Conditions for the integration of energy-efficient technologies into households. Elements of the Portuguese experience

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Abstract

This paper reports on some elements of the Portuguese experience related to the integration of energy-efficient technologies into Portuguese households.

It provides a description of the present situation, giving:

- a brief characterisation of the total electric energy consumption in the residential sector and the details of each main utilisation;
- the key documents to promote the different electro-technologies (fridges, washing machines, etc);
- the energy saving potential in the residential sector;
- the characterisation of the steps of a process; relevant information (legislation – labels…), main partners involved in a process.

The paper also looks to the future, providing: critical reflections about different hypotheses to implement deeply on the market the efficient technologies; main strategies to be followed in Portugal to improve residential buildings and to install more efficient electro-technologies; indications on who should be the main actors involved in a DSM & End-Use Energy Efficiency Plan.

Introduction

The integration of efficient technologies in households depends on factors which do not differ very much from one country to another, and depends also on country-specific conditions. Two examples: the energy price for the end-user must reflect energy policy and stimulate the demand transfer to empty hours periods – this is a type of condition of general application; the conditions to develop urban central heating system (district heating) depend on each country atmospheric characteristics, for instance in the case of a moderate climate country, like Portugal, district heating is less attractive from an economical point of view that in a Nordic European country.

This paper characterises the Portugal situation for what concerns the integration of efficient electro-technologies in the residential sector considering two horizons: present description and a glance to the future.

PRESENT DESCRIPTION

A BRIEF CHARACTERISATION OF THE TOTAL ELECTRIC ENERGY CONSUMPTION IN THE RESIDENTIAL SECTOR AND THE DETAIL OF EACH MAIN USES

Electric energy consumption in the residential sector represents (in 1997) around 26% of total electricity consumption of the country.

The average annual growth rate is around 5.1%/year in the last decade and is higher than the average variation of total electricity consumption (around 4.5%/year).

This situation is essentially due to the following reasons: increase of the number of lodgement units, increase of life level with the consequent comfort conditions improvement, and the increase of the penetration of electric household appliances.

The growth of the electric energy consumption in the residential sector is also some points higher than observed in "Private consumption" (2.9% per annum), the component of the "Gross Domestic Product" which it seems to have a linear correlation.

Probably this tendency progress will still maintain for a few more time, since the consumption per capita in Portugal is still around half of the level verifiable in OCDE.

The number of household is around 3.2 million in Portugal (continent) and total domestic sector consumption is around 8.1 TWh. The average consumption amount 2.6 MWh/year and the average subscribed power is near of 4 kVA.

Table 1 presents an evaluation of the breakdowns into the different applications of residential consumption and the penetration of electric household appliances.

After lighting, the washing machines and refrigerators are the most important applications in relation with electricity consumption.

Considering the penetration there are some appliances, such as Refrigerators, Irons and TV's near of the saturation. Others, such as Washing machines, Dryers, Dishwashers and Microwave ovens have increased their penetration during the last years. The Portuguese temperate climate explains, in part, the 41% of the households with space heating and the 3% of the households with space cooling equipment. Electric water heaters exist in 8% of the households and with the development of the natural gas network and the expectable more use of solar thermal collectors, this share may decrease in the near future. Also to be mentioned, in relation with cultural evolution of the Portuguese society, is the very quick penetration last years of Personal computers, which now exist in 14% of the households. On this residential electric energy consumption evaluation, some appliances, such as lighting, were estimated in a rough way.

Another assessment based on several monitoring programmes carried out by ADENE on the last years, come to different values of distribution of energy consumptions for final uses in the residential sector. Compared to the estimates previously presented, ADENE found higher values for the contribution of "Refrigerators&Freezers", "Space heating", "Water heating", and lower values for what regards "Lighting", "Washing machines", "Dishwashers". ADENE's values are presented on the Figure 1.

This estimation has a more rigorous information in some appliances that were not considered in a desegregate way in the previous one – such as lighting. However, it may not be so representative as the previous one, because on average it concerned high-income consumers.

THE KEY DOCUMENTS TO PROMOTE THE DIFFERENT ELECTRO-TECHNOLOGIES (FRIDGES, MACHINES, ETC)

The first important key documents result mainly from a national voluntary strategy in relation with "PACE" European community program (from June 1989 onwards) that promoted Rational Use of Energy and Efficient Equipments.

