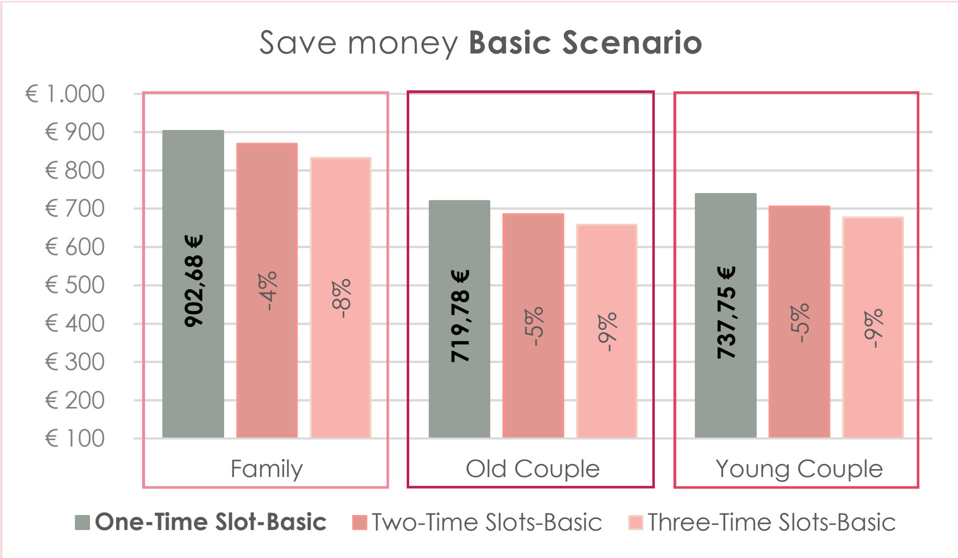
Consumption: from the highest to the lowest			
I	Electric heating	+	BASIC (YC, OC) & DEMAND RESPONSE
II	Lighting		
III	HVAC aux		
IV	Equipment		
V	Electric cooling	-	

Consumption: from the highest to the lowest			
I	Lighting	+	BASIC (FAM) DYNAMIC PRICING (Advance & Comfort)
II	Electric heating		
III	HVAC aux		
IV	Equipment		
V	Electric cooling	-	

Equipments Consumption			kWh/m²/y
I	**BASIC**	+	**50,327**
II	DP: TOU4		45,317
III	DEMAND RESPONSE		45,067
IV	DP: TOU4 Peak	-	44.067

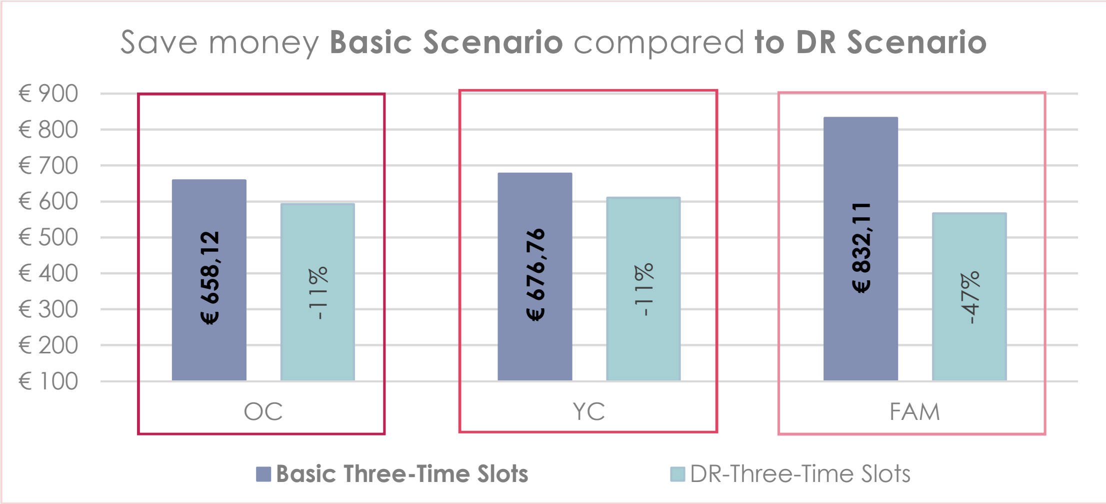
The following (from 23 to 27) graphs summarize the economic results of the different scenarios compared to each other to clearly understand the percentages of advantage among different tariffs.

The first chart shows the percentages of gain in the Base Scenario of the two Two-Time slots and the Three-Time slots complies with the most expensive one, namely the One-Time slot tariff; the most significant savings are obtained for the Old Couple and the Young Couple in the Three-Time slots tariff with a -9% compared to the One-Time slot rate.



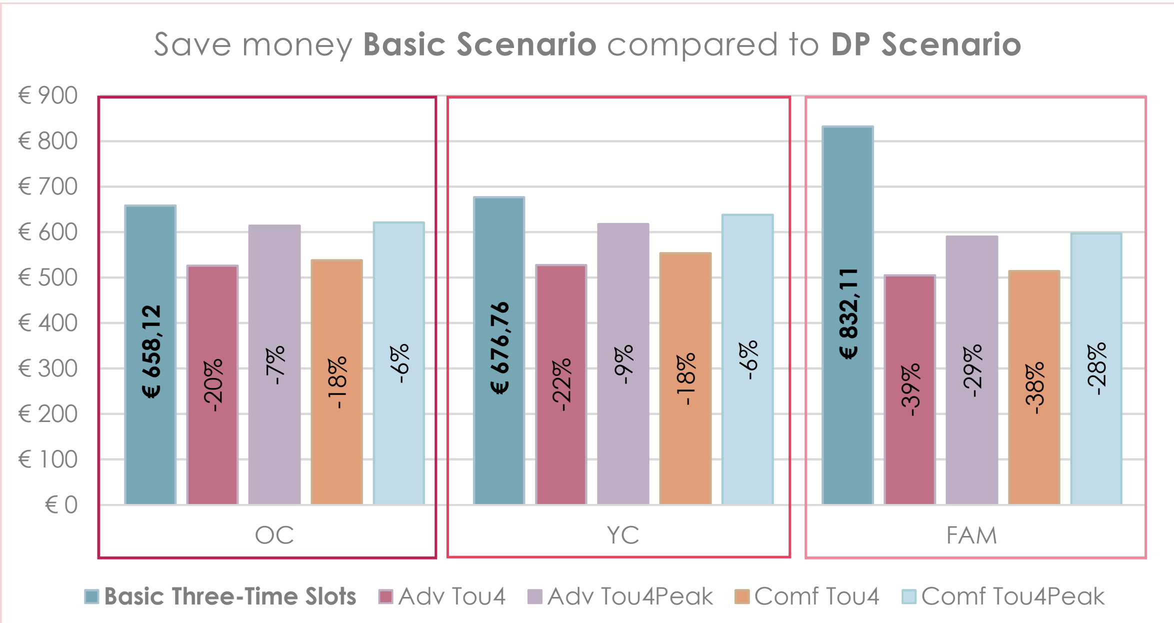
Graphics 23. Tariff One-Time slots and Two-Time slots compared with the Three-Time slots.

The following chart (24) shows the economic gain that can be obtained by comparing the tariff that has proved to be the most convenient in the Base Scenario and in the Demand Response Scenario, namely the Three-Time slots. In this case, we notice that there is a percentage of income for all three occupants, like Old Couple and Young Couple with a saving of 11%, the Family instead obtains a significant saving of 47% passing from the Basic scenario to that of Demand Response.



