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Package of measures to promote efficient air conditioning

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WEC ADEME project on energy efficiency policies

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1. Introduction

Air conditioning (AC) systems are important final users of electricity in industrialized countries and are becoming increasingly used also in developing countries, particularly in the household and services sectors. The energy consumption in this type of load is typically high and very sensitive to the system design and equipment selection, as well as to its operation and maintenance. For instance, air conditioning in households and tertiary sector buildings in hot climates can represent more than 50% of total consumption of electricity (Fu and Deng, 2009).

Few data are enough to indicate the rising relevance of air conditioning as an energy consumer and the need of a special attention in programs oriented to save energy and reduce energy losses. Air conditioners use about 5% of all the electricity produced in the United States (DOE, 2012). In the United States, from 1993 to 2005, energy efficiency of AC equipment improved by almost 30%, but household energy consumption for air conditioning doubled (Cox, 2012). World sales of AC appliances is expected to accelerate in coming decades, since most of largest metropolitan areas are in warm to hot climates, with a potential to create "an unprecedented increase in energy demand in many developing countries" (Sivak, 2009). Air conditioners sales are growing 20% per year in China and India (Rosenthal and Lehren, 2012). It is expected that China will surpass the United States as the world's biggest user of electricity for air conditioning by 2020 (Cox, 2012).

Figure 1. Windows in Shanghai, China (photo by Maciej Dakowicz).

Due to technological improvement and possible adoption of correct habits of use, energy efficiency measures in AC systems can be effective. There is a large room for improvement in this appliance, reducing energy consumption without affecting the energy service offered. The aim of the current study is to assess governmental measures implemented to foster efficiency in AC systems.

In order to set the stage for assessing some national programs and/or measures to promote efficient AC equipment and its efficient use, the space cooling technology and its dependence on energy supply are briefly introduced. This is followed by a review of energy saving alternatives from the conception phase to the effective use of AC systems. Then, a list of actual public policies adopted in a group of countries is presented. Some methodological issues concerning the evaluation of the energy impact of measures, such as appliance labeling or minimum energy performance standards (MEPS) adoption, are commented. The criteria adopted for the selection of national cases of public measures towards efficiency in AC systems to be evaluated is presented and eight countries 'case studies are introduced (Brazil, China, Ghana, India, Mexico, Thailand, Tunisia and United States). Based on the data available and information gathered on five countries adopting MEPS (Brazil, China, Ghana, India and Thailand), an evaluation of the associated energy impact is presented, considering the stock of equipment in 2010 and the promoted improvements. Finally, a set of remarks and recommendations are presented.

2. Air conditioning fundamentals

Appropriate air condition (temperature and moisture) is an essential comfort requirement, mainly in hot climates. This is the basic aim of the air conditioning technology, particularly applied in indoor space cooling since the first quarter of last century. Such technology is based on the application of refrigeration thermodynamic cycles, which are able to transfer thermal energy from colder areas to warmer ones, by using an external source of energy.

The amount of thermal energy that should be removed by an AC system from the indoor space in order to keep its temperature lower than the outside temperature is called heat load. It depends on:

a) the thermal energy input from outside, essentially due to the solar radiation crossing through windows and its effect on the walls and roof, plus the infiltration (or ventilation with) of warm air and leaks of cooled air, and

b) the thermal energy internally generated, associated to human activities, lighting and operating equipment within the conditioned space.

To specify correctly an air conditioner capacity for a given application, the total heat load can be estimated with a good accuracy, taking into account the building position (latitude) and orientation with regards to the sun path, the existence of shading effect (other buildings), the construction materials of walls and roof, the dimensions of conditioned space, the dimensions and positions of windows, doors and other openings and whether they have shading, the number of occupants, the heat generated by equipment, machinery and lighting. It is worth to observe that the proper design of a building, with a correct selection of materials and a good management of indoor sources of heat, can reduce considerably the heat load and thus decrease the required capacity and the energy consumption of AC systems.

Aiming to obtain a cooling effect, essentially two refrigeration cycles can be employed: a) vapor compression cycles, in general electric driven and largely used in household refrigerators and air conditioners, and b) absorption cycles, which use heat as principal source of energy and are applied in medium to large capacity systems.

The compression cycles are performed by special substances (refrigerants), which develop four sequential processes in a refrigeration device: 1) compression (consuming electricity), 2) condensation (rejecting heat to environment), 3) expansion and 4) evaporation (absorbing heat and producing the cooling effect). In the case of air conditioners, the cooling effect is used to lower the temperature of indoor air that pass through the evaporator coil, while the absorbed heat is rejected to the outdoor atmosphere by the condenser coil, as indicated in Figure 2. Sometimes the condenser is water-cooled in large AC systems.

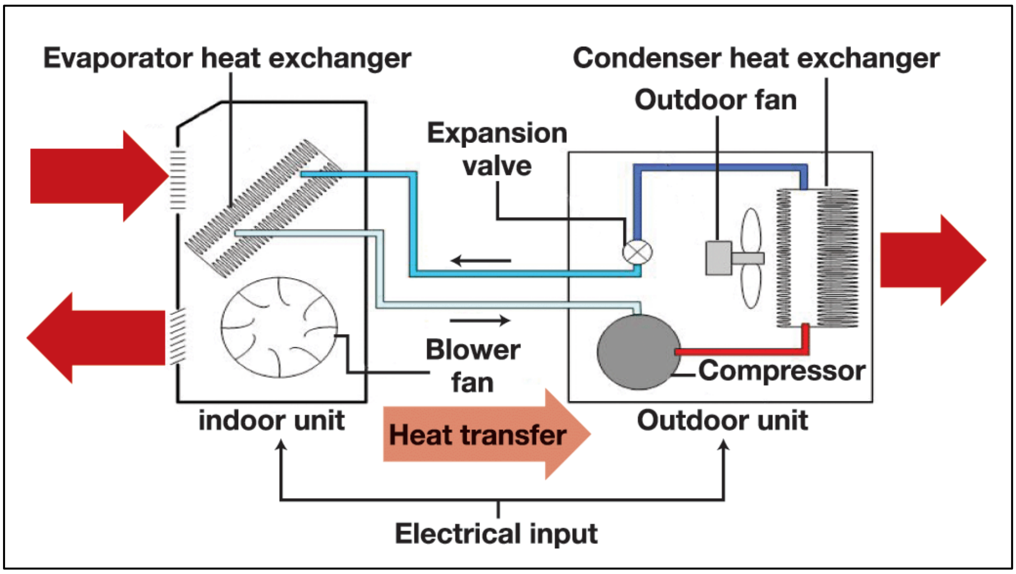


Figure 2. Vapor refrigeration cycle for air conditioning (Spectrum, 2012).

The energy efficiency of an air conditioner is generally expressed by its coefficient of performance, also called Energy Efficiency Ratio (EER), which is the ratio of the cooling effect produced (Q_{useful}) and the power consumed (W_{consum}):

$$EER\ [-] = \frac{Q_{useful}\ [kWh]}{W_{consum}\ [kWh]} \qquad (1)$$

This EER is the basic parameter used to indicate the energy performance of air conditioners, in efficiency labels and in MEPS regulation. With this regard, minimum values for EER for window and split air conditioners in selected countries are presented in Figures 3 and 4 (Lin and Rosenquist, 2008). In order to avoid confusion, it is advisable to note that in some countries, particularly in the United States, EER is calculated considering the cooling effect in Imperial units (BTU/h), and the electrical consumption in watts. In this case, the conversion is:

$$EER\ [BTU/Wh] = 3.413\ EER\ [-] \qquad (2)$$

It is also worth to mention that in some countries is used the Seasonal Energy Efficiency Ratio (SEER) to express the energy efficiency of AC systems. This parameter, instead of being evaluated at a single operating condition, as EER does, represents the expected overall performance for a typical year's weather in a given location. The SEER is thus calculated with the same indoor temperature, but over a range of outside temperatures over the course of a cooling season. Typically EER for residential central cooling units is 87.5% of SEER value, since SEER is generally higher than EER for the same equipment, due to part load operation (ANRI, 2008).

The maximum EER for an AC system can be estimated just from the operating temperatures (indoor and outdoor), independently of particular cycle and refrigerant used. It is interesting to observe that this theoretical value is generally significantly greater than the value observed in real equipment, somewhat indicating the existence of technical improvement potential.

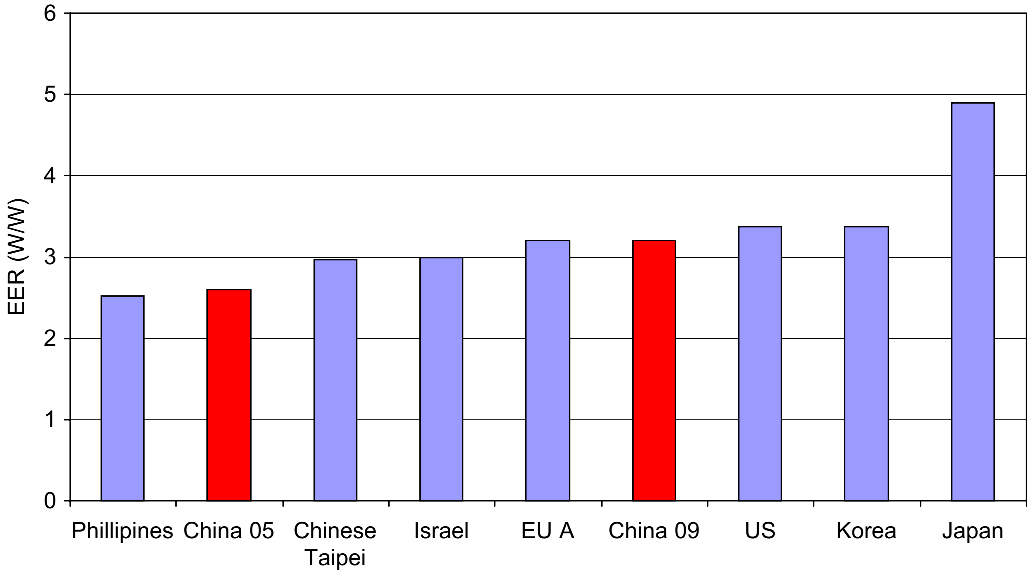


Figure 3. EER requirements of standards for split air conditioners smaller than 4.5 kW from selected countries (Lin and Rosenquist, 2008).

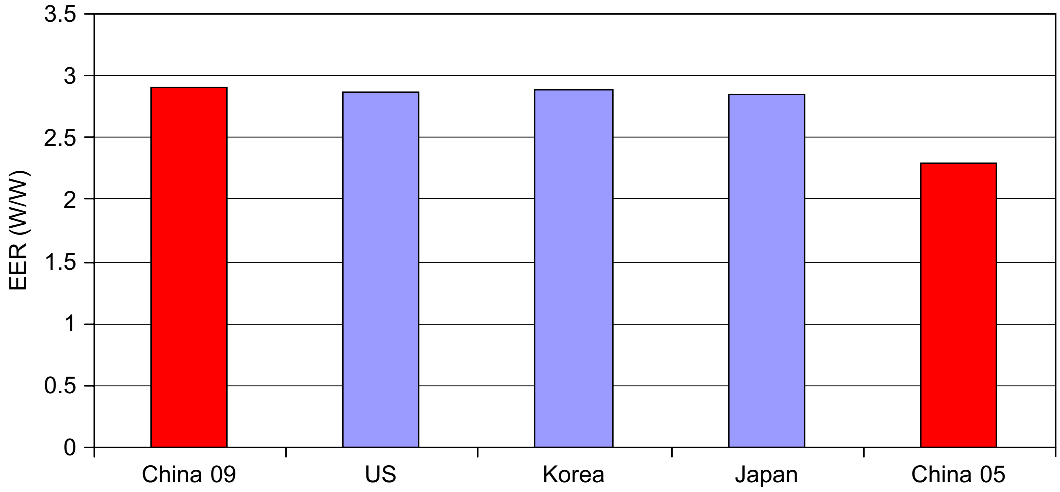


Figure 4. EER requirements of window air conditioner standards from selected countries (Lin and Rosenquist, 2008).

The actual energy efficiency of an air conditioner is very dependent on the operating temperatures in the cold and hot sides of this equipment. As a fundamental rule, the higher the difference of temperatures, the lower is the efficiency and thus, the greater is the energy consumption for a given cooling load. As a consequence, in order to increase EER and reduce energy consumption, the cooling temperature should be adjusted at highest value (of course, in the comfort range), whilst the temperature in the hot side, outdoor, should be kept at the lowest temperature possible, by placing the air conditioner in a ventilated place and protected from direct solar radiation.

It is interesting to note that the effective (internal) operating temperatures of an AC system are also defined by factors defined during its design and fabrication. In fact, the amount of heat transferred in the condenser and evaporator (cooling) coils depends directly on the difference of temperature in these components and the area of coils and fins exposed to heat transfer, respectively to the outdoor air and from the cooled air, as indicated in Figure 5. Frequently air conditioners presenting poor efficiency are cheap due to bad design of heat transfer parts, imposing lower evaporating temperature and higher condensing temperature, compared with a more efficient equipment operating in the same conditions. In a few words, it is relatively easy to produce a low price air conditioner, but is quite more challenging to produce an efficient low price air conditioner, which requires quality in design, material and parts, fabrication and control.