Table 1. The breakdowns into the different applications of residential consumption.

Electricity consumption in the domestic sector Portugal 1997 Nº of households = 3.2 million (approximately) Total Domestic sector consumption = 8.1 TWh Annual growth rate (last decade) = 5.1%/year		
Average consumption per household = 2.6 MWh/year Average subscribed power = Near of 4 kVA		
Domestic electricity consumption Portugal 1997	Number of appliances (% of Number of households)	Consumption (% of total Domestic Electricity Consumption)
Lighting	100%	20%
Refrigerators & Freezers		
Refrigerators	97%	9%
Freezers	50%	7%
Laundry		
Washing machines	83%	12%
Dryers	11%	1%
Irons	96%	8%
Space heating	41%	5%
Cooking		
Stoves	22%	3%
Ovens	22%	2%
Vacuum-cleaners	69%	5%
Dishwashers	19%	4%
TV's	98%	4%
Water heating	8%	2%
Space cooling	3%	0.4%
Miscellaneous		17.6%
Personal Computers	14%	
Total		100%

Sources: EDP, REN (Rede Eléctrica Nacional), Estimates based on Júlia Boucinha e Célia Godinho report [6].

The key documents to be mentioned are essentially all the official documents, notably publish by DGE (Portuguese General Directorate of Energy), the EDP (Portugal Electric Company) documents collection reporting RUEE (Rational Use of Electric Energy and Efficient Electro-technologies), and the studies and reports of CCE (Centre of Energy Conservation, now called ADENE – Portuguese Energy Agency).

Some of these key documents are referred hereafter with a short description of their content.

RUEE Collection

Several brochures and leaflets (see reference [11]).

RUEE Books

Three books were published recently (see reference [7], [8], [12]). Two of them are concerned with the Rational Use of Energy in a practical way. They contain a reference table on some of the existent electro-technologies that fit in the context of sustainable development. The other book contains 127 papers – more than 1 000 pages involving authors from 25 countries around the world – from the international conference organized by UIE (International Union of Electricity applications) and EDP.

Studies and Reports:

(See reference [1], [2], [5], [9]).

Energy Consumption in the Domestic Sector – DGE, December 1989 – which present the breakdown of different energy domestic applications.

Characterisation of energy consumption in the Domestic sector – EDP/CCE, April 1996 – which present a more deeply analysis of some applications.

Monitoring of energy consumption in Domestic Sector – CCE, December 1997 – which presents a pilot study in 25 households located in the main Portuguese cities where several electric appliances were monitored and analysed.

Added-Value Services on Energy Efficiency – EURELECTRIC (Paper coordinated by the Preservation of Resources Working Group), October 2001 – which report several energy services done by some European electric companies, including EDP.

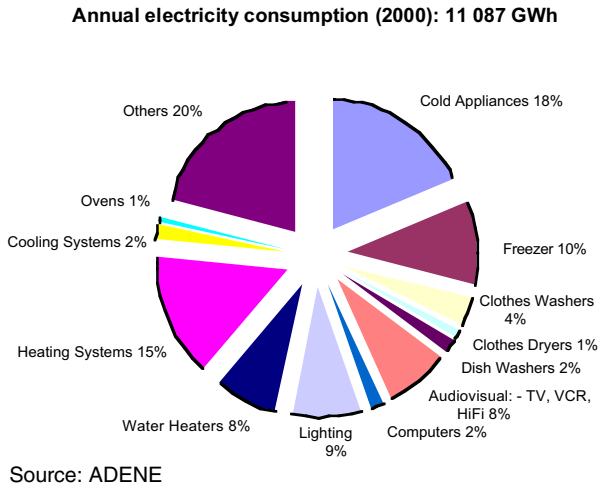


Figure 1. *The breakdowns into the different applications of residential consumption.*

The potential for energy savings in the Portuguese residential sector

A recent study carried out by ADENE on the energy saving potential in the residential sector (see reference [3]) was developed considering the characterisation of a future typical lodgement unity. Based on the information obtained from 100 households, this study consider a well equipped lodgement unit, with dishwasher and laundry machine, laundry dryer, computer, two or three televisions and, in a general way, several equipments with "stand-by" consumption (electronic equipments and also digital command).