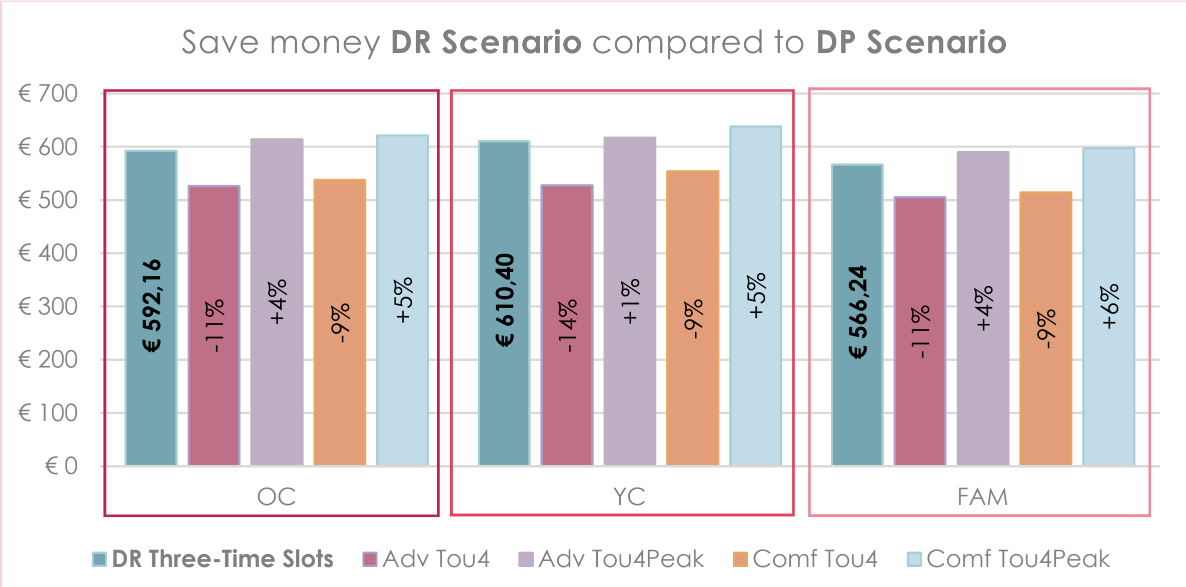
Graphics 24. Tariff Three-Time slots DR slots compared with the Three-Time slots Basic.

The comparison with the Three-Time slots Basic and the Three-Time slots DR was also made with the dynamic Tou4 and Tou4 Peak tariffs of the Advance and Comfort case.



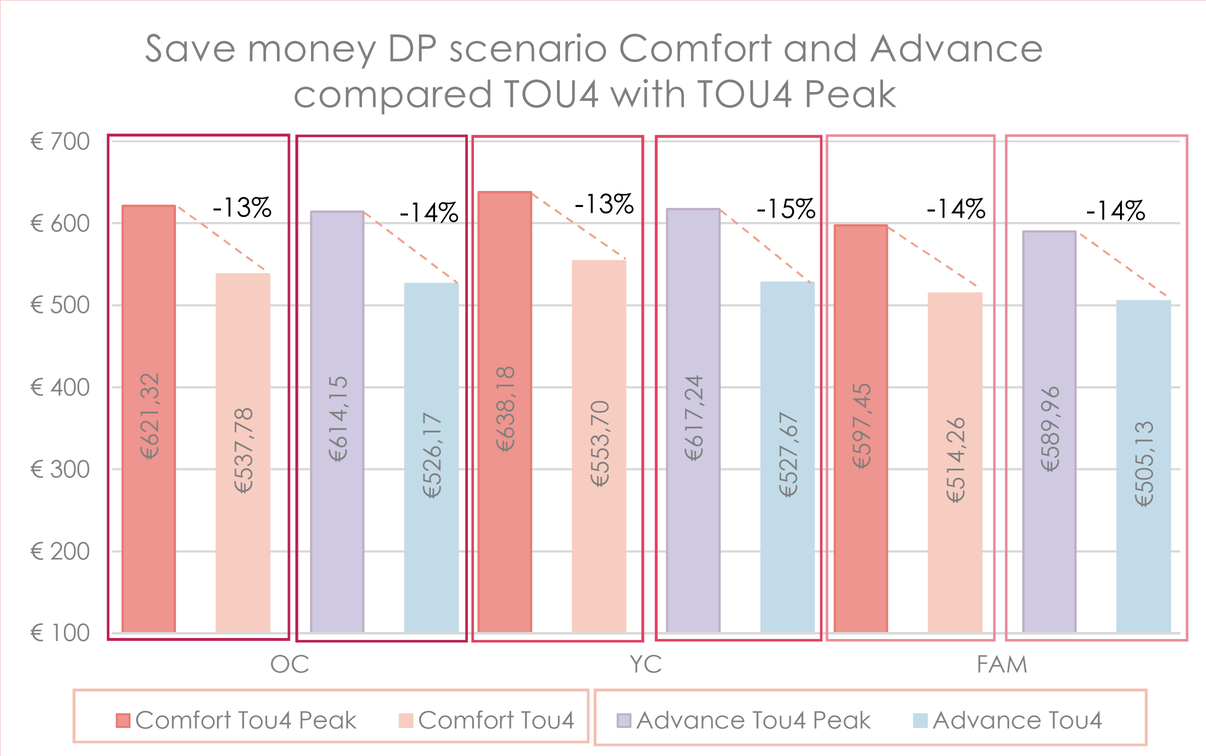
Graphics 25. Tariff Three-Time slots Basic slots compared with the Dynamic tariff.

It can be seen from Chart 25 that in the comparison between the cheapest tariff of the Scenario Basic (the Three-Time slots) and the Scenario Dynamic Pricing tariffs there are the greatest savings; the biggest savings are obtained by the Family with the Tou4 Advance tariff with a -39% compared to the Three-Time Basic slots, followed by the Tou4 Comfort fare (-38%), Tou4 Peak (-29%) and Tou4 Peak Comfort (-28 %). Equal this order also for the Young Couple and Old Couple.



Graphics 26. Tariff Three-Time slots DR slots compared with the Dynamic tariff.

From Chart 26, which always compares the dynamic tariffs of the third scenario (DP), but with the Three-Time tariff slots of the Scenario Demand Response. In this comparison, it is noted that among all the tariffs there is an economic saving, except in the case of the Three-Time tariff DR slots and Tou4 Peak Comfort for all occupants.



Graphics 27. Comparison of the Tou4 and Tou4 Peak Rates for scenario 3: Advance and Comfort

In Graph 27 for the Dynamic Pricing Scenario, the two dynamic tariffs (Tou4 and Tou4Peak) were compared for the Comfort case and for the Advance case. Between these two tariffs, the Tou4 price was the cheapest compared to the Tou4 Peak, with a minimum saving percentage of 13% up to 15% for all occupants, both in the Comfort and in the Advance case.

Among the Advance and Comfort Tou4 tariffs, the Advance case is also more advantageous, especially for the Family, with almost the same expense for Old Couple and Young Couple.

Chapter 10

10 PAPER

As an initial work done for the thesis I was assigned a paper to do, concerning the topic that I would then elaborate on in the chapters of the thesis, without however dealing with the case study.

The work for this article was very useful as it allowed me to gather all the material and sources needed to start the thesis chapters.

In this paper, carried out exactly like a scientific article, the different topics of the thesis are treated, plus there is also a part dealing with the new intelligence devices of different brands, which would improve both the consumption and the quality of life of the occupants.

The paper given below is:

Thesis Laboratory: Methods and Measurements for the Built Environment.

Student: Valeria Migliore.

Teachers: S.P. Corgnati, V. Fabi.

Title: "Consumption analysis in the residential sector: Italian situation and the possible introduction of dynamic tariffs and intelligent devices".

Year: 2017.