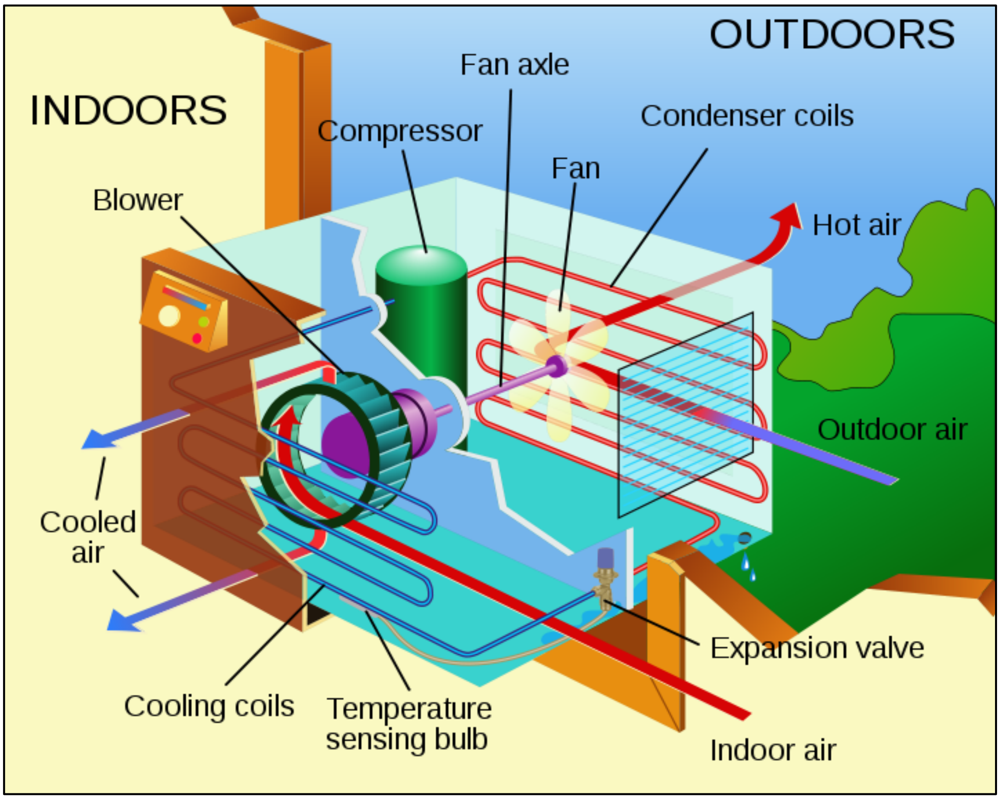


Figure 5. Schematic view of a window air conditioning unit (Wikipedia, 2013)

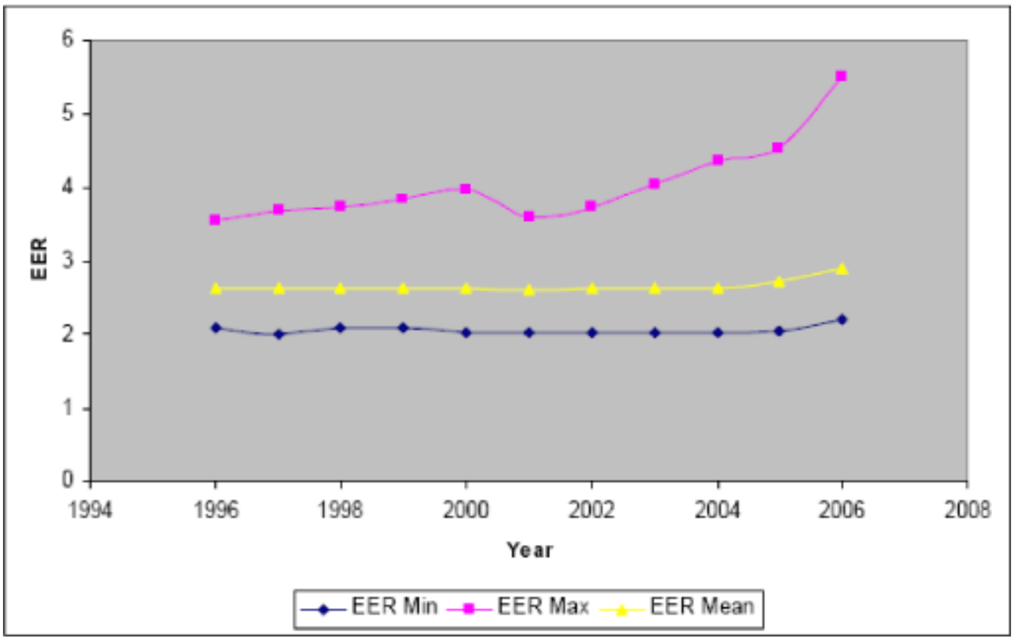


Figure 6. Evolution of the EER (minimum, maximum and model weighted average) for split, non ducted, air-cooled air conditioners up to 12 kW (DEPA, 2009, apud Eurovent (EU2006))

The increasing concern with energy consumption and the consequent governmental measures have stimulated the technological development of AC systems towards efficiency. Now EER values exceeding 20 are theoretically possible by improvements in the compressor, the heat exchangers (condenser and evaporator), and the ventilator. In fact, after issuing of the Eurovent Certification Scheme in 2002, the EER of the best models of room air-conditioners (up to 12 kW) has improved remarkably, as indicated in Figure 6, while it is also evident that the efficiency of the low efficiency models remained almost unchanged (DEPA, 2009).

For domestic and small commercial applications, the air conditioners can be window or wall type (also called single-package), in which all components are assembled in the same unit, or split type, which presents the cooling side and the heating rejection side in separated units. It is worth to mention that since the hot side is separated from the cold side, without heat transmission between them, split conditioners are generally up to 30% more efficient, as pointed out in Figures 3 and 4. Besides, they are quieter and do not use windows space. However, for the same capacity, split units cost more than windows units.

3. Energy saving measures in AC systems

Measures and actions to reduce energy losses can be proposed before the installation of an AC system, during its conception/implementation, or after the system has been installed, during its operation and maintenance.

3.1. Design and equipment specification

Certainly, it is during the project of a building when the initial and most relevant energy efficiency measures can be done with regards air conditioning. The adoption of energy efficient architecture, orienting and designing buildings properly, adopting techniques and resources such as "brise-soleil" and vegetation to protect walls and windows from direct solar radiation, aiming at well designed and correctly located windows and passages, separating rationally working and living spaces, applying natural and efficient lighting and other well-known procedures, will appreciably reduce the thermal load of the AC system.

The second step towards an intelligent AC system is done by selecting an AC equipment with the correct capacity (as function of the heat load, not the room area) and efficient technology. Equipment in this context means typically air conditioners in household and small capacity applications and chillers, fan coils, pumps, etc. in medium to large systems. All those equipment should be monitored by a suitably designed control system, able to accomplish accurately the requirement of indoor air quality (temperature, moisture and, in some cases, external air filtration). Sometimes the outside air can be used as a source of cooling air for AC systems.

Playing an important role in this selection of the right AC equipment, labeling programs inform consumers about the most efficient models, and MEPS excludes inefficient equipment from the market. It is worth to highlight the relevance of the control systems, able to adjust to optimal conditions the AC systems, using in some cases information from utility grid, under the concept of smart grid. For example, some utilities are offering to consumer systems able to program by thermostat using internet or mobile phones.

3.2. Operation and maintenance

As important as the proper design and equipment selection is the AC system operation, including maintenance activities. An energy-efficient building with an efficient AC system should be properly operated and conserved or it will waste energy.

Below are listed some general guidelines for an intelligent use of AC systems, to be diffused among consumers. In this direction, a permanent and properly planned information campaigns is a relevant measure to be taken into account.

a. Avoid to keep doors and windows opened in air-conditioned rooms[1]. All holes, cracks, and drafts should be sealed up. Nevertheless, some ventilation can be required.
b. Set the indoor temperature at a reasonable level. In many cases 24°C is enough[2]. If long-sleeves are needed, perhaps the room is too cold.
c. Avoid and reduce heat production inside the air-conditioned room, caused by lights, electronics, and dryers not in use, stoves, etc.
d. Be sure that:
    - the air conditioner is correctly maintained, clean and without strange noises.
    - the filter doesn't need to be cleaned or changed.
    - there is proper space outside to disperse hot air.
    - the outside part of the air conditioner is a shady place, perhaps trees and shrubs can be planted to keep out the sun.
e. Evaluate if is economically interesting to replace an old AC equipment by a more efficient one or retrofit the AC system, introducing new control systems.

1 In some buildings is adopted contact on the window that stop automatically the AC when the window is open.

2 According to ASHRAE Standard 55, the comfort zone for offices has temperature between 24.5 and 26°C and relative humidity below 60%.

4. Governmental measures towards efficiency for AC systems

Several countries have been promoting energy efficiency for AC systems. The actions towards the rational use of energy in the context of air conditioning can be divided in the following categories: a) regulation, setting minimum limits of efficiency and similar requirements of performance for air conditioners, b) financial or fiscal incentives to stimulate users to adopt more efficient air conditioning equipment and c) targeted information, orienting consumers to buy and use properly AC systems. This section is largely based on WEC surveys carried out by Enerdata on behalf of WEC and ADEME in 2009 and 2012/2013.

Using regulation, in line with the previous paragraphs, the measures can be oriented to efficient building project, proper equipment selection and equipment use guidelines. In Table 1 is presented a set of regulation measures, with some comments and example of countries where they have been implemented. Figures 8 and 9 present respectively the diffusion of energy efficiency labels and MEPS in air conditioning. According to the WEC survey, labels for residential air conditioners are mandatory in 52 countries (2/3 of evaluated countries) and planned in 10 countries, and MEPS for air conditioning for residential use are mandatory in 27 countries (1/3 of evaluated countries) and planned in 14 countries; these MEPS are often linked to label class, thus adopting the same evaluation procedure (WEC, 2012).

Table 1. Regulation measures to promote energy efficiency in AC systems

Measure	Comments	Countries (examples)
Energy Efficient Building Codes	The criteria for qualifying include reduced heat load and efficient AC	Many industrialized countries
Air conditioner labeling	Can be mandatory or voluntary	See Figure 7
MEPS (Minimum Energy Performance Standards)	Remove the least efficient products from the market	See Figure 8
Obligation of maintenance of air conditioners	Well maintained equipment saves energy	European countries
Ordinances on large buildings	Such as mandatory audits, energy managers etc., with impact on AC systems	Some cities and states in USA and India
Energy saving obligations for electric utilities	Utilities should develop energy efficiency programs, monitored by regulatory agencies	Italy, Brazil

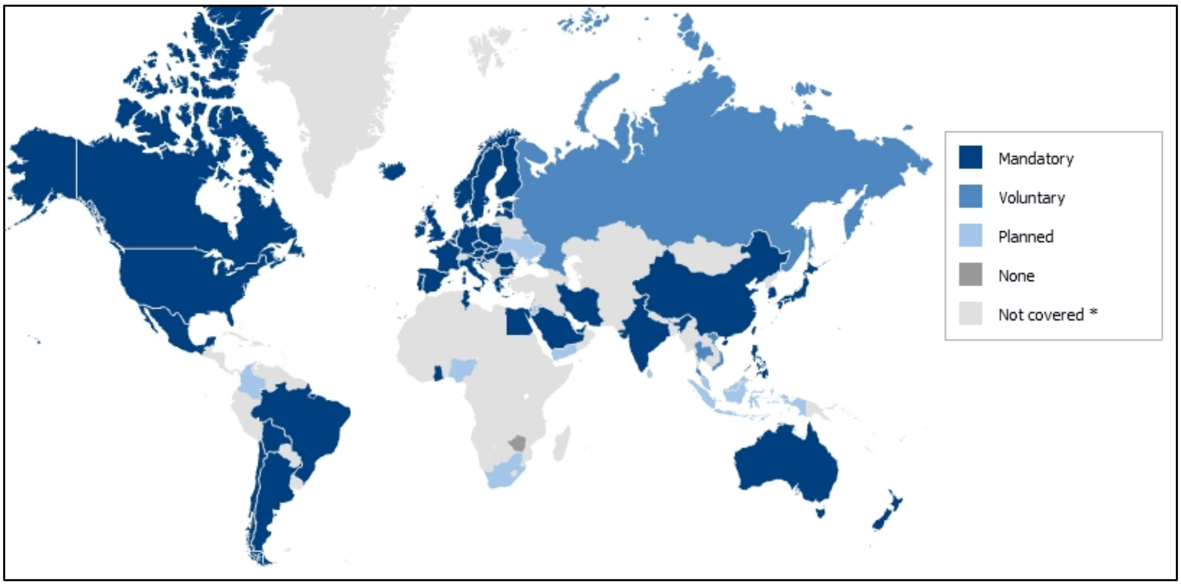


Figure 7. Diffusion of energy efficiency labeling of residential air conditioners (WEC, 2012)

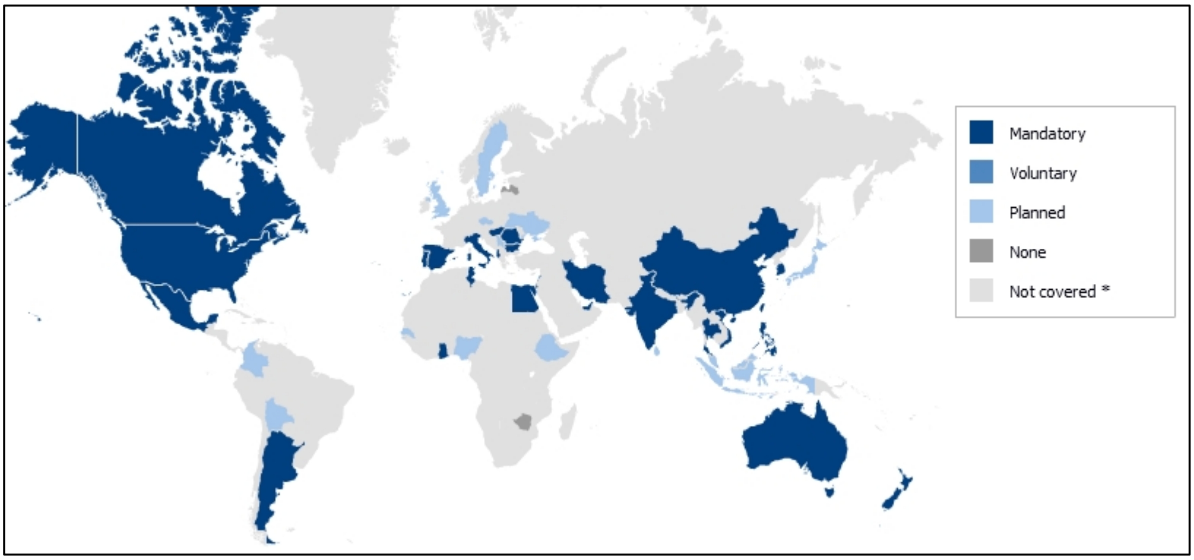


Figure 8. Diffusion of minimum energy performance standards (MEPS) for residential air conditioners (WEC, 2012)

In Table 2 are presented some examples of measures implemented using financial or fiscal incentives. The third category of measures, targeted information, focused in the groups of more relevant consumers, presenting guidelines for purchasing and operate properly AC appliances, can be easily found in the Internet, where different sources (utilities, air conditioners manufacturers, consumers associations, etc.) provide valuable information about principles of air conditioning, heat load estimation and reduction, equipment selection, etc. A good example is the "Topten" websites (www.topten.eu and www.topten.info), an online search tool on the most energy efficient products, covering Europe, China and USA, supported by the Intelligent Energy Europe Programme (from European Commission), two NGO's interested in promoting energy efficiency: European Climate Foundation and the World Wildlife Fund.

Table 2. Financial or fiscal incentives to promote energy efficiency in AC systems

Measure	**Comments**	**Countries (examples)**
Direct subsidies or tax reduction to efficient AC appliances		USA, Australia
Subsidies/soft loans for scrappage of old ones		Greece, Mexico
Demand Response approach to limit the use of air conditioners at peak time	Utility remotely controls the thermostat of consumers at peak time via smart meters and pays a compensation to the consumers	California (USA)

5. Selected cases of governmental measures to foster efficiency in AC systems

In order to explore the actual scenario of governmental programs and activities for promoting efficiency in air conditioning systems, which include of course stimulating the introduction of more efficient air conditioners in new applications and refurbishment of older units, as well as the adoption of more rational practices in operation and maintenance, some national cases were selected to be assessed in relation to the impact expected in the national energy consumption.