Figure 2 compares the corresponding to the equipments actually installed ("Actual"), with the consumption that would be generated by the three following situations of

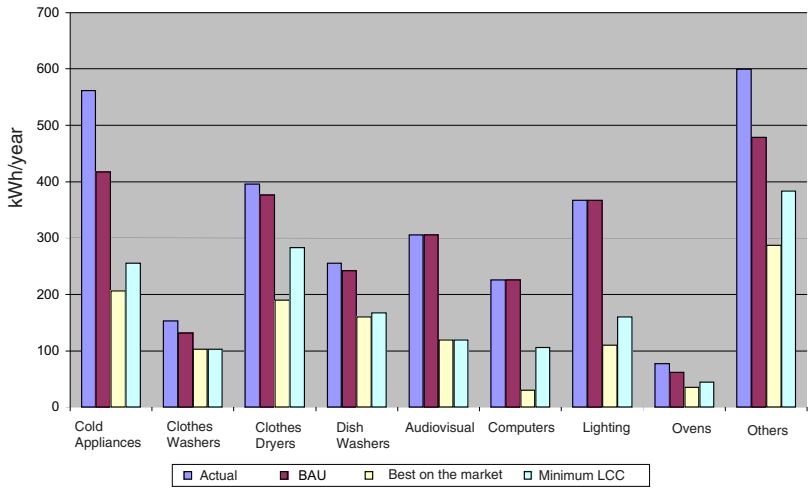
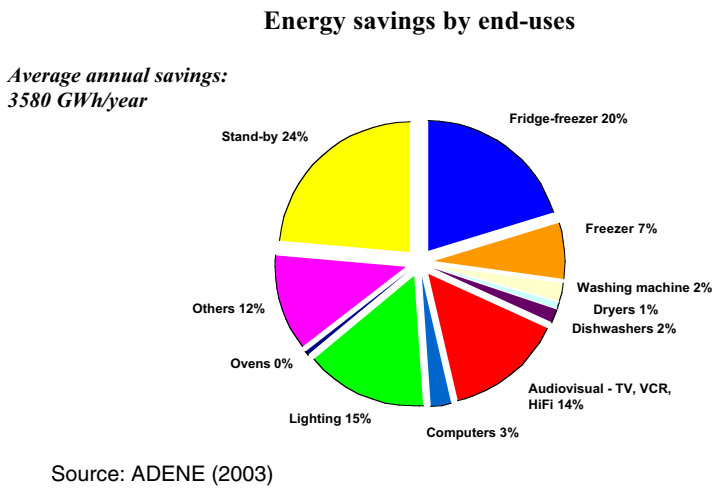


Figure 2. *Energy consumption by end- uses in typical Portuguese dwellings.*



Source: ADENE (2003)

Figure 3. *The breakdowns into the different end-use equipments of the energy saving potential.*

equipments substitution: "*business as usual*" which corresponds to the consumption if all the lodgements equipments were substituted with "medium" equipments of the Market ("BAU"); the better equipments actually available on the market ("Best on the market"); and the equipments that from consumer point of view correspond to the minimum Life Cycle Cost ("Minimum LCC").

Taking into account the best technologies available on the market, we can estimate, for the residential sector in Portugal, an energy saving potential of 3 580 GWh/year, with a distribution by end-uses illustrated in Figure 3.

THE CHARACTERISATION OF THE STEPS OF A PROCESS, RELEVANT INFORMATION, MAIN PARTNERS INVOLVED IN A PROCESS

The following table presents a synthesis of the development schedule, since 1989, of the main energy efficiency actions.

National PACE programme (period 1989/1990)