Consumption analysis in the residential sector: Italian situation and the possible introduction of dynamic tariffs and intelligent devices

Studente: Valeria Migliore
Docenti: Valentina Fabi, Stefano P. Corgnati
Politecnico di Torino

ABSTRACT

This study focuses on the consumption of the residential sector, particularly in Italy. There is a overview of the situation about the Italian national electrical system, which has not yet reached the completely liberalization of the electricity market, but only a "partial" liberalization, because all end users are still united by the same final cost structure of the consumed kWh. It also analyses the real household consumption and primary resources that are used to satisfy the home user. A more detailed look at the devices used and their consumption comes from three main monitoring campaigns: Eureco, Micene (Italian case) and Remodece. It also wanted to detail the new dynamic rates (TOU, CPP, PTR, RTP), comparing them with current Italians fare. This is to be able to imagine their future introduction in the Italian market as well, but as soon as the full liberalization of the electricity market will take place and with the help of new enabling technologies.

Keywords: Residential sector, Consumptions, Electricity, Liberalization, Monitoring campaign, Peak-demand, Appliances, Tariff, Dynamic Pricing, Enable technologies

1. Introduction

1.2 Outline of the situation in the Residential sector

The technical features and not of the buildings where people live in, where they work or spend time, impact not only the personal productivity, but also the well-being and interaction, but first, all the amount of energy, heat, and electricity that they consume. All buildings, however, do not only impact people but also strongly impact on the planet as they release a considerable amount of greenhouse gas, especially CO_2, which have led to significant climate change. The residential sector in terms of percentage takes the 75% of the total amount in Europe, against 25% of non-residential buildings, which are characterized by a more complex and differentiated part compared to the sector (Fig. 1) [1]. The part to deal in this article concern the residential sector, which in EU is more than 40% built before the 1960s, when still the standards for a sustainable construction and energy certifications were still far from being adopted. It has a building boom between 1961 and 1990, a period in which real estate has doubled (Fig. 2).

It is necessary to outline what is meant by the household sector, to be able to evaluate what are the actual uses and consumption. The family composed by person who lives alone or by a group of people who live together in the same house and share the expenses, including the essential elements of everyday life (Fig.3). The main factors that weigh on families' consumption are the number of people who live sharing in a house, the number and type of household appliances present, the house's characteristics and the occupants' personal consumption.

Whenever a switch or electric appliance is operated, there is a complex system that generates and provides the required electrical power.

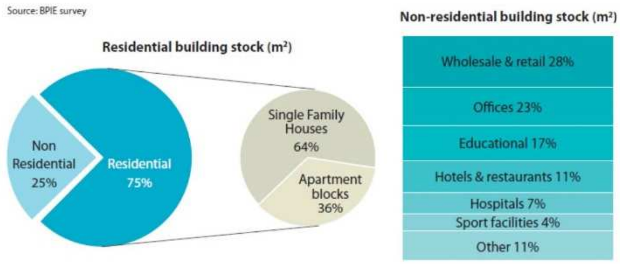


Fig. 1. Divisioning of European building typologies'

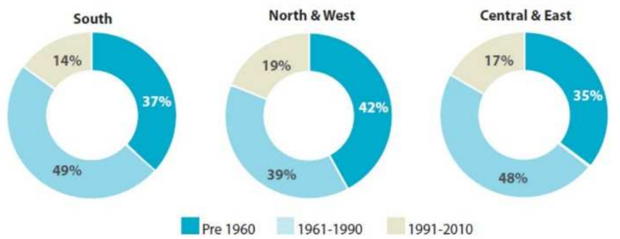


Fig. 2. Age categorisation of housing stock in Europe

Fig. 3. Boundaries of the household sector (green area)

2. Italian national electrical system

In Italy, the national electricity system is divided into three phases: generation, transmission, and distribution of electricity. [2]

Electricity as we know it does not exist in nature and it is, therefore, necessary to produce it. Making energy means turning energy into "electricity" from primary sources. This transformation takes place in power plants. From here, the produced energy is transmitted at high voltage (380 kV - 220 kV - 150 kV) to the consumption areas and through dispatching the network balances supply and demand for electricity 365 days a year and 24 hours a day. The electricity supply chain ends with distribution, i.e. electricity is delivered to medium and low voltage to end users. In Italy [3], energy is mostly produced and imported by foreign private companies, while the national monopoly is entrusted to the TERNA Group, regulated by AEEG. TERNA owns over 98% of the transmission grid and is responsible for planning, operating and maintaining the transmission system. The distribution, which is always born by local monopolies, has 140 DSOs, including a major company (covering 86% of Italian electricity demand) i.e. ENEL distribution (Ente Nazionale per l'Energia Elettrica). The most important local operators are A2A, ACEA, IRIDE, DEVAL, HERA. The Retailers are mostly private companies; they buy energy from generators and they sell it to final users. The Energy and Gas Authority (AEEG), on the other hand, is concerned with establishing and updating the basic electricity tariffs, its parameters and benchmarks, proposing programs for renewal and variation of licenses, Supervision Compliance with the rules of competency, to protect the end user.

2.1 The liberalization of the Italian market

The liberalization process of the electricity market in Italy [4] began with the Legislative Decree of 16 March 1999 no. 79 [5], which transposed Directive n. 96/92 / EC of 19 December 1996 [6] concerning common rules for the internal market in electricity (known as the Bersani Decree). Before the Bersani decree, the ENEL monopoly involved all phases of the power supply. Regarding the distribution of electricity, local networks were under concession and active in both sales and distribution. In addition, it was not possible for the end customer to choose the supplier. Following the first liberalization, the activities of production, import, export, purchase and sale of electricity become free, while transmission and distribution activities remain reserved to the State, which grants it to the National Transmission System Manager (GRTN- Gestore della Rete di Trasmissione Nazionale). Starting in November 2005, TERNA is entrusted with both the property and network management. The transmission and distribution phases are regulated and the tariffs established by the AEEG are applied uniformly throughout the national territory. GRTN becomes GSE. Electricity purchases are carried out under the Electricity Stock Exchange, managed by GME according to the offer system, or through bilateral contracts.

2.1.1 Only a formal liberalization

From 1 July 2007, every final customer could access supply contracts with any manufacturer, distributor or wholesaler both in Italy and abroad, but, it was only a "formal" liberalization because most consumers remained in the Protected marketplace and have not gone to the free market. Within the protected market [7], vendors supplying final consumers are supplied through market electricity, and in Italy, these transactions are carried out through daily MGP (Market the Day Before-Mercato del Giorno Prima) where they trade the quantities of energy for the next day. In this way, energy is exchanged for the next day in time blocks. The sale offers submitted that are accepted on the MGP are valued at the marginal price of the zone. Purchase offers that are accepted are then valued at the National Unity Price (PUN-Prezzo Unico Nazionale) (equal to the average prices of the different geographic areas weighted for the quantities purchased in those areas). In Italy, therefore, the electricity market is still not fully liberalized, even though there is a diversification of end users by type of consumption and tariff treatment since all types of users are combined with a final cost of kWh consumption. This final cost consists of: 1 sales services, 2 network services, 3 system charges, 4 costs associated with taxation (taxes). The first voice is related to the cost of electricity supply, which in turn consists of the cost of the energy component (PE, Energy Price), but also the costs of marketing, selling and dispatching. Indeed, only this PE component follows the trend of buying/selling offers in the markets. But this energy component (PE-Prezzo Energia) is different from the market PUN, as they follow two different price formation mechanisms.
The use of the PUN represents a potential barrier for the user who does not receive the correct real energy price but the zonal one, thus not being able to shift their consumption in the most convenient days or hours of the day. In 2018, the Italian government should achieve full liberalization of the electricity market, so that it can release customers from purchases by the single purchaser (AU).