The main criteria considered for the selection of these case studies was the diversity, either in terms of country characteristics and type of program. It was searched for case studies outside the OCDE, but there are few national programs in developing countries and an important additional constraint, which is the lack of enough data and information to undertake the required evaluation. Thus, after an initial screening of national energy efficiency programs focusing on AC systems, the available information was verified and finally eight different programs were chosen. Most of these case studies are related to implementation of minimum energy performance standards and labeling schemes, since they are effectively the most frequent action, but few cases were selected also considering economic incentives, as incentives for scrapping old units and buying more efficient equipment, and in the case of India, the information of users was included.

The national case studies selected are briefly presented in Table 3 and will be introduced in more detail in the following paragraphs. Further the similarities and differences among these programs will be commented.

Table 3. National programs selected to be assessed

Country	National Program for Efficient AC systems
Brazil	Minimum energy performance standards and labeling
China	Minimum energy efficiency standards and labeling
Ghana	Minimum energy efficiency standards
India	AC labeling and consumer information
Mexico	Incentives for scrapping old air conditioners
Thailand	Minimum energy performance standards and labeling
Tunisia	Minimum energy performance standards for buildings
USA	Federal Tax Credits for efficient AC equipment

5.1. Brazil

With the creation of PROCEL, the National Program for Electricity Conservation in 1985, the Brazilian Labeling Program was launched, jointly managed by PROCEL and INMETRO, the National Institute of Metrology, Standardization and Industrial Quality. This program has the objective of informing consumers about the efficiency of appliances and energy systems, by using the Energy Conservation National Label, a comparison label, which since 1988 is applied in voluntary basis in air conditioners. Afterwards, PROCEL created an endorsement label, the PROCEL label, which reinforce the better equipment, presenting the higher performance class (A). Figure 9 presents both labels adopted in Brazil.

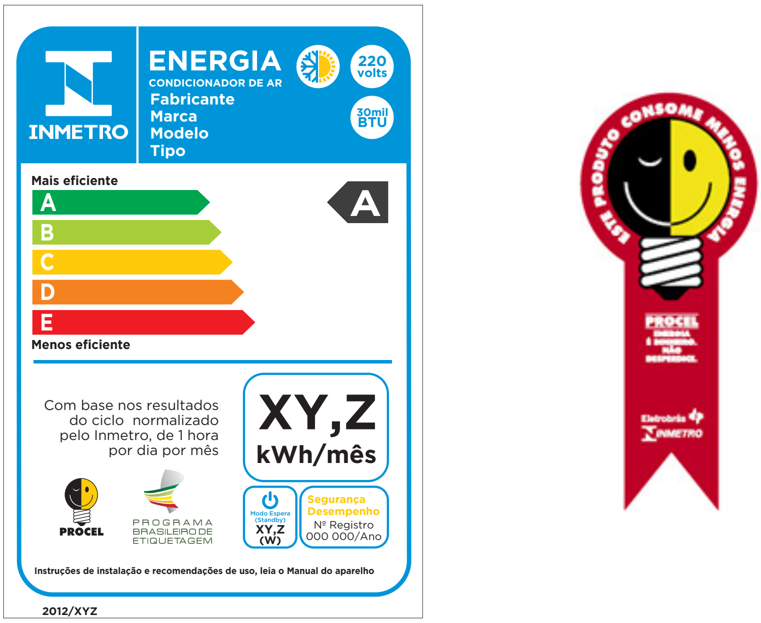


Figure 9. Energy Conservation National Label and PROCEL Label used for air conditioners in Brazil (Cardoso et al., 2012)

The PROCEL Label was applied to window conditioners (less than 6 kW) in 1999 and in split conditioners (less than 11 kW) in 2004. More recently, based on Law 10.295/2001, the Brazilian Law of Energy Efficiency, and according to a decision of Managing Committee for Energy Performance Standards, it was established in 2007 minimum values of EER (MEPS) for all air conditioners, window and split (up to 11 kW) types, sold in Brazil, after public consultation and discussions with energy companies, manufacturers and other stakeholders.

The current values of EER for labeling (updated in 2007) and MEPS limits for air conditioners are presented in the tables below (PBE/INMETRO, 2007 and MME, 2007).

Table 4. Energy performance (EER) classes for window type air conditioners in Brazil

Classes	**Capacity Range**			
	≤ 2.6 kW	2.6 to 4.1 kW	4.1 to 5.8 kW	≥ 5.8 kW
A (PROCEL Seal)	2.91	3.02	2.87	2.82
B	2.68	2.78	2.70	2.62
C	2.47	2.56	2.54	2.44
D	2.27	2.35	2.39	2.27
E	2.27	2.35	2.39	2.27

(PBE/INMETRO, 2007)

Table 5. Energy performance (EER) for split air conditioners in Brazil (up to 11 kW)

A (PROCEL Seal)	EER > 2.94
B	2.76 < EER ≤ 2.94
C	2.58 < EER ≤ 2.76
D	2.39 < EER ≤ 2.58
E	EER ≤ 2.39

(PBE/INMETRO, 2007)

Table 6. Minimum EER for window air conditioners in Brazil

Cooling Capacity - CC (kW)	**Minimum EER** (W/W)
CC ≤ 2.6	2.08
2.6 < CC < 4.1	2.16
4.1 < CC < 5.8	2.24
5.8 < CC	2.11

(MME, 2007)

Table 7. Minimum EER for split air conditioners in Brazil

Cooling Capacity – CC (kW)	**Minimum EER** (W/W)
CC ≤ 10.5	2.39

(MME, 2007)

Table 8 (ABRAVA, 2010) presents the annual sales of air conditioners and Table 9 (Cardoso et al., 2012) introduces additional information regarding AC systems use in

Brazil. These figures, associated to the EER evolution, allow estimating of energy impacts of the air conditioners labeling and MEPS implementation.

Table 8. Sales of air conditioners in Brazil, million units

Year	Type		Total
	Window	Split	
2000	0.67	0.44	1.11
2001	0.67	0.44	1.11
2002	0.69	0.46	1.15
2003	0.76	0.51	1.27
2004	0.71	0.48	1.19
2005	0.76	0.51	1.27
2006	0.94	0.62	1.56
2007	0.85	0.57	1.42
2008	0.85	0.56	1.41
2009	0.77	0.77	1.54
2010	0.81	0.81	1.62

(ABRAVA, 2010)

Table 9. Basic data on AC systems in Brazil

Air conditioner model and capacity range	**Typical unit capacity**	**Average typical unit consumption** (kWh/year)	**Stock in 2010** (million)
Window, 1.75 to 3.5 kW	2.6 kW (9 kBTU/h)	654	6,56
Window, 3.5 to 10.5 kW	6.2 kW (21 kBTU/h)	1,946	2,65
Split, 1.75 to 3.5 kW	2.6 kW (9 kBTU/h)	607	4,66
Split, 3.5 to 10.5 kW	6.2 kW (21 kBTU/h)	1,830	1,13

(Cardoso et al., 2012)

5.2. China

The impressive expansion of AC systems market in China, where 35 million air conditioners were sold in 2010 (Michel et al., 2011), is associated with the consolidation of this country as the main producer and exporter of this appliance worldwide. The energy consumption growth due to air conditioning load expansion is appointed as one of main reasons for the several power shortage that occurred in China between 2002 and 2004 and justified the Chinese Government attention to the efficiency of air conditioners (Lin and Rosenquist, 2006). According to these authors, in major Chinese cities along the eastern seashore such as Shanghai, air conditioning load accounts for 40% of the peak summer load.

The energy efficiency initiatives in China started in 1989 when the former State Quality and Technical Supervision Bureau (QTSB) issued the first set of standards on the energy efficiency of appliances including air conditioners. In April 2001, it was created the Standardisation Administration of China (SAC), which is currently responsible for establishing and monitoring national standards in this country and in charge of the China National Institute of Standardisation (CNIS) which is the main standards research institute. (Zhao and Graham, 2006, quoted by IEA, 2007). The main references for the Chinese case presented in this report was the IEA Information Paper on Energy Efficiency of Air Conditioners in Developing Countries (IEA, 2007) and the Lin and Rosenquist (2006 and 2008) papers.

In 2005, China launched an energy efficiency labeling program which classifies air conditioners in 5 performance grades in order to inform consumers and foster appliance makers to improve their products. At that time, the minimum energy efficiency requirements for air conditioners, in terms of EER, were raised from 2.37 stipulated in 1990 to 2.6, which is equivalent to an annual rise of 0.62%. As the energy efficiency of most of air conditioners was in the lowest of the 5 grades, the sales weighted average EER was 2.8 in 2005, but with the improvement of Chinese air conditioners, it was projected that average EER should increase to 3.2 in 2009 from 2.6 set by the MEPS in 2005, which corresponds to 5.3% of annual improvement (Jiang Lin, 2006, apud IEA, 2007), in other words accelerating the rate of improvement. With the introduction of MEPS, the share of less efficient models of air conditioners decrease from 70% to about 40% in just four years (Jianhong, 2009).

Conceptually, the Chinese program is similar to the approach other countries, combing MEPS and two kinds of efficiency label: a) the Energy Information Label, a classification label with five performance categories, and b) the Energy Conservation Label, an endorsement voluntary label administrated by the China Standard Certification Center (CSC), as presented in Figure 10. However, since the revision introduced in 2004, the EER values in China were progressively elevated and become quite tighter than adopted in other countries.

In the following tables, values of EER required for both labels valid from 2005 are presented (Lin and Rosenquist, 2008). According to the mentioned revision, from 2009 the minimum EER (MEPS) for air conditioners sold in China should be equal or greater than the values indicated in Table 11 (equal to Class 2 in Table 10), surely a relevant step towards more efficiency in this market. This new condition, which begun after 2009, means that in China it is allowed to only trade the two highest efficiency classes (1 and 2) of AC equipment.

Figure 10. Energy Information Label (mandatory) and Energy Conservation Label (voluntary) adopted in China for AC appliances (Zhou, 2008)

Table 10. EER specifications for Energy Information Label AC labeling in China from 2005

Type	**Rated cooling capacity**	**Energy efficiency class (EER)**				
		5	4	3	2	1
window	-	2.30	2.50	2.70	2.90	3.10
split	CC ≤ 4,500	2.60	2.80	3.00	3.20	3.40
	4,500 < CC ≤ 7,100	2.50	2.70	2.90	3.10	3.30
	7,100 < CC ≤ 14,000	2.40	2.60	2.80	3.00	3.20

(Lin and Rosenquist, 2008)

Table 11. Energy efficiency specification for Energy Conservation Label in China after 2005 and Minimum energy efficiency from 2009

AC appliance type	**Rated cooling capacity**	**Minimum energy efficiency (EER)**
window	-	2.90
split	CC ≤ 4,500	3.20
	4,500 < CC ≤ 7,100	3.10
	7,100 < CC ≤ 14,000	3.00

(Lin and Rosenquist, 2008)

5.3. Ghana

Ghana has no air conditioners manufacturers and thus imports the totality of equipment required. It was observed that “current import patterns allow manufacturers to send their least efficient models to Ghana even though these models may be barred from more developed economies because they represent extremely inefficient technology”[3]. Consequently, the average energy efficiency of air conditioners sold in Ghana was comparatively lower, as indicated in Figure 11.

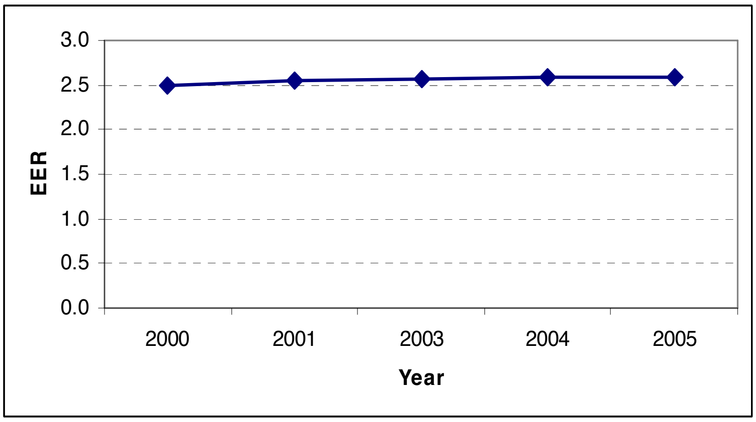


Figure 11. Energy efficiency (EER) of air conditioners sold in Ghana (AIE, 2007)

In the context of strong electricity demand growth of 90’s, the Ghana Energy Foundation (a consumer-based partnership between the public and private sectors – promoted energy efficiency and renewable energy) was founded. This institution, with CLASP (Collaborative Labeling & Appliance Standards Program) support, assisted the Ghana Standards Board (GSB) and Ministry of Mines and Energy to identify products and develop standards and labels (CLASP, 2010).

In 2005 a Mandatory Appliance Standards and Labeling program was launched and since then Ghana is operating a regime under which importers and retailers are required to import and sell only products that meet minimum efficiency and performance standards approved by the Ghana Standards Board. Thus, in accordance with the provisions of the Energy Efficiency Standards and Labeling Regulations, appliance manufacturers who export to Ghana and retailers who sell in Ghana are obliged to display an energy efficiency label, shown in Figure 12, which indicates the energy efficiency rating of the product before the first retail sale (Ghana Government, 2005). The EER requirement for each performance class is presented in Table 12.

In Ghana, more than 100,000 room air conditioners are sold each year with the number expected to grow by about 8% each year. The energy efficiency labeling

[3] Project Design Document of CDM on NM0072: Mandatory Energy-Efficiency Standards for Room Air conditioners in Ghana, quoted by IEA, 2007

program does not have any significant impact on air conditioner stock, but rather it aims at the new air conditioners meeting at least a minimum efficiency performance (EER=2.8) and that consumers have the life-cycle cost information needed to select air conditioner with even higher levels of efficiency (IEA, 2007).