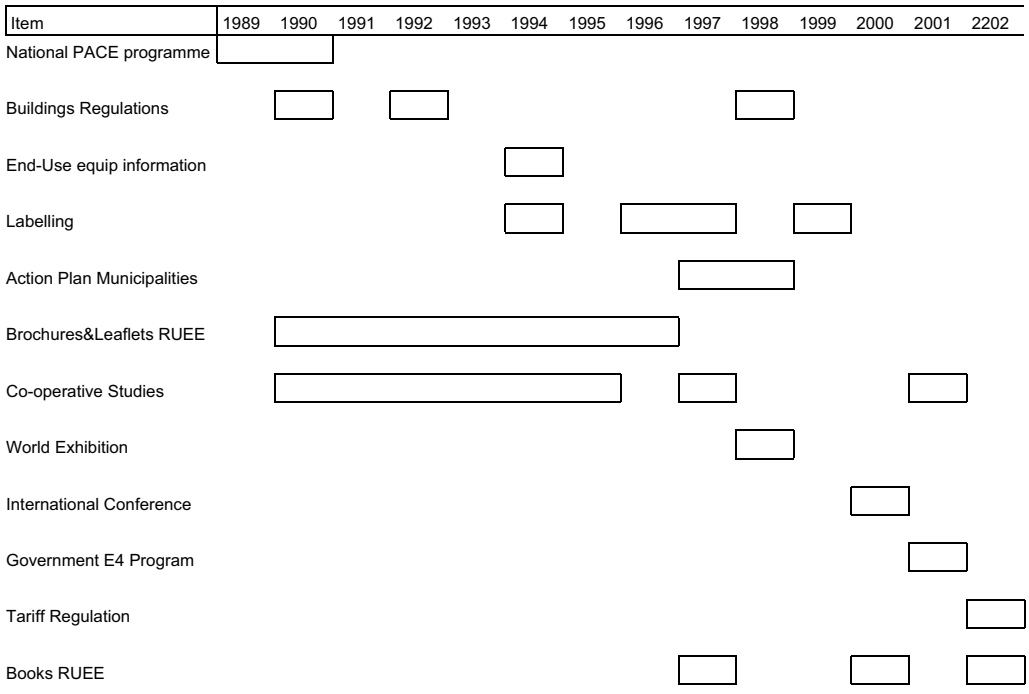
The national voluntary actions in relation with the "PACE" (European Community Action Programme for improving the Efficiency of Electricity End-Use – June 1989) consisted in a large group of actuations boarding several sectors of activities on multiple aspects: information to consumers, technical advice, demonstration, studies and other activities of support, co-ordination and control. The major stakeholders were involved on the Portuguese Consultative Commission of PACE program, such as: DGE (General Directorate of Energy), CCE (Centre of Energy Conservation), Research and development Institute, Quality Institute, EDP (Portugal Electricity company), Manufactures and representatives of end-use-equipments, University, Consumers representative Institute.

Building Regulations – Energetic systems on buildings (period 1990/1998)

Decree-law (DL): DL 40/90 (90.02.06) – Regulation of thermal "behaviour" characteristics of buildings and its new version DL 118/98 (98.05.07) – Regulation of energetic systems on buildings, which intends to discipline the dimensioning of the systems and insert other rational measures.

DL 156/92 (92.07.29) – Regulation of quality of the energetic systems on buildings.

Table 2. Development Schedule of the main actions of the process.



National PACE programme (period 1989/1990)

Information, Co-operative studies and promotion campaigns (period 1990/1997)

Brochures & Leaflets RUEE collection (EDP documents), considered very important documents to the sensitiveness and the information campaign.

Dual-rate time-of-day tariff: Clock and off-peak meter, and the promotion of the dual-rate time-of-day tariff, which proved to become a very decisive incentive for shifting consumption.

Co-operative studies EDP, CCE and electro-technologies manufacturers for cold domestic appliances (Refrigerators, Freezers, Combined Refrigerators and Freezers).

Join European (involving mainly utilities and non governmental agencies) studies such as the one involving more than 7000 wet appliances (Washing machines, Dryers and Dishwashers) marketed in Western Europe – EnR Working Group – June 1995.

Domestic sector characterisation studies and monitoring reports in household – CCE, EDP – where several appliances were monitored.

End-use equipment information and labelling (period 1994/2000)

Community labelling legislation was implemented in due time in Portugal (see reference [4]).

Action Plan with the Municipalities (period 1997/1998)

Action Plan (PAM) to promote endogenous sources and energy management in municipalities, with the main purpose of turning dynamic and rationalising energy consumption at local and regional levels, particularly in the tertiary, transport and domestic sectors. On its institutional fitting the general co-ordination was a responsibility of a Directive Committee that integrated a member of the Energy and Industry Secretary of State, members from DGE and CCE. A more operational group was directly dependent of that Directive Committee and some local groups with elements of municipalities were also involved on this Action Plan.