Another critical aspect of the Italian tariff system is the "progressivity" of electricity tariffs, which has contributed considerably to the current low electrification of Italy (compared to other countries such as France and Finland where it is widespread electric heating). This is because in this way the cost per kWh increases as the consumption increases, a completely abnormal system adopted following the energy crisis of the 1970s, to limit consumptions. Even with this aspect, however, AEEGSI is moving to implement a reform current electricity tariffs.

3. Residential consumption

In the residential sector, the final use of total energy depends mainly on heating, cooling, ACS, lighting and household appliances [8], in Figure 3 we can see all the uses that fall within the domestic sphere. In 2010, the domestic sector represented about 27% of the total consumption in the EU and has been above 25% in the last 20 years.
Data from 2015 show that households used mainly energy to heat their houses, with about two-thirds (64.7%) of their final energy consumption. In addition, the energy used for water heating was 13.9%, so the overall heating of the dwelling and water represented 78.6% of the energy consumed by households. The energy used for the lighting and use of most household appliances accounted for 13.8% of household energy, while the main appliances account for 5.7%, air conditioning 0.5% and others end uses 1.5%. [9]
Eurostat data, updated beginning of 2017, also show that the final energy consumption of European households is changing, however: in 2011 it represented 25.5% of total energy consumption, in 2012 it was 26.8%, in 2013 to 27 %, then falling in 2014 to 24.8% and slightly increasing in 2015 to 25.3%. [10] This growing trend in energy demand in the residential sector can be attributed to various factors, such as the increase of nuclear family (even mononuclear ones), the increasing demand of comfort, the increase in the average size of housing, followed by a significant increase of appliances inside the houses and a generalization of stand-by operation [2]. Below in Table 1 a list of some household appliances with their average annual consumption, average use and power [11].
Primary sources are used to obtain electricity, thermal energy and fuels. In 2014 [12], final energy demand dropped by 4.6% compared to the 2013, reaching around 120.8 Mtep, representing the lower absolute value of 18 years. The downward trend occurred since 2005 when energy consumption stood at around 146.6 Mtep.

Table 1.
Annual average consumption, power and average usage of some appliances inside the house. (Source: Associazione Consumatori and ENEA).

Appliance	Power [W]	Consumption [kWh/year]	Average usage
Computer	100	170 – (70)	2 h/day (no stand-by)
Conditioner	1000	420	4 h/day for 2 months
Dishwasher	3000	700	1 wash/day
Electric boiler	1200	3000	120 wash/day
Electric heating	15000	10000	6 months/year
Electric kitchen	3000	1100	2 cookers for 45 min/day
Electric oven	2000	65	1 h 20 min/week
Electric stove	2000	120	1 h/day for 2 months
Electric water heater	1000	2000	3 h 30 min/day
Freezer	300	600	Continuos
Hairdryer	1000	26	30 min/week
Hi-Fi	30	80 – (20)	2 h/day (no stand-by)
Iron	1000	26	1 h/week
Lighting	60-100	360	3 h 30 min/day
Linen dryer	3000	250	2 times/week (6 months)
Mixer	150	2	15 min/week
Personal computer	200	21	14 h/week
Radio	10	7.3	14 h/week
Recorder	20	4,2	4 h/week
Refrigerator 300 liters with freezer	200	240	Continuos
Sewing machine	100	1,2	1 h/month
Television	100	105	20 h/week
Toaster	1000	13	15 min/week
Vacuum cleaner	1000	39	45 min/week
Video recorder	100	36,5	7 h/week
Washing machine	3000	210	2 wash/week

All energy sources in 2014 (Table 2) compared to the previous year show a decrease in their use, more consistent in gas (-11.5%), followed by electricity (-2.8%), electricity Coal (-1.3%), oil (-1%) and renewables (-0.5%). The relevance of energy sources differs depending on the sectors: renewable sources increase by 7% in agriculture, 5% in industry and 1% in the civilian use sector. About 85% of the final consumption of renewable sources is attributed to the civil sector.
In 2014, the greatest contribution to overall energy consumption is attributed to the civil uses (including the domestic sector, trade, services and public administration) for which a share (36%) is higher than that of Transport (32%) and industry (23%). Over the last decade, the sector's incidence has increased by more than four percentage points. Some estimates give the domestic sector a particularly weight in the field of energy use in the civilian use sector due to the increasing diffusion of heating and cooling systems and the use of electrical appliances and electrical equipment and installations.
The energy mix has varied over time [13], showing more diversification from the past: gradual oil substitution, predominant in the 1990s, with gas and, in recent years, a considerable increase in renewable sources. From 2000 to 2014 the share of renewables has increased by 14 percentage points, an average growth rate of about 3% annual (Fig. 4). From a report by the Italian Ministry of Economic Development on the national energy situation [14] in 2015, there has been further downward pressure on oil and gas prices.

Table 2
Final energy uses in Italy by sectors, 2014. Source: Italian Ministry of Economic Development

	Industry	Transport	Civil	Agriculture	Non-energy uses	Bunkering	Total
Solid Fuels	2,82	-	-	-	0,07	-	2,89
Gas	11,88	0,86	21,15	0,12	0,51	-	34,51
Petroleum	3,86	36,25	2,80	2,09	4,20	2,30	51,51
Renewable Energy	0,04	1,08	6,75	0,007	-	-	7,87
Electricity	9,11	0,90	13,53	0,47	-	-	24,02
Total Mtep	27,71	39,09	44,23	2,69	4,78	2,30	120,80

For the first time in 10 years, world trade in coal has been reduced.
In the 1990 to 2015 period, the total amount of energy used by family members [15] increased by 2.1%, with a growing and discontinuous trend. The main energy product used in domestic uses is, in terms of Mtep, natural gas - "methane" - (Fig. 5). In terms of spending, Italian households spend mainly on the purchase of electricity and methane: in 2015 approximately 36 billion euros, of which 52% for electricity and 48% for methane (in 2013 they spent nearly 40 billion Euro, of which 53% for methane and 47% for electricity); Far less is the expenditure for LPG, biomass and diesel: about 6 billion euros in total (compared to nearly 8 in 2013) (Fig. 6).

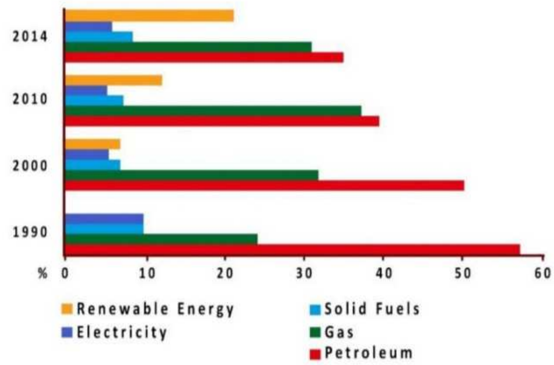


Fig. 4. Evolution of the mix of primary energy sources, from 1990 to 2014. ENEA data processing on MISE data (I numeri dell'energia 2015)