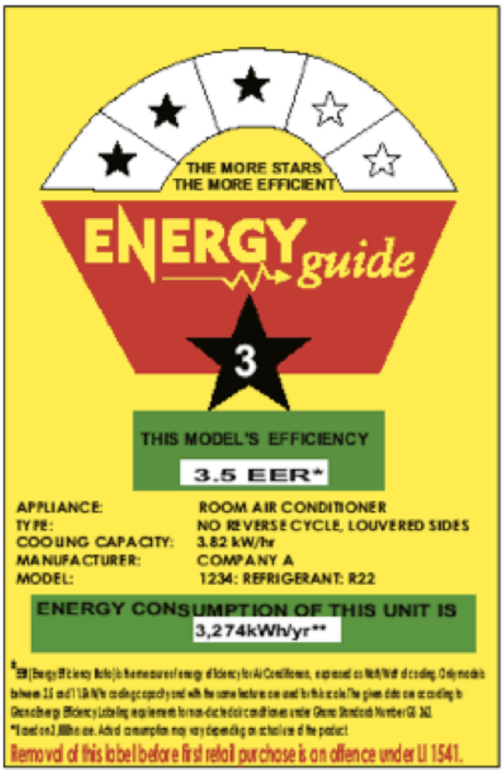


Figure 12. Energy Efficiency Label adopted for AC appliances in Ghana (Ghana Government, 2005)

Table 12. Energy efficiency specification for Energy Conservation Label in Ghana

Energy efficiency class	Required energy efficiency (EER)
5 star	4.00 < EER
4 star	4.00 ≥ EER > 3.75
3 star	3.75 ≥ EER > 3.45
2 star	3.45 ≥ EER > 3.15
1 star	3.15 ≥ EER ≥ 2.80

(Ghana Government, 2005)

5.4. India

With an extensive area and great population, India is a major energy consumer, which energy demand is increasing rapidly and imposing governmental measures to promote energy efficiency and reduce energy losses. In this direction, the Indian Government issued the Energy Conservation Act in 2001, to be implemented by the Bureau of Energy Efficiency (BEE) as the central coordination agency, in co-operation with other agencies at the state level created for implementation of the Act.

The Energy Conservation Act empowered the Bureau and Central Government to specify Energy Consumption Standards (MEPS), with legal support to interdict manufacture or sale or import of equipments and appliances that do not meet standards, as well as require to display properly the energy performance labels on equipments and appliances. Figure 13 presents the Indian energy efficiency label (Jose, 2011).

To complement the institutional framework to implement the labeling and MEPS program, jointly to BEE, should be mentioned BIS, the National Standards Body, responsible for the formulation and implementation of National Standards, including production and quality system certification, and the laboratories accredited by National Accreditation Board of Laboratories, educational institutions, manufacturers and manufacturing associations and consumer organizations.

To implement the labeling and MEPS program, aiming to reach the energy savings target, BEE developed a detailed plan, starting from the basic aspects until the final evaluation, assuming that a full cycle of actions could take up to 12 years. The main steps of this plan are: 1) Decide whether and how to implement Energy Efficiency Labels and Standards, 2) Develop a testing capability, 3&4) Design and implement a Labeling program and analyze and set Standards, 5) Design and implement a communication campaign, 6) Ensure program integrity and 7) Evaluate the program, in line with the CLASP recommendations (Wiel and McMahon, 2001).

According to a 2004 survey, the Indian air conditioners market was dominated by window units, which represented about 83% of production, with a limited share of split units (McNeil et al., 2005). However, this situation possibly changed, as occurred in other countries, with the increase of split conditioners sales. Another change in the recent years is the rise of residential use of AC systems (Jose, 2011).

The most common capacity of air conditioners in India is 3.5 kW (12,000 Btu/h), which represent more than 78% of sales; with an average efficiency (EER) of 2.6 (W/W) (McNeil et al., 2005). It was estimated by these authors that an increase of efficiency to 2.76 (W/W) implies a 7.2% reduction in energy consumption, reducing annual use from 1191 kWh to 1105 kWh. In this assessment, the authors assumed that the regions in India where AC is common (North) have a six months cooling season. They adopted also that commercial users (assuming these are mostly office buildings) use AC 8 hours a day, 20 days a month, while residential users use AC 4 hours a day, 30 days a month. This gives 960 hours per year for commercial users, and 720 hours for residential.

Finally, they assumed that by 2010, residential sales (and therefore affected stock) would be equal to commercial, so in average it was assumed that a typical AC system in India operates 840 hours per year.

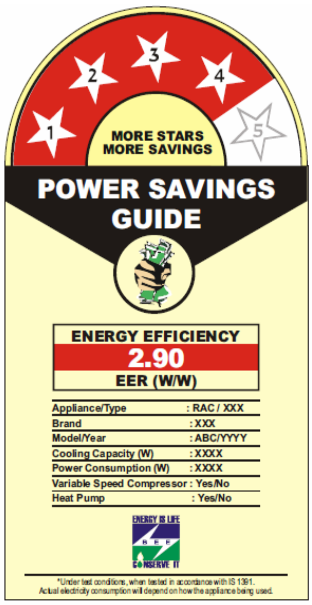


Figure 13. Energy Efficiency Label adopted for AC appliances in India (Jose, 2011)

As an outcome of the labeling program, the participation of more efficient equipment has increased, displacing the less efficient ones, as indicated by Figure 14. Thus, the average value of ERR for 2009-2010 reached 2.72 (W/W), rising about 2% per year after the start of the labeling program (Jose, 2011).

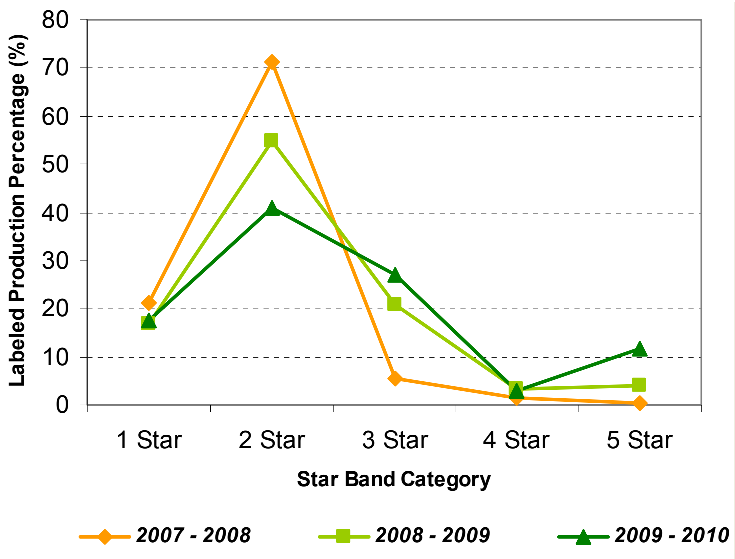
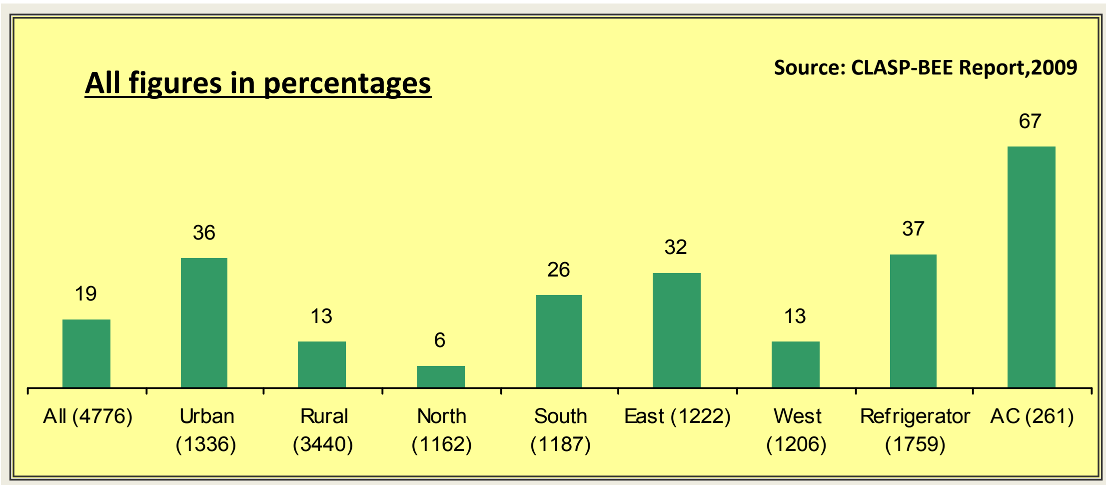


Figure 14. Market evolution for star rated air conditioners in India (Jose, 2011)

An important differential of the Indian labeling and MEPS program with regards to similar programs is the emphasis on educational and awareness aspects. A massive and monitored communication campaign has been promoted, oriented to the different group of consumers, including short courses, mass media advertising and distribution properly designed material: posters for shops, "Promoter Cards" (pocket book for show room salesmen to explain labeling to customers, including estimates of benefits in electricity bill and payback) and "Piggy Leaflets" (with the essential parts of Promoter Cards, to be given for customers) (BEE, 2010). Very possibly, the good results obtained are associated to this concern with interaction with consumers. In Figure 15 the results of a Public Opinion survey are presented, indicating that labeling of air conditioners is the most noticed among other appliances and good efficiency is one of the three most relevant factor to be taken into account when purchasing air conditioners, after long life and appliance price.



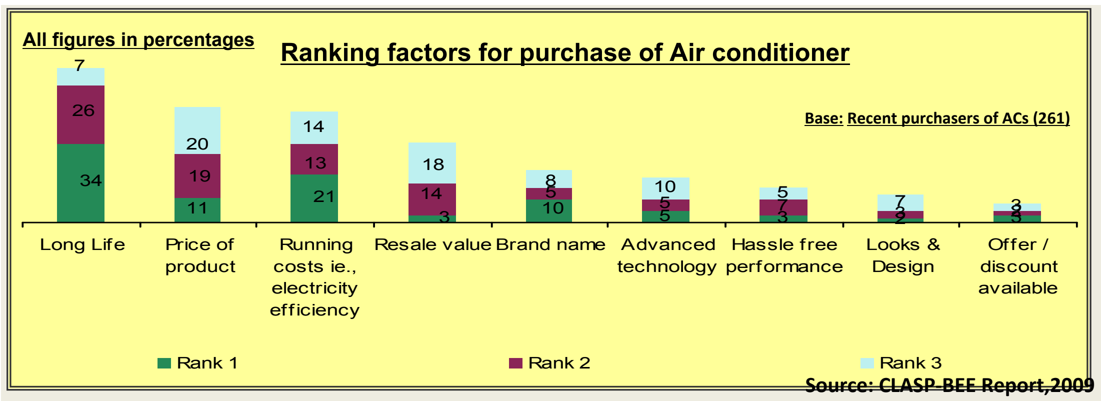


Figure 15. Results (partial) of Public Opinion survey in India (BEE, 2010)

5.5. Mexico

Mexico deserves attention not only because has been developing AC systems labeling and MEPS programs (Sanchez et al., 2007), but particularly because the Mexican institutions have been also implementing relevant programs of incentives for scrapping old air conditioners, possible exactly due to the existence of such labeling and MEPS programs.

As many other developing countries, electricity consumption is expected to grow at fast pace (3.6% annual growth rate) during the 2009-2024 period, to reach in the end of this period a total consumption of 333 TWh, which means a 60% increase compared to 2008 levels (SENER, 2009 apud Praz, 2011). Consumption from the residential and industrial sectors is expected to grow the fastest, but to expand the generation capacity at this rate is challenging. Besides the elevated capital costs, the Mexican electricity market is largely subsidized and costs exceed electric tariffs for all segments except for the commercial and industrial sector. Given the large participation of residential consumption and the low price/cost ratio of this segment, 75% of the total electricity subsidies go to the residential sector.

Although energy efficiency savings have been not systematically considered in the planning process of Mexican electricity infrastructure, energy efficiency is now one of the nine guiding axes of energy policy in Mexico. The National Energy Strategy, published in 2010, set the objective of reducing total energy consumption by an average of 280 TWh over the 2010 -2024 period. This achievement would represent a 1% reduction in the annual total primary energy consumption growth rate. It is expected that 30% will come from the reduction of electricity consumption by final users (SENER, 2010 apud Praz, 2011).

In the Mexican households where air conditioning is used, it accounts for approximately 25% of residential electricity consumption. In 2010 it was estimated that about 20% of Mexican have AC systems but there is an increase in their penetration, thus it can be projected a large expansion in energy consumption associated to this final use, that could represent an incremental consumption in 2030 equal to three times residential electricity use in 2005 (Johnson, Alatorre, Romo, & Liu, 2010 apud Praz, 2011) To address this consumption growth, the Mexican government main strategy is twofold: to update air conditioner MEPS and building codes, and to accelerate the substitution of inefficient air-conditioners. In this direction, in 2006 a revised Mexican standard for energy efficiency evaluation of air conditioners was approved (SENER, 2006).

In recent times, three programs were developed in Mexico to provide financing to residential users that wish to replace an old inefficient air conditioner for a new and more efficient unit. Two programs were closely related:

1. The Program for the Financing of Electric Energy Savings (PFAEE, acronym in Spanish) led by FIDE, which developed the substitution program from 2002 to

2006, replacing 129,889 air conditioners in this period (PFIDE, 2009 apud Praz, 2011). FIDE is the trust fund for the savings of electric energy, created in 1990 by CFE (State owned main public utility) with support of the main Mexican business organizations. FIDE is a private institution, focused in promoting energy efficiency and operating aligned with Mexican government strategies.

2. The Program for Systematic Savings (ASI, acronym in Spanish), managed by FIPATREM. This institution is a trust fund, older than FIDE, pushed by the federal government in the 1990's with the specific objective of providing electricity savings for the residential sector. FIPATERM began financing the thermal insulation installation and in 1997 the substitution of electric appliances such as air conditioners was incorporated as part of the FIPATERM ASI, operating in the states bordering the US (Baja California and Sonora), the tropical states of the Yucatan Peninsula plus Chiapas and Tabasco (Gomez Rodriguez, 2005 apud Praz, 2011).

Because of its origins and long operation time, FIPATERM actions were reported separately from the PFAEE's reports, as indicated in Figure 16, indicating the replacement of 100,268 window air conditioners between 1997 and 2010 (Praz, 2011). The long experience of this program allows to observe two trends; the migration from window air conditioner towards split technology and an increase in cooling capacity of new AC systems versus replaced ones. Considering the weighted average, the replaced equipment capacity was 6.3 kW, while the installed new equipment is 7.3 kW, about 15% more, an important aspect to take into account to predict the results of investments in accelerated substitutions.