World Exhibition (1998)

The buildings constructed in the EXPO area can be referred as examples for urban sustainable development. In the new residential area created during the preparation of the EXPO98 in Lisbon, and after that world exposition, new architecture conceptions appear with solutions to the passive capture of solar energy – Bio-climatic buildings. One example is "Torre Verde", a building with good orientation, very good envelope, "*massive* or *trombe* walls", double windows, etc.

International UIE/EDP Conference (2000)

An international Conference organised by EDP and UIE (International Union of Electricity Applications), in Lisbon 1- 4 November 2000, to exchange experiences with regard to the role of electricity in the planning and sustainable development of cities in the 21st century. A large amount of information was gathered – more than a hundred papers from more than twenty countries – on recent developments on electro-technologies and the role of electricity in achieving sustainable development in the urban environment.

Government E4 Program – Energy efficiency and Renewable energies (October 2001)

This Government programme includes a National Program (P3E) promoting energy efficiency in buildings that among others measures, intends to increase the exigency degrees – with a revision version – of the existent buildings regulation previously mentioned. It also intends to introduce energy building label – in a similar graphic presentation than domestic appliances labels – presenting the estimated energy consumption and the correspondent CO_2 emissions. Finally, it aims also at promoting DSM actions in a more consistency way.

Regulator Tariff Regulation (January 2002)

Tariff Regulation, which clarify some aspects concerning the electricity utility involvements on the developments of DSM actions.

A glance to the future

CRITICAL REFLECTIONS ABOUT DIFFERENT HYPOTHESES TO IMPLEMENT DEEPLY ON THE MARKET THE EFFICIENT TECHNOLOGIES

Although the Portuguese domestic sector is very heterogeneous, with people of different background, social states, habits, formation and information levels, income levels, it has had some evolution with DSM initiatives developed in the recent past.

Today household buildings and equipments are more efficient compared to the 1990/92 situation before the PACE programme and the two buildings Regulations. However changes have been slow, some conservative positions still persist, and there are not many exemplar demonstrative cases to exhibit.

The average efficiency of appliances marketed in Portugal has improved significantly in the last years but it is still lower than the European Union average. Factors such as climate, social and economic conditions and other barriers (lack of funds, administrative barriers, etc.) may explain the differences.

Given the existing energy saving potential we consider that the group of DSM&End-Use Energy Efficiency actions developed until now have been insufficient.

There is a lack of knowledge about the advantages of applications of heat pumps in the residential sector, namely the use of heat pump type air conditioners and electrical water heater using the night power and the regeneration heat pump.

Domotic (home automation) exists especially on the basis of its principles but with few cases to demonstrate the advantages of it.

Also, for heat pumps and Domotic the prices are not affordable for residential consumers.

There is still a lot to do for the integration of energy-efficient technologies in existing buildings and new buildings, such as:

- Thermal retrofitting (second exterior insulation; improvements to the roofs; interior insulation; replacement

of windows by double glass; ventilation improvements) for existing buildings with low level of insulation.

- Measures for new buildings with a better thermal performance (Low energy buildings exploring the use of passive solar energy construction).
- Measures to introduce new and better appliances (More energy efficiencies equipments, Automatic control, Domotic & Telemetering).
- DSM actions implemented until now were developed without Cost/Benefit analysis.

These considerations bring us to the conclusion that to implement energy efficiencies programmes there is a need to develop a new vision for a consistent policy (Community orientations; Energy national policy; Sector activity regulation) and on a global basis (environmental improvement, energy efficiency, renewable).

MAIN STRATEGIES TO BE FOLLOWED IN PORTUGAL TO IMPROVE RESIDENTIAL BUILDINGS AND TO INSTALL MORE EFFICIENT ELECTRO-TECHNOLOGIES

With electric market liberalization it becomes more necessary to assure the essential conditions to develop DSM & End-Use Energy Efficiency actions. It is very important that the involved actors (energy companies, end-users and society in general) recognize clearly that they have benefits and in that way they fortified their intervention, keeping the programs active.