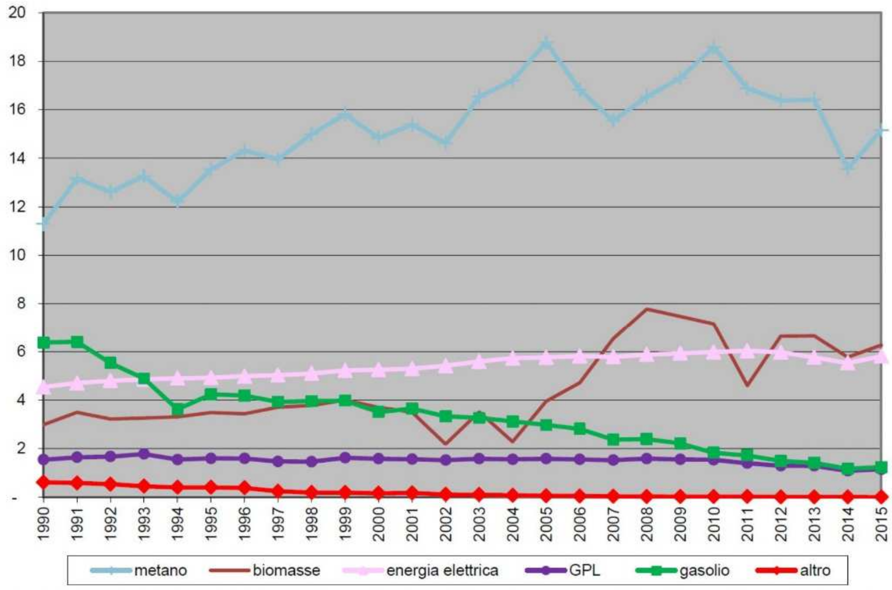


Fig. 5. Household use for household use (heating/cooling, hot water, kitchen use and household appliances), for energy products - Years 1990-2015 (Mtep)

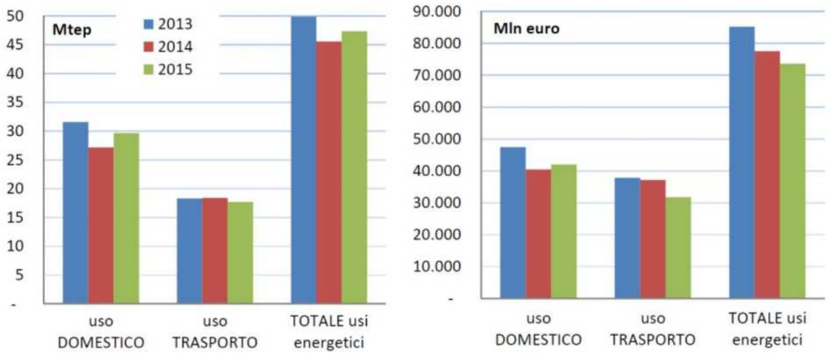


Fig. 6. Energy use (Mtep) and energy products (millions of euros) of households, by type of employment and product - Years 2013-2015, Istat, Contabilità ambientale

Data from the RSE processing on Terna data [16] show the low prevalence of electrical consumption in the Italian residential sector, equal to 22% of total national consumption (Table 3).
Between 2010 and 2013, Italy recorded an average electricity consumption per capita of 1100 kWh / person, which is lower than the European average (1566 kWh / person), with a specific consumption in the residential sector of 2700 kWh / family, which compared to the residential consumption of the main countries, shown in the Figure 7 [7]; This is due to Italy's low electrification, which is still very much on fossil fuels for thermal services (ACS, heating and cooking), unlike countries such as Finland and France where electric heating is widespread. This, represents a potential barrier in our country, because the margin whereon we can operate, in the field of electricity consumption, is limited.

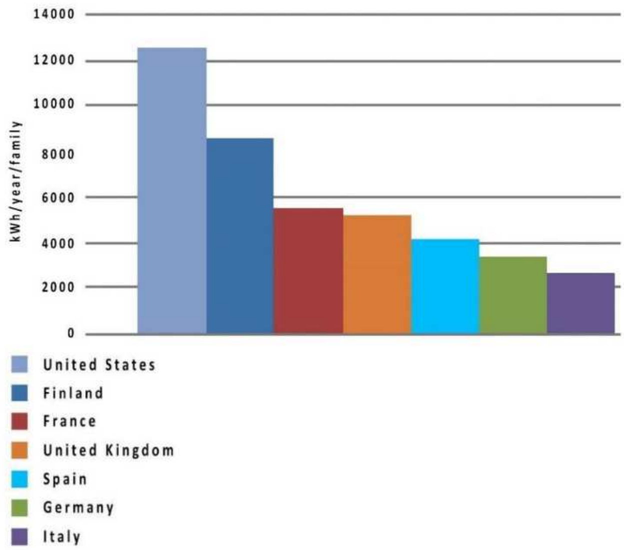


Fig. 7. Electrical consumption in the residential sector by family

Table 3. Residential electrical consumption's trend from 2010 to 2014 in Italy. RSE data from Terna

	2010	2011	2012	2013	2014
Residential consumption (TWh)	69,5	70,1	69,4	66,9	64,2
Total consumption (TWh)	309,9	313,8	307,2	297,3	291,1
% Residential/Total	22,4%	22,4%	22,6%	22,5%	22,1%

4. Main Consumption of the Households Monitoring Campaigns

There have been many domestic consumer monitoring campaigns conducted over the years until now, to understand the habits and consumption of households. Today, in modern society, especially families are one of the causes that, directly and indirectly, create environmental pressures as final consumers. The modern user employs always more services that induce higher consumption, starting from house appliances, communications, means of transportation and leisure [16].
At the same time, more and more families have shown greater environmental awareness, favouring the purchase of low power consumption appliances and ecological products.
An important step, then, is to highlight residential energy consumption (demand Energy for heating, ventilation or air conditioning, on hot water needs, electricity for lighting and other

uses of the considered use) and user behaviour to control consumption.

4.1 Eureco

One of the largest databases, coming from monitoring campaigns, about the household energy consumption, is the European project Save called Eureco, which aims to raise awareness and increase knowledge in this issue in European countries. This project has developed through a campaign in 100 families in four European countries: Denmark, Portugal, Italy and Greece, to obtain consumer data about the main domestic uses of households.
This study collects the most relevant information available today in Europe, concerning residential electricity consumption.
Eureco follows an approach and methodology like an earlier project, the Ecodrome, which was carried out in France, between 1995 and 1997, monitoring 20 families. The results of the French project showed that households could save up to 40% of the initial consumption of electrical appliances by using efficient household appliances, thus saving average 1200 kWh / year per household. The aim of the Eureco project was to test whether the Ecodrome conclusions could be valid for other European countries as well.
For Eureco project, each individual electrical end-use was monitored every ten minutes, for a whole month.
The goals of the Eureco project were three:

- Describe in the best way possible the state of the household appliances in the countries.
- Discovering new trends or consumptions that have not yet been well-defined and understood it to anticipate future trends.
- Evaluate the potential savings that can be achieved in the house business by replacing existing appliances with more efficient appliances and can confirm the results of Ecodrome.

The devices chosen to be monitored were divided into two lists:
- First List: Family Consumption, Cold Appliances, Lighting, Audio visual Systems, Washbasins.
- Secondary list: Dishwasher, Boiler circulation pumps, Personal computer, Air conditioning.
In these monitoring campaigns, there are various important aspects to refer to, such as geographic location, housing size, household composition, supply contracts, etc.
In addition to the total annual consumption of electricity, the campaign has obtained the maximum and minimum power requirements in the four countries, but also when the maximum powers are required and with what values (W) (Table 4), thanks also to graphs that show the percentage distribution of which appliances consume in peak hours in December (Fig. 8) and July.
The importance of the part of the "Miscellaneous" appliances is emphasized because it includes all unmonitored appliances, standby power or water heaters and kitchen appliances (which can reach 600 kWh/y).