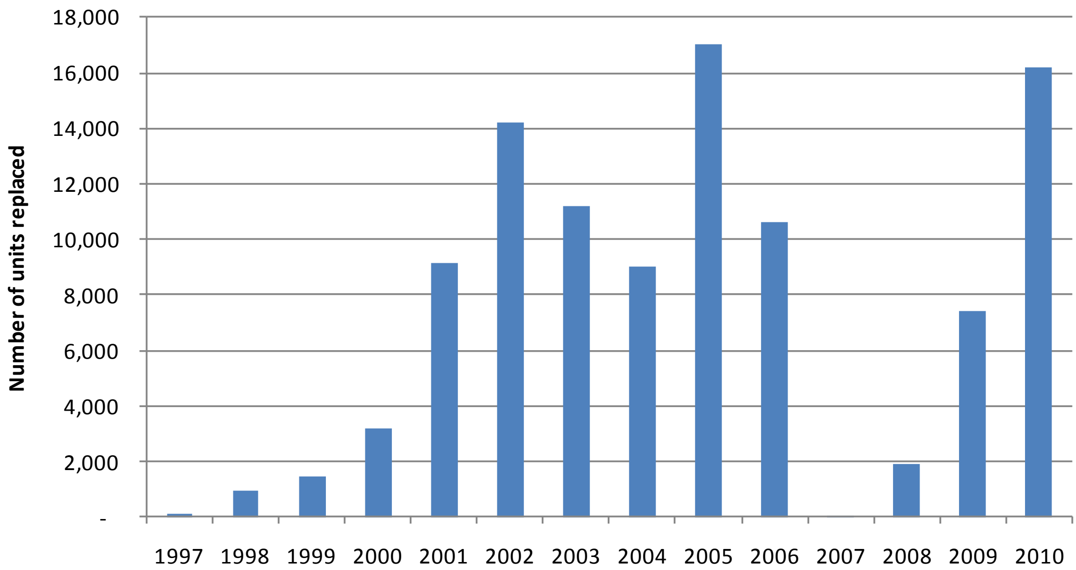


Figure 16. Air conditioners replaced in Baja California through FIPATERM ASI program (FIPATERM, 2010 apud Praz, 2011)

A third and more ample program for air conditioners replacement was implemented more recently. In 2009, in the framework of the Energy Reform Law, the Mexican government (with the support of the World Bank and of KfW) provided funding to be managed by FIDE to promote energy efficiency. Among other initiatives, the Program of Substitution of Electrical Appliances for Energy Efficiency (PNSEE, acronym in Spanish) aimed to replace 1.9 million refrigerators and air conditioners by 2012, covering up to 50% of the acquisition cost of new units (SENER, 2012). Depending on the consumption level, the financial support to consumers can be given as direct subsidy and/or loan over 4 years reimbursed via the electricity bill.

The PNSEE was managed by FIDE with rules and structure similar to those defined for the PFAEE program. Thus, the eligibility criteria for the participation in the air conditioning substitution were:

- be a customer billed by electricity rates that apply to regions with summer minimum average temperatures equal to or greater than 30°C
- have a old air conditioner functioning 10 or more year with a capacity of 0.75 TR (tons of refrigeration) to 5 TR.
- the old air conditioner has to be delivered at the moment of receive the new one.
- the size of the new equipment cannot exceed in more than 1 TR the capacity of the replaced air conditioner.

It was estimated that the PNSEE program promoted an annual substitution of 85,171 air conditioners during the 2009-2012 period, which means a total of 340,648 units replaced (Praz, 2011). Table 13 presents the basic information on these programs.

Table 13. Mexican programs for air conditioners replacement

Program	Institution	Period	Conditioners replaced
Program for the Financing of Electric Energy Savings (PFAEE)	FIDE	2002-2006	129,889
Program for Systematic Savings (ASI)	FIPATREM	1997-2010	100,268
Program of Substitution of Electrical Appliances for Energy Efficiency (PNSEE)	FIDE	2009-2012	85,171

(Praz, 2011)

5.6. Thailand

As a tropical emerging country, with the electricity consumption basically concentrated in the residential and commercial sectors (46% of total consumption in 2010), the impact of air conditioning loads is relevant in Thailand. According to Sangsawang (2010), air conditioning represents 46% of residential consumption of electricity. Asawutmangkul (2011) presents different values: in households 19% and in commercial buildings 50-65% of electricity is consumed for cooling.

Aiming to promote energy efficiency and the rational energy development in this country, the Government of Thailand approved in 1992 the Energy Conservation Promotion Act (ECP), reinforced with the ECP Act B.E. 2550, issued in 2007 and effective since June 2008. Under this legislation, was implemented an institutional framework, under Ministry of Energy guidance, with the Electricity Generating Authority of Thailand (EGAT) taking care of efficiency labeling and promotion of electric appliances, and the Department of Alternative Energy Development and Efficiency (DEDE) in charge of similar activities for non-electric equipment, plus the development of testing laboratories network. EGAT and DEDE act in co-operation with the Thai Industrial Standards Institute (TISI), an agency of Ministry of Industry, responsible for setting the minimum energy performance standards (MEPS) in Thailand (Asawutmangkul, 2011).

The efficiency labeling and MEPS scheme adopted in Thailand is similar to the schemes observed in other countries. The minimum energy performance standards are prepared by DEDE, but they are regulated by TISI, while for labeling the standards are prepared by DEDE, and the labeling programs implemented by DEDE (non-electric appliances) and EGAT (electric appliances). The most efficient appliances can receive an endorsement label, attributed on voluntary basis and according to HEPS (High Energy Performance Standard), defined in collaboration between DEDE and EGAT. Figure 17 shows the efficiency label and Figure 18 presents the basic procedure for MEPS (compulsory) and HEPS (voluntary) concession in Thailand. This graph informs the fraction of products withdrawn from the market and can be used to assess the impact of MEPS adoption in Thailand.

The labeling of air conditioners in Thailand began in 1995 and a regular Monitoring and Verification program has been conducted by EGAT (Phumaraphand, 2012). Table 14 synthetizes the current ERR figures of MEPS and HEPS for air conditioning in Thailand, for equipment with cooling capacity lower than 12 kW (Sangsawang, 2010). This program has been supported by a promotional campaign, with advertising in media, focusing inform consumers and strategic partners (government agencies, producers, etc.) and create a positive attitude with regards to the program, including actions in schools and tax incentives (25% tax break on Corporate Tax on equipment cost in energy efficiency projects) (Sangsawang, 2010).

Figure 17. Energy Efficiency Label in Thailand (Asawutmangkul, 2011)

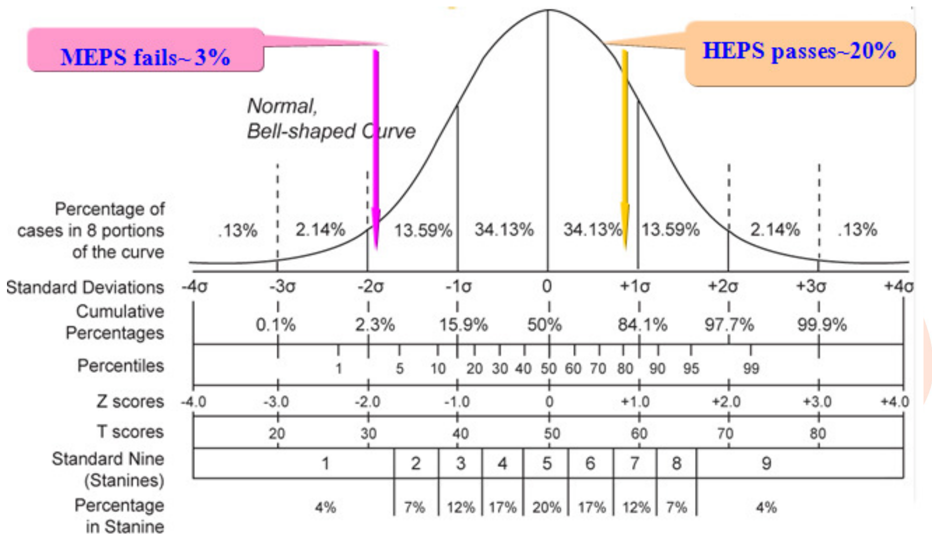


Figure 18. Criteria for MEPS and Energy Efficiency Label and HEPS Endorsement Label (Asawutmangkul, 2011)

Table 14. Energy efficiency limits for window and split air conditioners in Thailand

Cooling capacity - CC	minimum EER (W/W)	
	MEPS	HEPS
CC ≤ 8 kW	2.82	3.22
8 < CC ≤ 12 kW	2.53	3.22

(Sangsawang, 2010)

5.7. Tunisia

Tunisia government has been developing energy efficiency programs motivated by the economic growth and increasing energy demand, which have overloaded the Tunisia's electricity grid in recent years. In fact, due to limited natural resources, energy imports are increasing since 2000. The climate is mostly hot and arid, and in the North also warm-temperate, imposing frequent use of air conditioning. In this context, the energy efficiency programs have focused on buildings in the residential and tertiary sectors because currently they are jointly one of the most relevant energy consumers, forecasted to be the greatest consumer sector in 2020 (World Bank, 2012, apud bigEE, 2013).

The Ministry of Industry and Energy (Ministère de l'Industrie, de l'Energie et des Petites et Moyennes Entreprises, TMIE) is responsible for the national energy policy in Tunisia, particularly through its Directorate General for Energy. Founded in 1985, the Tunisian National Agency for Energy Management (Agence Nationale pour la Maîtrise del' Énergie, ANME) is in charge of implement the energy efficiency policy. Another institution active in energy efficiency in Tunisia is the Tunis International Centre for Environmental Technologies (Centre International des Technologies de l'Environnement de Tunis, CITET), which promotes the adoption of environmental technologies in the country.

Developed under the concepts indicated in Figure 19, the main action of the Tunisian government on energy efficiency is a mandatory minimum energy efficiency standards (MEPS) and energy labeling program for new buildings and extensions to existing buildings. Minimum energy performance standards for buildings are especially important in countries like Tunisia, where the construction activity is very high. For new buildings in the public sector, thermal insulation is obligatory since April 2005 and according to the Law 2004-72 (revised 2009-7) new buildings and extensions to existing buildings should follow statutory requirements for temperature and energy in buildings and develop compulsory energy audits of plans for major construction projects (ANME, 2010).

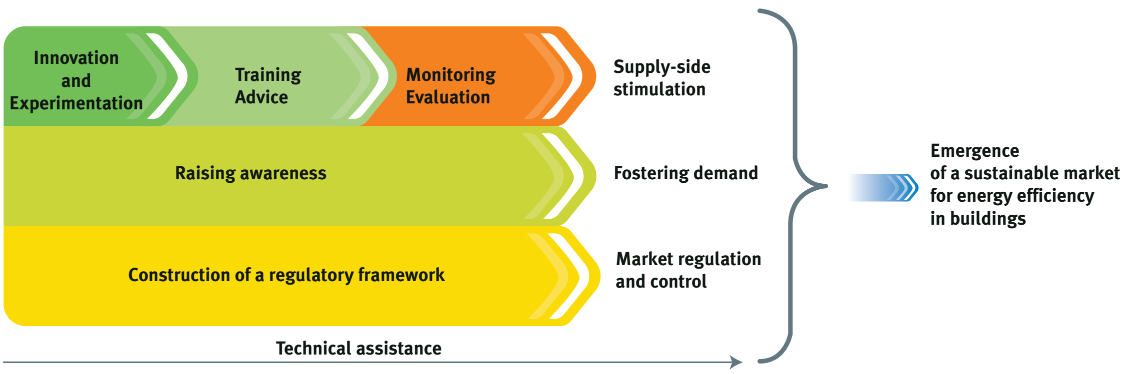


Figure 19. Tunisian building energy efficiency policy (ANME, 2010)

Temperature requirements in buildings depend on the location of the building. Thus, ANME sub-divided Tunisia in three zones, in order to facilitate the proper design of heating and air-conditioning equipment as well as temperature optimization in buildings. The thermal insulation regulation is combined with PROMO-ISOL, a promotional program for insulation, and PROSOL, a program for solar water heaters (RCREEE 2010, apud bigEE, 2013).

With support from PNUD and Agence Française de Développement (AFD), an ample project on efficient buildings was developed. Based on 43 successful demonstration projects, involving the residential houses (affordable and luxury) and tertiary sector buildings (schools, hospitals), ANME develop seven guides oriented to professionals directly involved with building design and construction, and focusing at low-cost interventions that would add less than 10% to the cost of the building. These interventions are basically focused on six points (ANME, 2010): architectural design, wall and roof insulation, choice of materials, use of high-quality glazing in terms of optical and thermal performance, use of renewables and use of energy-efficient lighting in buildings.

A label indicating comfort and energy performance of buildings was implemented; its main elements are depicted in Figure 20, establishing: a) a minimum performance requirement, b) four efficiency classes above this level depending on the consumption reduction with regards to the minimum requirement (the best class was assumed as consuming less than 60% of the minimum performance level) and c) three classes presenting performance bellow the required one (the worst case for buildings consuming more than 50% above the minimum performance level). Such classification is interesting to add (or reduce) the market value of buildings in this country according to their energy efficiency.

This labeling program has two relevant groups of supporting activities (FEEM et al. 2010; Saheb 2012, apud bigEE, 2013):

- a broad set of capacity building activities, such as training courses in construction techniques, methodologies and software for temperature simulations; e-learning program set up to orient architects in the design of energy efficient buildings; tools to aid the design of low energy buildings made available to construction professionals, technical guides covering buildings for different purposes (housing with or without equipment, hotels, hospitals, shops, offices and teaching establishments), guides to climate zones and capacities evaluation for heating and air conditioning equipment, and temperature simulation tools;
- an extensive communication program including television, radio and newspaper advertisements, as well as a dedicated web-site for the several types of people and professionals potentially interested (RCREEE, 2010, apud bigEE, 2013).

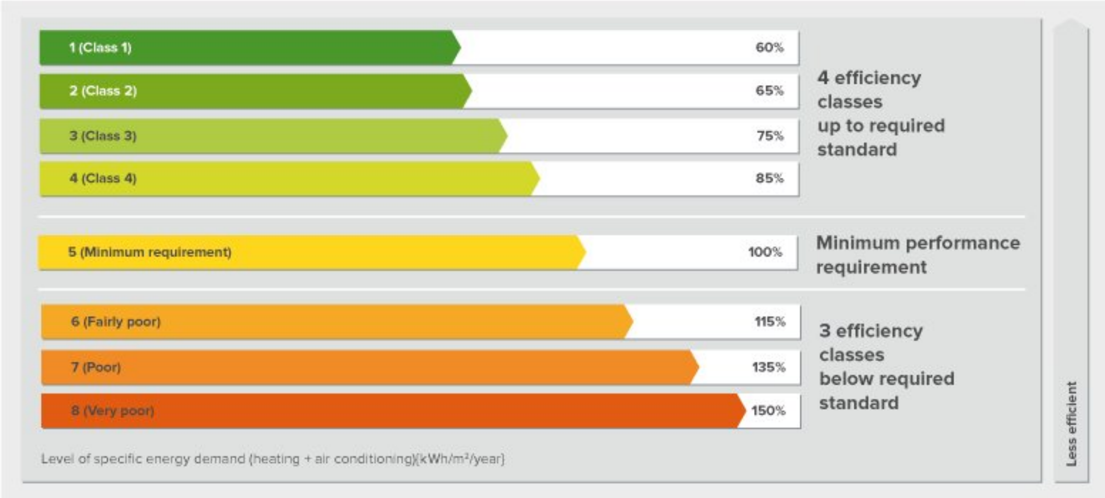


Figure 20. Tunisian building energy efficiency label main elements (FEEM et al. 2010; Saheb 2012, apud bigEE, 2013)

It is worth to mention that the Tunisian initiatives on energy efficiency have been developed within a broad planning framework, the Four-Year Energy Control Plan 2008-2011, with an objective of save 24% in primary energy intensity up to 2016 (Blanc, 2012).