It is necessary to prosecute information and sensitive actions:

- Continue to sensitise existing and potential consumers with case studies;
- RUE information campaigns, especially toward younger people;
- Information about the latest efficiency technologies.
- Stimulate consumers to participate on the changes:
- Manufacturers and Merchants that may contribute on the Marketing of efficient equipment, Rebates on the acquisition of more energy efficient apparatus, Guarantee of functioning conditions;
- Governmental special measures in order to increase the return of energy conservation investments such as monetary incentives, Taxes deduction;
- Energy companies with Promotion of efficient equipment, Developments with their customers DSM Programs.

One of the most suitable instruments in this sector is co-operative procurement with the manufacturers and retailers to assure more energy-efficiency models available in the Portuguese market, supported by an efficient and efficacious application of national and community existing standards. This may permit "Market transformation" which consists in the promotion of the acquisition of more efficient equipments and the stimulation to the appearing of more efficient products (Better insulation for refrigerators and freezers, water storage heaters, electric ovens; better compressor and motor efficiency for refrigerators and freezers; less water consumption by washing machines, dishwashers; etc), with the consequent of the inefficient products retiring from the market.

Also the intervention that the agents are essentially national, as it happens on building conception and corresponding energetic systems, need to be more dynamic. This is not the case of the majority of end-use equipments that are manufactured out of Portugal. So, and reinforcing the existing legislation on building and HVAC systems conception, it seems to be open an important area of intervention of energy companies, through according firmed with designers and constructors (Partnership Project). This may turn possible to conceive and to equip, from the beginning of the process, new multiple apartment buildings with efficient technologic and better comfort conditions with low energy consumption.

New residential buildings as good examples, in terms of energy, have to consider several aspects such as the following:

- Employ best practice solutions at design level in order to satisfy minimum comfort standards with low energy consumption;
- Incorporation of renewable energies and dispersed generation;
- Energy management;
- Integration of more efficient apparatus;
- Inclusion of a "model apartment" to visit and demonstrate its good functioning.

Intervention promoting efficient solutions in social housing, is also needed.

To illustrate one example of a single family residential building which represents a good construction dwelling with energy-efficient end-use equipment, it is presented hereafter the residence of Prof. Traça de Almeida (Figure 4) in the centre of the city of Coimbra (Portugal) which has about 300 m^2 floor space, with a footprint of 16x11m and with the main facade facing south.

The main characteristics are:

Figure 4. *Example*

The envelop: The southern side has 36 m² of windows, which are protected from the summer solar gain by overhangs and a balcony. The double glazed aluminum framed windows have built-in thermal barriers in the frame. The west side is earth sheltered on the first level and together with the northern side have a small window area. The double walls have the cavity filled with extruded polystyrene insulation.

Solar-electric hot water system: The water heating systems uses a 6 m² solar collector, coupled to a 300-liter tank, which provides more than 80% of the hot water needs. The tank has an electric resistance heater for back up.

Ventilation: Low vapour emission materials were used in the building, such as furniture, water based paints and varnishes, leading to a reduced need for ventilation. Forced ventilation is used in the kitchen and bathrooms. Natural ventilation is used elsewhere.

Winter/Summer comfort: Space heating and cooling is provided by three air-to-air heat pumps with a nominal COP of 4 (rated with an external temperature of 7 degrees C for heating). The house also has a fireplace with heat recovery and a nominal thermal power of 10 kW, which seldom needs to be used.

Lighting system: During daytime the large windows provide plenty of natural light. With the exception of decorative chandeliers, which use incandescent lights, all the remaining lighting is provided by compact fluorescent lamps.

Appliances: Cooking is carried out with a microwave oven, vitroceramic plate hob, and an electric oven with timer. High-efficiency (Class A) washing and dishwashing machines are used. Clothes drying are uses solar energy on a protected shelter in the back of the house. A combined freezer-fridge with 300 liters is used for food storage.

Communication and security system: An Internet network is available with access points in all rooms. The house has a programmable security system featuring an embedded network with motion detectors, window tampering (vibration and breakage) detectors and magnetic sensors in the window shutters and doors.

Total low energy consumption: The electricity consumption averaged over one year is very close to 10 kWh per day. The subscribed power is 6.9 kVA and the average consumption is 3.5 MWh/year. The tariff option is the double-rate tariff (off-peak period from 10 PM to 8 AM). Slightly above half of the consumption is carried out in off-periods.