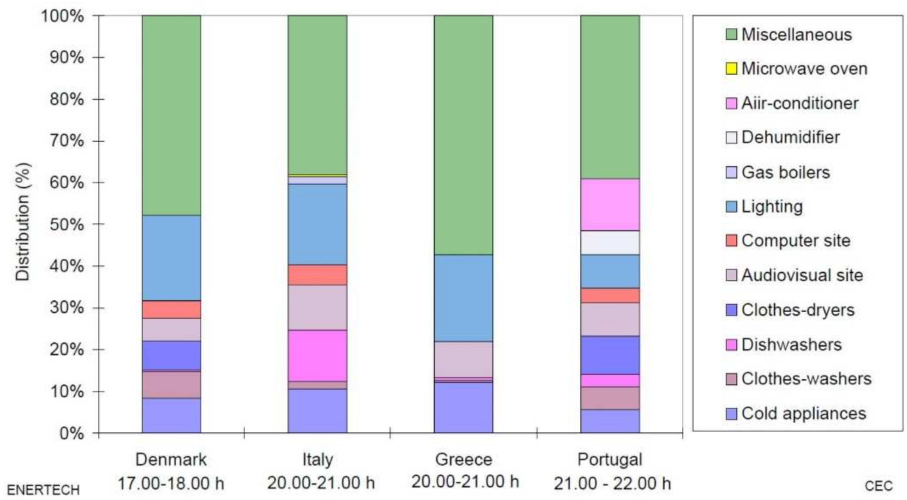


Fig. 8. The structure of the power of the appliance demand during the peak-hour in December, from the grid point of view (minimum values). Eureco Project

Tab. 4. Legal peak-demand hours throughout the year, and then in December and July. Eureco Project

Country	Denmark	Greece	Italy	Portugal
Yearly average peak-demand hour	[18,19]	[21,22]	[21,22]	[22,23]
Average peak-demand hour in December	[17,18]	[20,21]	[20,21]	[21,22]
Average peak-demand hour in July	[17,18]	[21,22]	[21,22]	[22,23]

4.2 Micene

In Italy, the Micene Project [17] was the continuation of the Eureco project, still in the residential sector, in 110 houses, which represents the widest database of this kind in the domestic sector in Italy. Also, here were monitored: cold appliances, lighting, washing machines and dishwashers, electric water heaters, audio and personal computers. Figure 9 show the percentages of the electrical consumption of each monitored device during the campaign.
The food preservation sector is one that has improved its performance, following the introduction of labelling of household appliances. Technology has a lot to do in this area, so it is best to choose the best available model and in some cases, replace obsolete equipment.

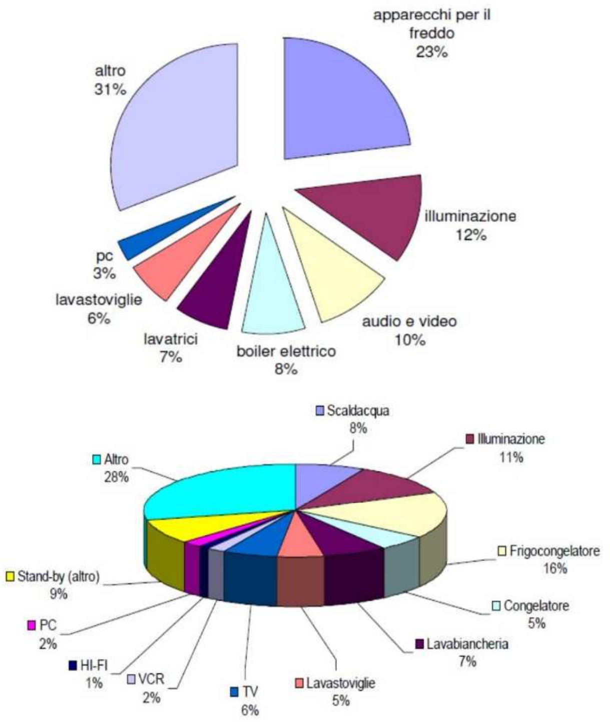


Fig. 9. Breakdown of electrical end-use consumption in monitored houses

The sales data of 2005 about cold appliances [18] show that in some markets class A + appliances are beginning to have a significant penetration at European level. Following the results obtained [19], it was also possible to confirm that in the case of freezer cabinets, consumption varies considerably depending on age (the latest appliances consume less energy). For cold appliances, average daily loading curves show that there are no peaks accentuated, total power demand is almost constant in 24 hours (with peaks slightly highlighted in the evening and at lunchtime, resulting from larger openings from part of the users). By comparing the two previous graphs (Fig. 8 and Fig. 9) with the graph showed in Fig. 10 [20], it can be seen how the percentages of final use consumption, from the Eureco and Micene project, have a correlation with the results Consumption at European level; In fact, the largest percentage is attributed to "other uses", followed by "cold appliances" and "lighting".
A significant percentage is also covered by washing machines (clothes washer and dishwashers) that have been monitored both in the Eureco and Micene projects. On average, 280 washing cycles are performed per year. It is important to highlight that consumptions depend mainly on the cycle temperature (Tab. 5). So, it can drastically reduce your laundry consumption by changing your habits, far more than buying an efficient washer, but also reducing the number of wash cycles. Also for the dishwasher [13], can apply the same considerations to the washer.
In the case of audio-visual equipment in Europe, reference is made to the International Conference Eedal 2006 [20]. GfK presented at the EEDAL'06 conference [19] data about selected number of EU-15 Member States that confirmed the increased penetration of TV in households (more TVs per household) and the increased number of viewing hours.

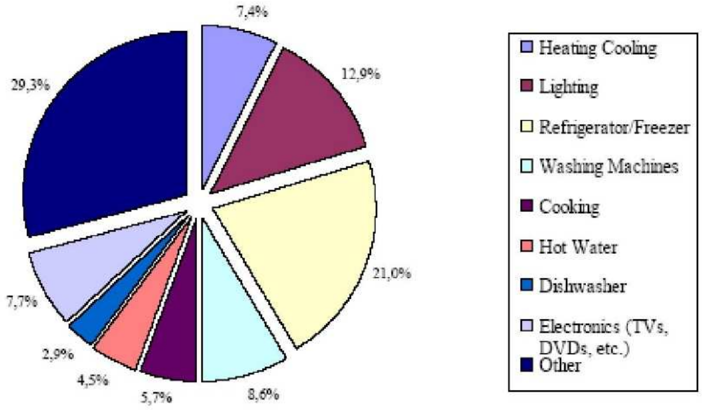


Fig. 10. Distribution of residential electricity consumption in EU countries, 2004

Tab. 5. Energy consumption of washing cycles depending on the temperature of the cycle

Cycle temperature	Denmark	Greece
Cold cycle	149 kWh	2,5 Eurocent
Cycle 30-40°	497 kWh	9 Eurocent
Cycle 60°	1097 kWh	20 Eurocent
Cycle 90°	1800 kWh	32 Eurocent

4.3 Remodece

Another important project that (like the French campaign Ecodrome, Eureco and the Italy Micene project) is Remodece, [21] that has as its goal the understanding of current electricity use by European households resulting from different types of equipment, consumers' lifestyles, and comfort levels. This project is also important because has evaluated how much electricity could be saved using the most efficient appliances and by the reduction of standby use.

Remodece project (2006-2008), carried out in 12 European countries such as Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Norway, Portugal, and Romania.

The average electricity consumption per Remodece household per year (excluding space and water heating) was 2700kWh. In Figure 11 is possible to see that also in this campaign, the refrigeration is the appliances' group that requiring the largest part of the total household electricity consumption (28%).

The Figure 12 shows the load curves for a typical European household for a typical weekday of the year, based on the monitoring campaign carried out.