5.8. United States of America

In the United States, a great energy consumer, there is at governmental level enough awareness about the relevance and potential of energy efficiency. Consolidated programs towards the introduction of more efficient equipment and good practices have been developed at federal and state level. Mature programs such as the endorsement label Energy Star, largely adopted to promote efficient products and several governmental and non governmental agencies, led by the Department of Energy's Office of Energy Efficiency and Renewable Energy establishes a comprehensive framework to deal with energy efficiency information, involving national laboratories, public utilities, environmental protection agencies and non-profit organizations. There are multiple reliable sources of information at sectorial level or final use level, and a group of qualified laboratories operate under Department of Energy support and guidance. Thus, it is evident that the classic tools to face the challenge of promoting energy efficiency are sufficiently well known in US. However, the high energy consumption and energy intensity, in this country indicate that there is an ample room for promoting energy efficiency in order to reach effective results.

In order to explore different measures for promoting energy efficiency in different contexts, the American case in the current study was chosen considering the economics incentives developed to promote replacement of inefficient air conditioners. This kind of incentive have been developed in the US at federal and state levels and a large diversity of programs were or still are in operation, but following essentially the same rules (Energy Star, 2012).

At federal level, as part of the Energy Policy Act of 2005 and subsequently amended and extended several times, the US government launched the Federal Tax Credits for Consumer Energy Efficiency oriented to finance energy efficiency improvements, including the installation of highly efficient AC systems. In line with this program, the Tax Incentives Assistance Project (TIAP), sponsored by a coalition of public interest nonprofit groups, government agencies, and other organizations in the energy efficiency field (such as Alliance to Save Energy, American Council for an Energy-Efficient Economy, California Energy Commission, Vermont Energy Investment Corporation, Energy Foundation, DoE, EPA, among other), was created in 2005, aiming to give consumers and businesses information they need to access the federal income tax incentives for energy efficient products and technologies (TIAP, 2012).

In the last amendment, this program was set to operate until the end of 2013, under the framework of the American Recovery and Reinvestment Act. This program finance homeowners who want to install energy efficient equipment in their existing homes, under the following rules with regards to AC systems (for the 2012&2013 period) (Energy Star, 2013):

- equipment to be used should be awarded with the Energy Star label.
- credit rate of 10% of cost up to $300 or a specific amount from $50–$300, to be applied diverse improvements such as adding insulation, install energy efficient exterior windows and energy-efficient heating and air conditioning systems.
- must be an existing home and the principal residence of taxpayer (new construction and rentals do not qualify).

The table below presents the energy performance requirement for an air conditioning equipment to be qualified as Energy Star one and access the Federal Tax Credits for Consumer Energy Efficiency.

Table 15. Energy efficiency limits for air conditioners eligibility to the Federal Tax Credits for Consumer Energy Efficiency in the US

AC system	**Efficiency Requirements** (W/W)
Split system central air conditioners	SEER > 4.69 and EER > 3.81
Packaged central air conditioners	SEER > 4.10 and EER > 3.52

(Energy Star, 2013)

6. Energy impact of the selected cases of governmental measures to foster efficiency in AC systems

In order to explore the actual scenario of governmental programs and activities for promoting efficiency in new air conditioning systems, which include stimulating the introduction of more efficient air conditioners in new applications and refurbishment of older units, as well as the adoption of more rational practices in operation and maintenance, five national cases were selected to be assessed in relation to the impact expected in the national energy consumption: Brazil, China, Ghana, India and Thailand, countries which adopted MEPS and for wich data are available for this assessment. For other countries studied in this report, the available information on the energy impact is presented in the end of this chapter.

In this chapter initially are presented general data and the basic assumptions adopted, followed by the results estimated for 2010 sales and accumulated for the period 2010-2022, assuming 12 years of average useful life for air conditioners.

6.1. General data and assumptions

For the five countries for which the energy impact was estimated, according to the information presented in the previous chapter and based essentially in the same references, Table 16 presents a synthesis of main national data of interest for this study: population, stock and sales of AC systems in 2010, average (population weighed) national cooling degree-days (BizEE, 2013) and estimated operating time of AC systems. This last parameter was assessed from the national cooling-degree days value, lineally adjusted with base on annual cooling degree-days observed in Manaus (Brazil), 1,558 °C.day (evaluated for a reference temperature of 23°C) and corresponding to a measured operating time of 1,700 hours, as indicated in Figure A.1 in Annex A, where is presented the methodology adopted.

Table 16. Population, AC systems market data (2010) and operating conditions for AC systems in selected countries

Country	Population	AC systems		Cooling degree days	Annual operating time
		Stock	Sales		
	(million)	(thousand)	(thousand)	(°C.day)	(h)
Brazil	195	15,000	1,600	2,015	2,199
China	1,339	100,425	35,000	1,046	1,141
Ghana	24	1,800	100	2,949	3,218
India	1,173	87,975	2,800	3,120	3,404
Thailand	67	5,025	419	3,567	3,892

Another essential set of values to estimate the energy impact of MEPS refers to the energy performance, indicated by the EER. In Table 17 and Figure 21 are shown the relevant values of this parameter: average EER of removed models, EER established by the minimum energy performance standard (MEPS) and the EER of the most efficient models of air conditioner, defined as the minimum EER for the highest efficiency label class. Almost all these values were presented and referred in the previous chapter. Their variation indicates primarily the level of importance attributed to the rational use of energy and the negotiation achievements of the government energy efficiency agencies with manufacturers and suppliers of this equipment in each country. The MEPS value and most efficient EER for India and the EER of AC models removed after MEPS adoption for Thailand were not informed and thus these parameters were assumed as the average values adopted for other countries.

Table 17. Energy efficiency ratio (EER) of AC systems for models removed after MEPS adoption, MEPS and minimum ERR for the more efficient class

Country	Average EER of removed models	EER for MEPS	Minimum EER for the more efficient class
Brazil	2,08	2,40	3,02
China	2,30	2,90	3,20
Ghana	2,50	2,80	4,00
India	2,30	2,70	3,50
Thailand	2,30	2,82	3,22

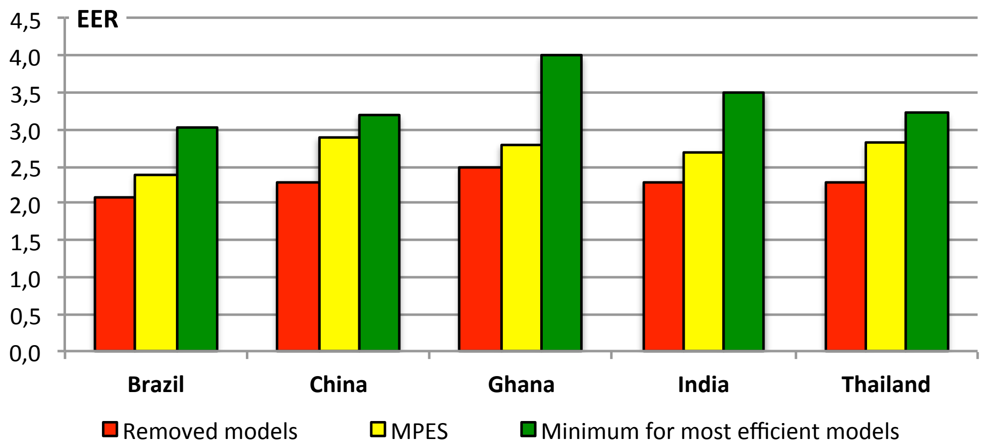


Figure 21. Energy efficiency ratios (EER) utilized as reference for estimating energy impact of MEPS

Additional assumptions were: a) average loading at 70% of the nominal capacity, as suggested in studies conducted in Brazil, b) average capacity of 3.5 kW, the average nominal capacity in India, China and Brazil, assumed as the representative AC unit, and c) an outside temperature of 35°C, in line with the value adopted in standard performance tests. Considering these assumptions and applying the operating time indicated in Table 16 and the EER values presented in Table 17 in Equation (A.7, Annex A), it is straightforwardly estimated the unitary annual consumption of air conditioners for each EER case, as indicated in Table 18.

Table 18. Annual unitary energy consumption of air conditioners for selected countries, (kWh/year)

Country	Removed models	MEPS models	Models at inferior limit of more efficient class
Brazil	2071,8	1795,6	1426,9
China	972,6	771,4	699,1
Ghana	2522,7	2252,4	1576,7
India	2901,1	2471,3	1906,4
Thailand	3316,8	2705,2	2369,1

From these results and considering the MEPS adoption, is possible to establish two scenarios for the market change:

a) low impact scenario: the removed models (not allowed to be commercialized) was replaced by models presenting EER at MEPS level, a minimum value, and

b) high impact scenario: the removed models was replaced by models with an EER corresponding to the minimum efficiency required for the highest class of efficiency.

In Table 19 and Figure 22 are presented the unitary annual energy saving for both scenarios, indicating the relevant impact of adopting more efficient air conditioners than MEPS models, except for China, where the difference of performance among the label classes is not so expressive. These values depends on not only the efficiency of air conditioners, shown in Table 17, but also the annual load in each country, indicated by the annual operating time, presented in Table 16. Possibly, in the actual context, inefficient models with be replaced by a mix of models presenting approximately the same efficiency distribution observed in the stock excluding the removed models, and so, these scenarios represent upper and lower limits for the impact of MEPS adoption.

Table 19. Unitary energy saving for selected countries, (kWh/year)

Country	Removed models are replaced by: MEPS models (low impact scenario)	Removed models are replaced by: Models at inferior limit of more efficient class (high impact scenario)
Brazil	276	645
China	201	274
Ghana	270	946
India	430	995
Thailand	612	948

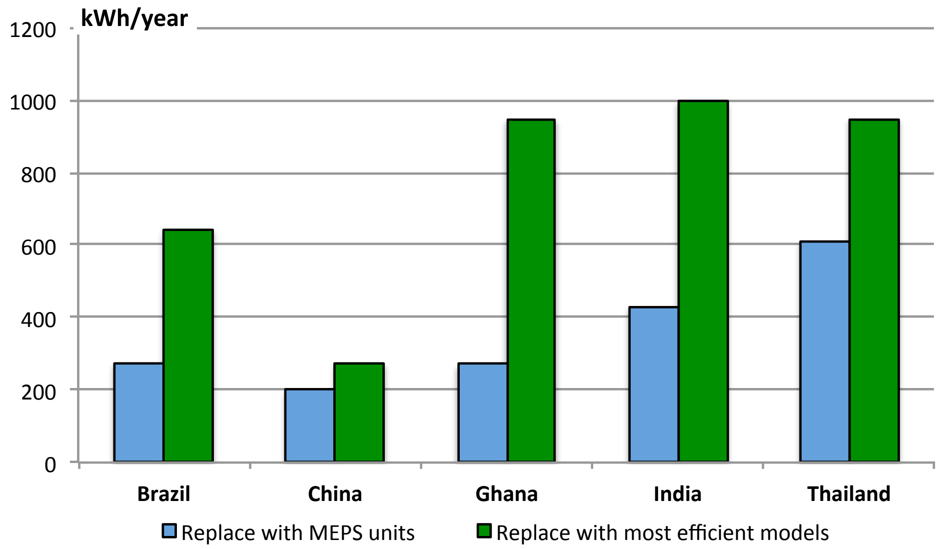


Figure 22. Unitary energy saving for selected countries

6.2. Energy savings and avoided capacity

To estimate the energy impacts promoted by MEPS, in a context of limited sales data or surveys with actual information about the market changes motivated by this measure in each country, as observed in the selected countries, is necessary to assume the share of sales affected by MEPS adoption. Considering the Chinese and Indian cases commented in this report, the fraction of air conditioners sales impacted by the MEPS is assumed to be 30%.

Thus, taking into account the values of unitary annual energy consumption estimated above and the estimates of annual sales of air conditioners, indicated in Table 15, and applying the Equation (A.8, Annex A), is possible to estimate the annual energy impact, as indicated in Table 20, with values for 2010 for the scenarios considered. For both scenarios it was assumed that the effects of MEPS started in the year following the issue of legislation. From these estimates of energy savings, and assuming a load coincidence (or simultaneity) factor of 70% (Cardoso et al., 2012), it was calculated the avoided capacity due to the introduction of more efficient air conditioners.

Table 20. Impacts of MEPS in the air conditioners market, estimate for 2010

Country	Stock annual energy saving (MWh/year)		Capacity saved (MW)	
	low impact scenario	high impact scenario	low impact scenario	high impact scenario
Brazil	26,519	61,907	8.4	19.7
China	281,723	382,968	172.8	234.9
Ghana	2,703	9,46	0.6	2.1
India	72,205	167,104	14.8	34.4
Thailand	15,366	23,810	2.8	4.3

Considering that air conditioners useful life is about 12 years (CLASP, 2012), it is interesting to project the accumulated impact of the introduction of more efficient appliances, which means to estimate for a given future year the effect of the more efficient equipment sold during this year, as well as the effect of more efficient equipment marketed in the previous years. In this context, is necessary to forecast the evolution of air conditioners stock and the growth rate of sales, which depends on several factors, such as income level, financing conditions, equipment penetration and relative price of conditioners, etc.

In emerging countries there is a large room for expanding the stock of air conditioners. According to estimates based on housing surveys (ENERDATA, 2013), between 2000 and 2010, when Brazil and Ghana increased annually about 7% while in China and Thailand this stock expanded around 18% per year. Thus, in line with the two scenarios previously adopted for conditioner replacement, to estimate the accumulated energy impact in the period 2010-2012 of adopting MEPS, two values for the sales annual growth rate were adopted: 7% for the low impact scenario, and 18% for the high impact scenario, corresponding to an evolution of conditioners stock of 225% to 730% for the 12 years period. It should be observed that in the studied countries the current penetration of air conditioning appliances is still relatively low and the number of households does not limit the stock of air conditioners, since in many situations there are more than one conditioner per dwelling.

Under these hypotheses and adopting the same scenarios used for the annual impact evaluation, Table 21 presents the results of annual energy savings and avoided capacity for the selected countries in 2022. The efficiency degradation during the economic life of air conditioners was not considered, since it is relatively low (Cardoso et al., 2012).

Table 21. Impacts of MEPS in the air conditioners market, projection for 2022

Country	**Stock annual energy saving** (TWh/year)		**Capacity saved** (MW)	
	low impact scenario	**high impact scenario**	**low impact scenario**	**high impact scenario**
Brazil	717	5.414	228	1.724
China	7.613	33.493	4.669	20.542
Ghana	73	827	16	180
India	1.951	14.614	401	3.005
Thailand	415	2.082	75	375

These values should be taken as reference limits of the potential impact of introducing more efficient air conditioners that last for several years. To evaluate the significance of the estimated energy impacts of more efficient equipment is worth to use relative values: a) per capita, b) related to the residential electricity consumption, and c) per unit of air conditioner. Table 22 shows these values, considering the results presented in the previous paragraphs for the estimated savings in the end of the period 2010-1022, for both scenarios.