MAIN ACTORS INVOLVED IN A DSM & END-USE ENERGY EFFICIENCY PLAN

It is the public power that should take the initiative of this process, through the definition of the orientation of energy policy, condition necessary to the involvement of other agents on energy efficiency.

By other way, the Energy Companies, by their position, credibility and knowledge of customers needs, can and should develop a fundamental role in these programs implementation. Beyond that, they have administrative infrastructures that allow them to reduce the transaction costs involved on the promotion of technologies of high level penetration.

The Figure 5 represents the main actors that may be involved in a DSM & End-Use Energy Efficiency Plan:

- Energy Companies, the principal responsible for delivering the initiative, in general in a partnership project with Manufacturers and Services providers.
- End-Users.
- "National Authority for Energy" (that we suggest to be created), the responsible of National Energy Policy.
- Energy Regulator.

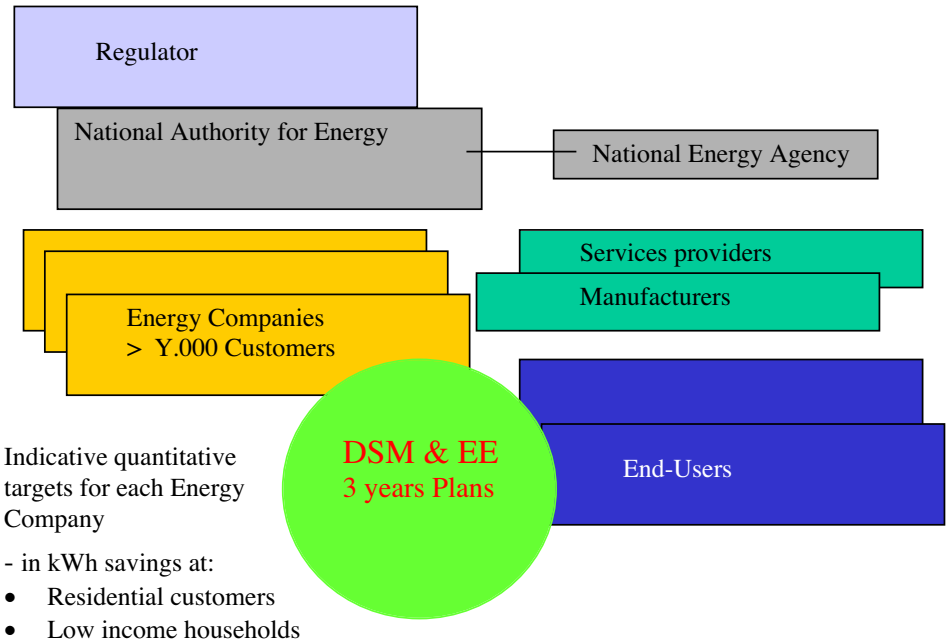


Figure 5. *The main actors that may be involved in a DSM & End-Use Energy Efficiency Plan DSM & End-Use Energy Efficiency Plan – Residential sector.*

Others actors are municipalities that dispose of a group of power at the urban and territorial plan and at the environment protection.

The "National Authority for Energy" that we suggest to be created will be the responsible of National Energy Policy in charge of the definitions of the global targets to be envisaged by the main "Energy activities", such as Upstream Energy Efficiency, Renewable Energy Sources, Combined Heat and Power, Distributed generation, Demand-Side-Management & End-Use Energy Efficiency.

The National Energy Agency, as independent entity, must appear on the most part of promotion mechanism of the DSM & End-Use Energy Efficiency Plan. Its task might be to: evaluate programs, monitoring, do fitting studies; collect founds proceeding from financial mechanisms. Meanwhile, it is within the scope of "National Authority for Energy" (or equivalent entity) to define the intervention level pretended by the Agency.

Conclusion

There is a need to develop a new vision for a consistent policy (Community orientations; Energy national policy; Sector activity regulation) and on a global basis (environmental improvement, energy efficiency, renewable).

Portugal has a great energy saving potential and efficient electro-technologies to be improved in residential sector. However, the successful integration of energy-efficient technologies into portuguese households imposes a threefold conditions: a consistent national energy policy on a global basis – nearest of the consumer, more dynamic and more ecological – , the recognition at the highest level of the need to implement DSM&End-Use Energy Efficient Plans, the commitment of the key actors involved.

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