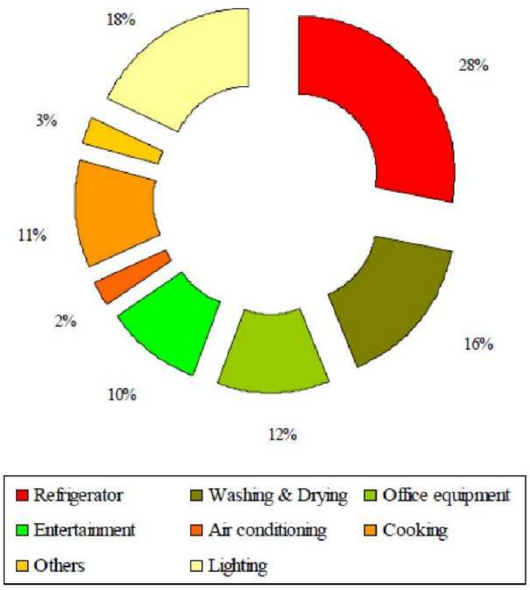


Fig. 11. Electricity consumption breakdown in the residential sector in the countries participating in the Remodece, excluding electric space and water heating

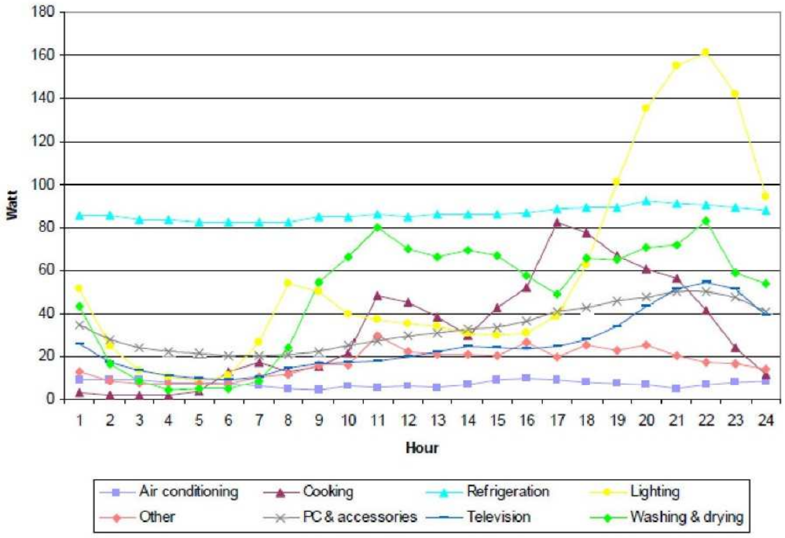


Fig. 12. Electricity consumption in group of appliances for a typical household on a typical day of the week, Remodece

5. Tariffs

Through monitoring campaigns (such as those mentioned in the previous chapter 4) numerous data are collected over the years, relating to the consumption of household appliances; this data is very useful source for understanding family habits and therefore can offer innovative pricing systems and to promote customer demand management.
A very simple pricing system is obviously based on a constant energy price, but it does not avoid overloading the power grid during critical times of the day.
A new billing strategy, powered by "Smart meters" (which facilitates the detection of power consumption data), allows the application of tariffs that vary during the hours of the day; these tariffs are defined as "Dynamic Pricing", linked to what is the real price of electricity, which in Italy (as explained in paragraph 2), due to the use of the PUN, is not clearly readable on the bill (Fig. 13).
Implementing these dynamic rates requires, however, a more complex new generation infrastructure, a "Smart Grid", that is an advanced power grid.
Directive 2009/72 / EC of 13/07/2009 [22] addresses, among other things, the one related to Smart Grids; The Directive indicates that *"the Member States should encourage the modernization of distribution networks, for example through the introduction of intelligent networks built to promote the decentralized generation and energy efficiency"*.

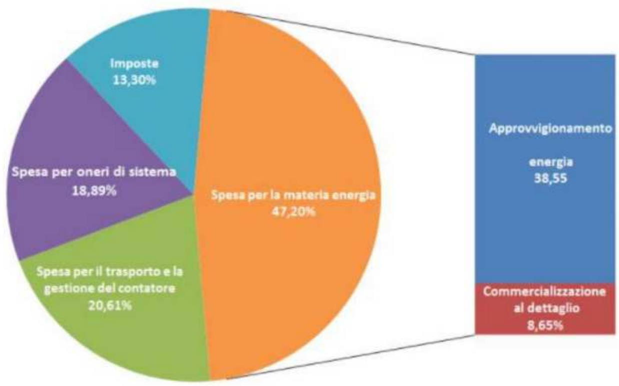


Fig. 13. Percentage composition of the electricity price for a type electric consumer (with 3kW of power used and 2700 kWh of annual consumption) in the trimester 2017 [23]

5.1 Dynamic Pricing

The electricity charging of constant price is a very simple system, [24] which provides only one price of electricity, independent of time and day of consumption; The disadvantage is that customers are not encouraged to shift their electricity demand and consequently decrease the stress on the infrastructure, especially during peak hours. As distinct from constant price, there are real cost electricity tariffs, i.e. "Dynamic Pricing" tariffs, with which the price paid by the customer is based on the actual cost of supply at the time of consumption: this requires detached energy meter,

for each period in which deafferents prices are applied, but it makes it possible to reach price signals to consumers in a correct way.
Dynamic pricing programs, based on anticipated demand, set different prices for electricity at different times of the day [25]. Whit this program, energy consumed during peak hours, when demand on the electric grid is the highest, costs more than that consumed during off-peak hours. Dynamic pricing incentivizes customers to decrease their energy use during peak hours to reduce stress on the electric grid. The only requirements to implement a dynamic pricing program are a smart meter and two-way communications between the energy provider and consumer. Smart meters are going through a rapid deployment nationwide, with the Institute for Electric Efficiency estimating that by 2020 nearly all residential U.S. customers will have them.
The four major dynamic rates currently are:

- Time Of Use (TOU)
- Critical Peak Pricing (CPP)
- Peak Time Rebate (PTR)
- Real Time Pricing (RTP)

5.1.1 Time Of Use (TOU)

Time-of-Use pricing [25] divides the day into distinct time periods and provides a static schedule of rates for each period. The price of electricity is higher during the peak period and lower during the off-peak period. Prices may also vary by season. TOU rates are not widely considered dynamic because they are fixed and are not based on actual market conditions, so they do not address the extraordinary demand placed on the grid during times of extreme peak usage, such as a heat wave. This differentiates TOU from the other dynamic pricing programs.
However, these programs are still effective in lowering peak loads and reducing the need for peaking capacity. They reliably flatten demand in typical periods of peak use throughout the year, and because the rates are known in advance, consumers can vary their usage in response to such prices, either shifting usage to a lower price period or reducing their consumption overall.

5.1.2 Critical Peak Pricing (CPP)

With Critical Peak Pricing (CPP) [7], there are "event" days during the year when wholesale prices are higher or when the network is more stressed. These event days can be fixed or variable and customers are warned the day before these critical events; During these days, but in peak hours' customers get a discount, while all other days of the year pay a fixed fare. This rate is also easy to understand and encourages the customer to send a clear price signal to reduce consumption over a limited number of hours during the year.
This tariff is not very widespread because of the very high prices during these critical hours and because they are considered more intrusive than the TOU (because they do not take advantage of smart metering systems, but the customer is contacted in advance of a critical day). Often, it's use combine TOU-CPP tariffs, but that is very complex and requires a lot of attention from the customer.

5.1.3 Peak Time Rebate (PTR)

With PTR rates [7], to customers are offered a discount during critical events without raising tariffs in other hours. In this way, users are paid to reduce their consumption on critical days, compared to a baseline forecast. Not participating in the event, the existing fare price is paid. These tariffs, which are generally more commonly accepted compared to PCC rate and more understandable, allow it to reduce the bill only in the short term, because in the long-term tariffs may increase to cover the cost of discounts made. In addition, a baseline consumption profile must be carefully determined for each customer.

5.1.4 Real Time Pricing (RTP)

RTP tariffs [7] are the most flexible tariff which allows it to shift your own consumption, as they are related to the market price of electricity. The customer can be informed one hour before or a day earlier on the trend in hourly prices, providing the most accurate timeliness of dynamic pricing signals accurately and reflecting changing market conditions.
Generally, customers are traders and industrial sectors, but some utilities in the US and the European Union (e.g. Norway and Spain) also offer tariffs for the residential sector. This is because it is difficult to respond adequately to the prices of this offer without automated technologies.