Table 22. Indices for impacts from adopting efficient air conditioners, relating savings estimated for 2022 with population and residential consumption in 2010

Country	**Population (2010)**		**Residential electricity consumption (2010)**	
	kWh saved/capita		%	
	low impact scenario	**high impact scenario**	**low impact scenario**	**high impact scenario**
Brazil	3.58	27.07	0.7%	4,9%
China	5.69	25.01	1.3%	5,8%
Ghana	3.04	34.47	2.0%	23,1%
India	1.66	12.46	1.3%	9,5%
Thailand	6.20	31.08	1.9%	9,5%

Since the studied countries are diverse in development and climate, as well as present different penetration and level of importance of AC systems loads, the indices presented in this table must be taken with care, but anyway their differences and similarities give an interesting perspective about the relative importance of the MEPS in AC systems. In the same context, the index of energy saving projection to 2022 compared with residential consumption observed in 2010 was calculated in order to give a reference of the magnitude of this economy with regards the energy consumption in this sector.

Concluding, as follows the results available in the literature for the other countries commented in this report are presented, considering other kind of efficiency programs besides MEPS. The Mexican program of incentives for scrapping old air conditioners was detailed studied by Praz (2011), who estimated that together, the FIPATERM and FIDE PFAEE 2002-2006 programs achieved a saving of 2,371 GWh, while the estimated results from the PNSEE program are 4,710 GWh. This is equal to average annual savings of 482 GWh or 0.45% of annual residential electricity consumption in 2008.

For the Tunisian program, establishing minimum energy performance standards for buildings, relatively limited information about results was found, however, the successful demonstration projects, already commented, presented savings from 10% to 40%, at low cost (ANME, 2010).

The US program, Federal Tax Credits for Consumer Energy Efficiency, oriented to finance energy efficiency improvements, has been systematically assessed and its energy impact has been evaluated (Meyers et al., 2008), however the specific impact of efficient AC systems introduction was not found in the available literature, that indicates between 4% to 8% energy reductions resulting from standards in the commercial and residential sectors.

7. Final remarks and recommendations

The use of air conditioning has been expanding strongly in many developing countries and this load is becoming the highest in the residential sector, mainly in tropical countries. In this context the adoption of measures to improve the energy efficiency, fostering the commercialization of more efficient equipment and its rational application in this end use, is very relevant and has been successfully implemented in several countries. As indicated in this study, discussing and exploring the outcome of these measures in eight countries, the results are relevant.

The most adopted measures to promote energy efficiency in AC systems are the labeling of models accordingly their energy performance and the definition of minimum energy performance standards (MEPS), both depending on performance certification standards. This energy performance certification is also an important element for other measures, such as financial or fiscal incentives to buy (or replace old units) efficient air conditioners, energy efficient building codes that depend on the adoption of efficient and certified equipment.

The results of the present study, as well as the difficulties faced in its execution regarding data availability, confirmed the importance of developing regular evaluation of energy efficiency and impacts of energy efficiency programs, offering consistent assessment of the evolution of national stock of appliances and allowing benchmarking. In this direction, it is also necessary and opportune: a) reinforce the information and database on AC systems (number and characteristics of units, operation conditions, consumer behavior, etc.), b) promote the improvement and harmonization of AC energy efficiency certification and standards (eg. introduction of SEER) and c) promote the integrated approach of AC systems and building energy efficiency programs.

It is observed a large variation of energy consumption for air conditioning in similar conditions, due to differences in the equipment efficiency and operational procedures, indicating opportunities for improvement. In the arsenal of measures is worth to observe that there are some innovative options, still limitedly implemented and deserving more attention of energy authorities, such as voluntary agreement among producers (setting common targets of performance), mandatory maintenance/auditing of AC systems and proper indoor temperature setting.

Regarding this last type of measure, Figure 23 presents the variation of cooling degree-days (CDD) in Manaus (Brazil) as function of reference temperature, exemplifying the effect of selecting different temperatures in the operating time of AC systems. In this case, considering a setting point at 23°C, an usual value, the increase or decrease of one degree centigrade respectively reduces 23% or increase 22% the operating time of an AC system, thus affecting directly the energy consumption.

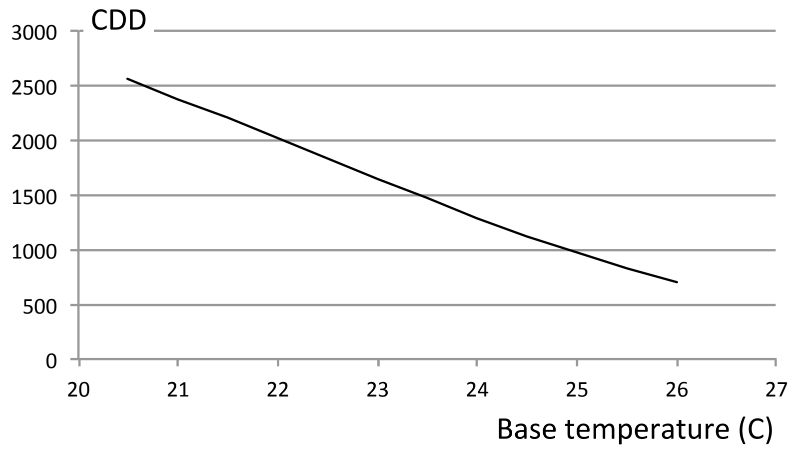


Figure 23. Energy efficiency ratios (EER) utilized as reference for estimating energy impact of MEPS

With the aim of increase the energy efficiency in air conditioning the technological aspects are usually highlighted, but as observed in many parts of this document, the behavior and consumer habits are also very relevant. In this direction the Indian and Tunisian programs offer good examples of public campaigns looking for to increment the awareness on correct use of AC systems, and surveys evaluating and monitoring the results of these campaigns. Adopting modern social media and computational resources, innovative programs have been put in place, such as sharing information about a household's electricity consumption compared to its neighbors (Davis, 2011) and employing electricity bills as media for diffusing rational practices in appliances use (Dromacque, 2013).

Finally, it is fundamental to stress that, for promoting energy efficiency in AC systems and in all other systems, energy prices should represent actual costs. Subsidies and tariffs distortions give wrong economic signal and create relevant barriers for the rationality in energy use.

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Annex A

Methodology for assessing the energy impact of efficient AC systems

Taking into account the aim of the current study, following is presented a general methodology to evaluate the energy impact of efficiency improving measures, associated to market changes (equipment and habits of use), and a more specific model for air conditioning systems. This model will used to estimate the energy saving that can be expected from the measures to promote efficient air conditioning equipment and, considering energy tariffs and equipment costs, to assess the feasibility of each measure. More details are available in the literature (Cardoso et al., 2012 and Cardoso et al., 2009).

A.1. General model

The energy impacts are estimated comparing two situations, baseline and the situation after the adoption of more efficient equipment or changes in operation. Thus, essentially the variables to be considered are:

a) unitary energy consumption of the equipment (nominal and real performance, efficiency degradation);

b) stock of equipment (marketed products, in operation); and

c) actual operational conditions (time of operation, load, temperature, etc.).

The basic equations to express the relationship among these variables in order to obtain the energy impact of each scenario, from the more general context towards the expression of one appliance consumption, are presented as follows:

a) Energy saving: for a chosen period of time, the energy economized is the difference between the consumption in baseline conditions and the consumption after the adoption of the most efficient equipment or use:

$$EE = CEE_B - CEE_E \qquad (A.1)$$

where:

EE - annual energy saving (GWh).

CEE_B - energy consumption of the stock of equipment in the base line (GWh).

CEE_E - energy consumption of the actual stock, with efficient equipment (GWh).

b) Energy Consumption of the stock of equipment: for both hypotheses of composition of the stock of equipment, in a certain year, the energy consumption is the sum of the estimated partial consumptions for the several regions, sectors and efficiency classes in the evaluated context. Of course, the disaggregation adopted depends on the homogeneity criteria and data availability. Those partial consumptions are estimated by the product between the number of equipment and the consumption of representative equipment, which can be choose or defined according the real market data available:

$$CEE_K = \sum_{regiões} \sum_{setor} \sum_{classes} CEP_K \quad (A.2)$$

$$CEP_K = CM_{jK}.P_j \quad (A.3)$$

where:

CEP_K - Annual energy consumption of the stock of equipment in the condition K (GWh).

CM_{jK} - Average unitary consumption annual of the equipment of the region/sector/efficiency class for the year j (kWh).

P_j - Stock of equipment in the region/sector/class in the year j (million of units).

K - Refers to the scenario of composition of the stock of equipment (base line or considering equipment or use more efficient).

c) Stock of equipment: the amount of equipment in a given region/sector/class in a certain year can be estimated by the sum of the sales during a time equal to the useful life and the equipment discard after reaching their useful life:

$$P_j = \sum_{i=j-VU}^{j} V_i - S_j \quad (A.4)$$

where:

P – Stock of equipment (millions of units).

V – Annual sales of equipment (millions of units/year).

S – Discarded equipment (millions of units) (can be used a discarding function of time) i – Index related to the age of the equipment (year).

j – Index related to the year of analysis (year).

VU – Useful life of the equipment (year)

d) Average unitary consumption: taking into account the region/sector operation conditions, the average annual consumption of a representative equipment in a certain year can be given weighing the unitary consumptions of the models marketed in function of their sales during the a period of time considering the equipment useful lifetime. The stock of equipment presents several models, with the same and different ages.

In order to simplify this estimative, two successive pondering equations can be used, initially considering the models sold in the same year, and afterwards among the consumptions in several years. It should be observed that such considerations admit that the use patterns, under the homogeneity hypothesis, are preserved among the different models.

$$CM_{jK} = \frac{\sum_{i=j-VU}^{j} C_{iK} . V_i}{\sum_{i=j-VU}^{j} V_i} \qquad (A.5)$$

$$C_K = \frac{\sum_{i=modelos} CP_{iK} . V_i}{\sum_{i=modelos} V_i} \qquad (A.6)$$

where:

C – Annual consumption of an equipment representative of the stock of equipment, new and used, for a given region/sector/efficiency class, in the year j (kWh).

CP – Annual consumption of a model, in the standard conditions, for a given region/sector/efficiency class, in the year j (kWh).

A.2. Model for air conditioning systems

Simplifying the general approach, taking into account the actual use conditions of air conditioners, the expression bellow can be adopted to estimate the annual energy consumption of these appliances, allowing to consider the use under ambient (outside) temperatures different from the value adopted in standard performance tests (35°C, dry bulb) (Cardoso et al., 2012).

$$C = \frac{L\ P\ t_{oper}}{EER}\left(\frac{T_{ext} - 10}{25}\right) \qquad (A.7)$$

where:

C - Annual energy consumption of an air conditioner (kWh)

L - Average load factor, level of use of nominal capacity (-)

P - Nominal capacity of the equipment (kW)

t_{oper} - Annual time of operation (hours)

T_{ext} - Ambient (outside) temperature (°C)

EER - Energy Efficiency Ratio (W/W), defined in Equation (1)

This expression can be adapted to include in-door temperature selection and other effects. The time of operation can be estimated using climatic station data, such as degree-days or from surveys in real operating equipment. In Figure A.1 is presented the accumulated frequency of ambient temperature in Manaus, a city in the Northern Brazil, and an estimate of average external temperature while AC systems are operating (30,4°C in this example), assuming that they operate in the higher temperatures and given the operating time (1.700 hours in this example) (Cardoso et al., 2012).

The annual energy saving resulting from changes in air conditioners performance, induced by MEPS and considering the market modification due to the introduction of better models can be estimated comparing the consumption before (baseline) and after the adoption of minimum performance requirement in the portion of sales affected by that measure. Depending on the useful life and kind of appliance, cumulative effects can be estimated and degradation effects of efficiency parameters should be taken into account.

$$E_{saved} = f_{changed}\ S\ (C_{before} - C_{after}) \qquad (A.8)$$

where:

E_{saved} - Annual energy savings in the stock of air conditioners (kWh)

S - Annual sales of air conditioners (units)

C - unitary annual consumption, defined in Equation (A.7) (kWh)

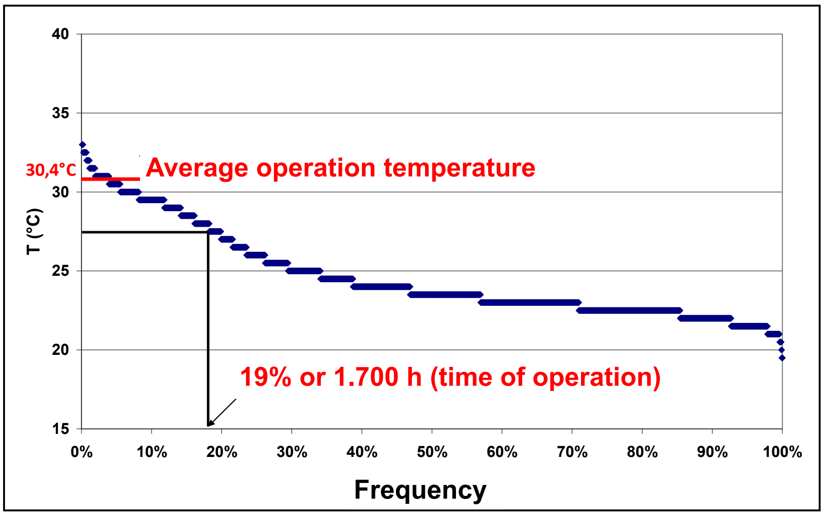

Figure A.1. Outside temperature in Manaus (Brazil)) and average temperature for a given operation time (Cardoso et al., 2013)

Closing this presentation on a methodology for assessing the energy impact of measures for promoting efficiency in AC systems, some comments should be addressed on the comparability of data and results. In fact, there are relevant differences among the procedures and standards that can be used for evaluating the energy efficiency in air conditioners, in some cases considering the part load operation and the seasonal effects, thus resulting values remarkably different for EER and SEER (seasonal effects included) in each case. As a good example, an efficient split air conditioner produced in China was tested according to four compliance standards, presenting results significantly different, as indicated in Table A.1.

Table A.1. Efficiency index results for the same equipment according to different measurement standards (Michel et al., 2011)

Compliance test standard	**Cooling efficiency** (in W/W)	
GB/T7725 (China, current since 2004)	6.21	SEER
EN 14511 (Europe, current in 2007)	4.90	EER
FprEN 14511/prEN 14825 (European, draft in 2010)	8.56	SEER
ARI 210/240 (USA, current since 2008)	7.86	SEER

Brazil

Context

With the creation of PROCEL, the National Program for Electricity Conservation in 1985, the Brazilian Labeling Program was launched, jointly managed by PROCEL and INMETRO, the National Institute of Metrology, Standardization and Industrial Quality. This program has the objective of informing consumers about the efficiency of appliances and energy systems, by using the Energy Conservation National Label, a comparison label, which since 1988 is applied in voluntary basis in air conditioners. Afterwards, PROCEL created an endorsement label, the PROCEL label, which reinforce the better equipment, presenting the higher performance class (A).