5.2 Italian fare

Time-of-use tariff at two-part periods rate was introduced in Italy in July 2010 as the standard tariff for residential (default) users; it provides for variable prices of electricity depending on the hour

of the day: the price is higher during “peak hours” (F1 time slot) and lower during “off-peak hours” (F2 and F3 time slots) [26]
The time slots set by AEEGSI are:

- F1 - Monday to Friday, from 8 am to 7 pm, excluding national holidays;
- F2 - Monday to Friday, from 7 am to 8 am and from 7 pm to 11 pm; On Saturdays, from 7 am to 11 pm; National holidays excluded;
- F3 - Monday to Saturday, from 00.00 to 7.00 am and 11.00 pm from 12.00 pm; On Sundays and holidays, all hours of the day;
- F2 + 3 or F23 - from 7 pm to 8 pm every weekday, all Saturdays, Sundays and public holidays.

Below, we can see in Tab.6 [27] the prices per kWh calculated based on the amounts updated in the second quarter of 2017 by AEEGSI.

Tab. 6. Prices per kWh per client type in Italy (3 kW residential power, consumption of 2,700 kWh/year), excluding taxes (Source: AEEGSI fourth trimester 2017)

Constant energy price (monorario) €/kWh	Two part periods price (Bioraria)	
	Price band F1 €/kWh	Price band F2 e F3 €/kWh
0,170012	0,177522	0,166472

6. Application of dynamic prices in Italy

Several studies [28] on the possible application of dynamic tariffs in Italy have arisen from the need to be in line with the times and considerations made on the validity of the current two-part periods tariff (Biorara tariff) price system of electricity, introduced years ago in Italy.
By analysis the existing national system, the results have proved that it is an unfitting method today; It would be useful to revise it, modifying the time slots or anticipating new ones, also considering the massive diffusion of renewable energy generation systems that have changed the hours when the price of electricity is lower. But although it is well documented that the two-part periods tariff price signal is no longer aligned with market prices, there are no adequate studies to quantify the economic value of the benefit that could obtain with this one.
Everything started with the prosumer, the "producer citizen", who with an important initial economic investment has built up its own generation system. It generally has a greater predisposition to emerging technologies and, in the specific case, an interest to take advantage of his economic investment. The various dynamic rates highlighted in paragraph 5.2 have obtained positive advantages both in the United States and in other European countries, that have decided to adopt them. From July 2015 in Spain, households can subscribe to commercial offers based on a price per hour linked to the results of the Spanish electricity market (with tariffs TOU and RTP). In France, since many years, the "Time" tariffs (CPP) are in force, where the price of energy depends on the type of day of the year, with 22 days a year so-called "reds" at very high costs. The French Authority has announced that consumers in these critical days have achieved a reduction in consumption by more than 40% and has led to an average reduction in bill costs of around 7%. In Finland, where a household's electrical consumption is much higher than in Italy, bundled electric power bundles are available for automatic control systems of the electric heating system, which can thus take advantage of the most convenient hours of the market Electricity spot (RTP tariffs). Generally, the introduction of dynamic price options allows certain user profiles to achieve notable savings on the electricity bill: 4% in the UK, 10% in Germany, up to 15% in Finland.
So, let's see what it is and what would allow these rates to be applied in the Italian scenario.

6.1 Barriers and Practices necessary for possible application of dynamic prices in Italy

A study by Energy-House [7] showed how applying these dynamic rates in Italy could provide many benefits to those consumers who are mindful of the economic and environmental aspects, especially the more "energetic" users. This analysis has made it possible to identify the best practices to be made, before proceeding to large scale roll out by new tariff options.
The first step will certainly the project for replacement the existing counters, with the introduction of new generation electric meters. Referring to the Italian context (as already highlighted in paragraph 2), technical barriers

(accessibility of measures), energy barriers (controllable loads) and regulatory barriers (predefined price schemes) have been identified.

6.2 Using Enabling Technologies

Regardless of the dynamic pricing programs employed, they all share a set of fundamental technologies and best practices that help realize optimum results.
In addition to being able to help customers handle power consumption in response to variable price signals, enabling technologies can achieve even better results in terms of peak power reduction on the power grid, but especially in terms of acceptability of the "dynamic pricing" option; This is because the options that offer greater benefits (in terms of potential savings) are also the riskiest. So, the choice of a user will be determined by his or her risk appetite. New enabling technologies allow the consumer to receive information about their own consumption and energy prices, and can thus monitor and manage their consumption.

6.2.1 BAT: Best Available Technologies

Helping the households, in addition to smart meters, there are also new intelligent house appliances that can communicate with each other and can be programmed even at a distance to plan their use in the most convenient and minimum overweight hours of the day. Many households' appliance brand has been making products always more intelligent and able to communicate with us through apps that can be downloaded on tablets and smartphones or are present on the device. Among the most popular brands that offer such products are Whirlpool, Electrolux, LG, Bosh, Samsung, Siemens and much more. These brands produce e.g. washing machines that, thanks to the installation of electronic sensors inside them, understand the right amount of detergent to be used in relation to the laundry load in the basket. In this way, the system will minimize the use of resources and maximize performance, advising depending on the different laundry, washing with the most suitable water temperatures and amounts of water. Many appliances can also be programmed and started remotely.
It is can also remotely control the dishwasher, which in new models, thanks to a high-pressure water jet allows to have always cleaner dishes with the minimum consumption.
Refrigerators of the Samsung Family Hub line [29], e.g. are equipped with a Touch Full HD screen and can interact with other Samsung connected devices and thanks to three cameras within, the user can check the availability and expiry date of foods inside the refrigerator, even when is out the house, using his smartphone. But it can also talk to Samsung's house devices such as Smart TV, so you can watch favourite programs on the refrigerator display and listen to music. The Whirlpool brand [30], on the other hand, has a 6th Sense Live Technology line-up that sends app notifications if the door remains open and allows you to create an inventory of products with their respective expiry dates. Other intelligent devices are the oven and microwave, which by choosing the type of program you want, can automatically adjust the temperature and cooking times of a dish ensuring maximum energy efficiency. Bosh Ovens [31] thanks to the House Connect feature have access to numerous recipes, which can be saved in the app so that the oven is already pre-set for preparation.

7. Conclusion

In this paper, starting from a household consumption benchmark analysis, the Italian domestic situation was analyzed. The study started by analyzing the existing stock of European housing with its various characteristics, which may impact residents' consumption. The daily household consumption was then analyzed in detail, mainly thanks to the three major monitoring campaigns carried out so far and which represent complete databases both at European and Italian level (Eureco Project, Micene Project and Remodece Project). In addition, this article analyses in detail the tariff situation in Italy, as well as how and by whom the national electricity system is managed, in all three main phases of production, transmission and distribution of electricity. Has been examined the past Italian situation as, although for years it has been trying to liberalize the electricity market in Italy, it has only come to a "partial" liberalization, which has led domestic customers not to leave the protected market.
From the past until now, it has been possible to note that current Italian tariffs are now ineffective and no longer aligned with the actual electricity price, especially because of the expansion of "prosumer" (consumer-producers who have Built its own generation plant using renewable sources) does not reflect the trend on which the Italian time slots are based. This analysis, however, has not only led to the awareness that nowadays Italian tariffs are no longer so affordable for households. In fact, following the identification of tariffs applied in other countries (TOU, CPP, RTP, PTR), it was

possible to imagine what the most appropriate rates would be for the Italian context and what would be encouraged their application. One of the chapter in this paper deals with the means that would allow real savings in the domestic bill, also thanks to those enabling technologies that would allow the consumer to make the most of the new tariffs.

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FIGURES

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