Brazil has a park of about 15 million air conditioners, growing rapidly due to annual sales of 1.6 million units (estimates for 2010).

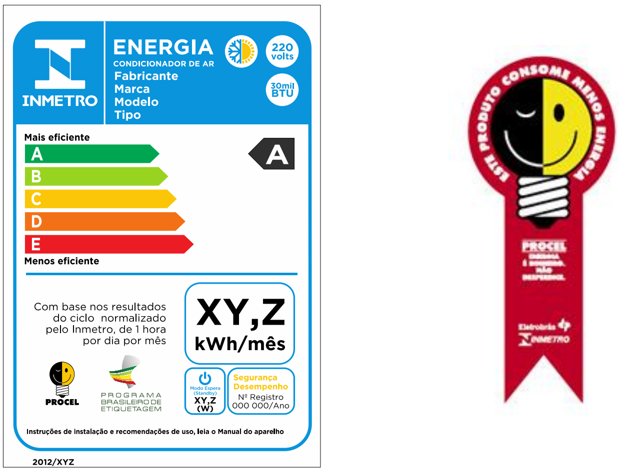

Figure 1. Energy Conservation National Label and PROCEL Label used for air conditioners in Brazil (PROCEL and INMETRO)

Objective

Foster the commercialization of more efficient equipment and inform consumers about the efficiency of appliances and energy systems, by using the Energy Conservation National Label, a comparison label, which since 1988 is applied in voluntary basis in air conditioners. Afterwards, PROCEL created an endorsement label, the PROCEL label, which highlights the better equipment, indicating models of the higher performance class (A).

Programme description

Management

PROCEL, the National Program for Electricity Conservation and INMETRO, the National Institute of Metrology, Standardization and Industrial Quality.

Sponsor

Brazilian Federal Government

Mode of intervention

The PROCEL Label was applied to window conditioners (less than 6 kW) in 1999 and in split conditioners (less than 11 kW) in 2004. More recently, based on Law 10.295/2001, the Brazilian Law of Energy Efficiency, and according to a decision of Managing Committee for Energy Performance Standards, in charge of the Ministry of Mines and Energy, it was established in 2007 minimum values of EER (energy efficiency ratio) mandatory for all air conditioners, window and split (up to 11 kW) types, sold in Brazil, after public consultation and discussions with energy companies, manufacturers and other stakeholders.

In the table as follows is presented the EER values for air conditioners in Brazil.

Table 1. Minimum EER for air conditioners in Brazil (MME, 2007)

Cooling Capacity - CC (kW)	Minimum EER (W/W)
Window models	
CC ≤ 2.6	2.08
2.6 < CC < 4.1	2.16
4.1 < CC < 5.8	2.24
5.8 < CC	2.11
Split models	
CC ≤ 10.5	2.39

Follow-up

PROCEL develops annually an assessment of energy impacts of its Label and the Ministry of Energy and Mines made in 2012 an evaluation of the outcome of Law of Energy Efficiency.

Impact/evaluation

Ex-post evaluation

Based on a reference air conditioner operation, considering performance levels before and after MEPS adoption and the sales fraction affected by MEPS, it was estimated the annual and accumulated energy saving and the avoided generating capacity. The annual operating time was estimated considering the degree.days data for 23°C as the reference temperature.

Market transformation

It is estimated that 30% of sales of are replaced by efficient equipment (MEPS or more efficient)

Energy savings

For replacing low efficiency air conditioners with MEPS equipment: 26 GWh in 2010 and due to the accumulated effects, 106 GWh in 2022, corresponding to a saved installed capacity of 34 MW.

For replacing low efficiency air conditioners with air conditioners of more efficient class in labeling: 62 GWh in 2010 and due to the accumulated effects, 248 GWh in 2022, corresponding to a saved installed capacity of 79 MW.

Lessons and conditions of replication

An experienced management team

Very important, due to necessity of undertake certification tests considering the local conditions and the experience abroad, in permanent dialog with conditioners manufacturers and traders, consumers representatives, academy and universities, and government institutions.

Develops a market for energy efficiency

By informing properly consumers about the better equipment models and creating a demand for these models.

Conditions of applications

It is essential the availability of expertise and a good system for performance certification of AC systems, as well as a good system of monitoring and consumers information.

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Contacts	PROCEL and INMETRO

China

Context

The impressive expansion of AC systems market in China, where 35 million air conditioners were sold in 2010 (Michel et al., 2011), is associated with the consolidation of this country as the main producer and exporter of this appliance worldwide. The energy consumption growth due to air conditioning load expansion is appointed as one of main reasons for the several power shortages that occurred in China between 2002 and 2004 and justified the Chinese Government attention to the efficiency of air conditioners (Lin and Rosenquist, 2006). According to these authors, in major Chinese cities along the eastern seashore such as Shanghai, air conditioning load accounts for 40% of the peak summer load.

In 2005, China launched an energy efficiency labeling program which classified air conditioners in 5 performance grades in order to inform consumers and foster appliance makers to improve their products. At that time, the minimum energy efficiency requirements for air conditioners, in terms of EER (energy efficiency ratio), were raised from 2.37 stipulated in 1990 to 2.6, which is equivalent to an annual rise of 0.62%. As the energy efficiency of most of air conditioners was in the lowest of the 5 grades, in 2005 it was set by MEPS (minimum energy performance standards) legislation that the average EER should increase to 3.2 in 2009 from 2.6, which corresponds to 5.3% of annual improvement (Jiang Lin, 2006, apud IEA, 2007). With the introduction of MEPS, the share of less efficient models of air conditioners decrease from 70% to about 40% in just four years (Jianhong, 2009).

Figure 1. Energy Information Label (mandatory) and Energy Conservation Label (voluntary) adopted in China for AC appliances (Zhou, 2008)

Objective

Foster the commercialization of more efficient equipment and inform consumers about the efficiency of appliances and energy systems, by applying in air conditioner performance and endorsement labels, and defining MEPS.

Programme description

Management

The energy efficiency initiatives in China started in 1989 when the former State Quality and Technical Supervision Bureau (QTSB) issued the first set of standards on the energy efficiency of appliances including air conditioners. In April 2001, it was created the Standardisation Administration of China (SAC), which is currently responsible for establishing and monitoring national standards in this country and in charge of the China National Institute of Standardisation (CNIS) which is the main standards research institute. (Zhao and Graham, 2006, quoted by IEA,

	2007).
Sponsor	Chinese Government
Mode of intervention	Conceptually, the Chinese program is similar to the approach adopted in other countries, combing MEPS and two kinds of efficiency label: a) the Energy Information Label, a classification label with five performance categories, and b) the Energy Conservation Label, an endorsement voluntary label administrated by the China Standard Certification Center (CSC). However, since the revision introduced in 2004, the EER values in China were progressively elevated and become quite tighter than adopted in other developing countries.

In the tables as follows, values of EER required for both labels valid from 2005 are presented. According to the mentioned revision, from 2009 the minimum EER (MEPS) for air conditioners sold in China should be equal or greater the values indicated in Table 11 (equal to Class 2 in Table 10), surely a relevant step towards more efficiency in this market. This new condition, which begun after 2009, means that in China is allowed to trade just the two higher efficiency classes (1 and 2) of AC equipment.

Table 1. Energy efficiency specification for Energy Conservation Label in China after 2005 and Minimum energy efficiency from 2009 (Lin and Rosenquist, 2008)

AC appliance type	Rated cooling capacity	Minimum energy efficiency (EER)
window	-	2.90
split	CC ≤ 4,500	3.20
	4,500 < CC ≤ 7,100	3.10
	7,100 < CC ≤ 14,000	3.00

Follow-up: The outcome of this program has been regularly studied and assessed by independent researchers (see References).

Impact/evaluation

Ex-post evaluation	Based on a reference air conditioner operation, considering performance levels before and after MEPS adoption and the sales fraction affected by MEPS, it was estimated the annual and accumulated energy saving and the avoided generating capacity. The annual operating time was estimated considering the degree.days data for 23°C as the reference temperature.
Market transformation	Estimated that 30% of sales of are replaced by efficient equipment (MEPS or more efficient)
Energy savings	For replacing low efficiency air conditioners with MEPS equipment: 282 GWh in 2010 and due to the accumulated effects, 1,690 GWh in 2022, corresponding to a saved installed capacity of 1037 MW. For replacing low efficiency air conditioners with air conditioners of more efficient class in labeling: 383 GWh in 2010 and due to the accumulated effects, 2,300 GWh in 2022, corresponding to a saved installed capacity of 1,409 MW.

Lessons and conditions of replication

An experienced: Very important, due to necessity of undertake certification tests considering the

management team	local conditions and the experience abroad, in permanent dialog with conditioners manufacturers and traders, consumers representatives, academy and universities, and government institutions.
Develops a market for energy efficiency	By informing properly consumers about the better equipment models and creating a demand for these models.
Conditions of applications	It is essential the availability of expertise and a good system for performance certification of AC systems, as well as a good system of monitoring and consumers information.

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Ghana

Context

Ghana has no air conditioners manufacturers and thus imports the totality of equipment required. It was observed that "current import patterns allow manufacturers to send their least efficient models to Ghana even though these models may be barred from more developed economies because they represent extremely inefficient technology" (Project Design Document of CDM on NM0072: Mandatory Energy-Efficiency Standards for Room Air conditioners in Ghana, quoted by IEA, 2007). Consequently, the average energy efficiency of air conditioners sold in Ghana was comparatively lower, as indicated in Figure 1.

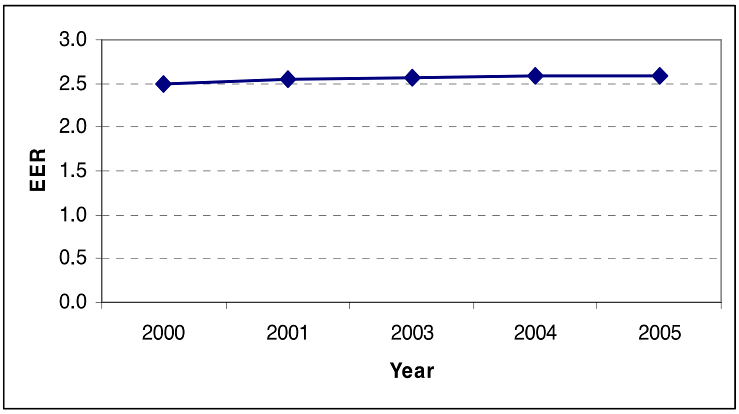

Figure 1. Energy efficiency (EER) of air conditioners sold in Ghana (AIE, 2007)

In the context of strong electricity demand growth of 90's, the Ghana Energy Foundation (a consumer-based partnership between the public and private sectors – promoted energy efficiency and renewable energy) was founded and worked, with CLASP (Collaborative Labeling & Appliance Standards Program) support, to assist the Ghana Standards Board (GSB) and Ministry of Mines and Energy to identify products and develop standards and labels (CLASP, 2010).

In Ghana, more than 100,000 room air conditioners are sold each year with the number expected to grow by about 8% each year. The energy efficiency labeling program does not have any significant impact on air conditioner stock, but rather it aims at the new air conditioners sold meet at least a minimum efficiency performance (EER=2.8) and that consumers have the life-cycle cost information needed to select air conditioner with even higher levels of efficiency (IEA, 2007).

Objective

Foster the commercialization of more efficient equipment and inform consumers about the efficiency of appliances and energy systems, by applying in air conditioner performance label.

Programme description

Management

Ghana Standards Board, a governmental agency.

Sponsors

Ghana Government and Collaborative Labeling and Appliance Standards Program (CLASP)

Mode of intervention

In 2005 a Mandatory Appliance Standards and Labeling program was launched and since then Ghana is operating a regime under which importers and retailers are required to import and sell only products that meet minimum efficiency and performance standards approved by the Ghana Standards Board. Thus, in accordance with the provisions of the Energy Efficiency Standards and Labeling Regulations, appliance manufacturers who export to Ghana and retailers who sell in Ghana are obliged to display an energy efficiency label, shown in Figure 2, which indicates the energy efficiency rating of the product before the first retail sale (Ghana Government, 2005). The EER requirement for each performance class is presented in Table 1.

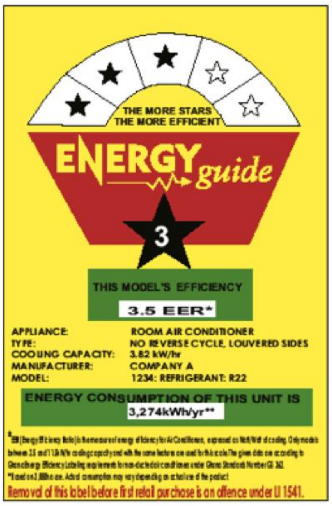

Figure 2. Energy Efficiency Label adopted for AC appliances in Ghana (Ghana Government, 2005)

Table 1. Energy efficiency specification for Energy Conservation Label in Ghana (Ghana Government, 2005)

Energy efficiency class	Required energy efficiency (EER)
5 star	4.00 < EER
4 star	4.00 ≥ EER > 3.75
3 star	3.75 ≥ EER > 3.45
2 star	3.45 ≥ EER > 3.15
1 star	3.15 ≥ EER ≥ 2.80

Impact/evaluation

Ex-post evaluation

Based on a reference air conditioner operation, considering performance levels before and after MEPS adoption and the sales fraction affected by MEPS, it was estimated the annual and accumulated energy saving and the avoided generating capacity. The annual operating time was estimated considering the degree.days data for 23°C as the reference temperature.

Market transformation

Estimated that 30% of sales of are replaced by efficient equipment (MEPS or more efficient)

Energy savings

For replacing low efficiency air conditioners with MEPS equipment: 2,703 MWh in 2010 and due to the accumulated effects, 6,487 MWh in 2022, corresponding to a saved installed capacity of 1.41 MW.

For replacing low efficiency air conditioners with air conditioners of more efficient class in labeling: 9,460 MWh in 2010 and due to the accumulated effects, 22,700 MWh in 2022, corresponding to a saved installed capacity of 4.94 MW.

Lessons and conditions of replication

An experienced management team	Very important, due to necessity of evaluate appliances performance considering the local conditions and the experience abroad, in permanent dialog with air conditioners traders, consumers representatives and universities, and government institutions.
Develops a market for energy efficiency	By informing properly consumers about the better equipment models and creating a demand for these models.
Conditions of applications	It is essential the availability of expertise and a good system for performance certification of AC systems, as well as a good system of monitoring and consumers information.

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India

Context

With an extensive area and great population, India is a major energy consumer, which energy demand is increasing rapidly and imposing governmental measures to promote energy efficiency and reduce energy losses. In this direction, the Indian Government issued the Energy Conservation Act in 2001, which empowered the Central Government to specify Energy Consumption Standards (MEPS), with legal support to interdict manufacture or sale or import of equipments and appliances that do not meet standards, as well as require to display properly the energy performance labels on equipments and appliances. Figure 1 presents the Indian energy efficiency label (Jose, 2011).

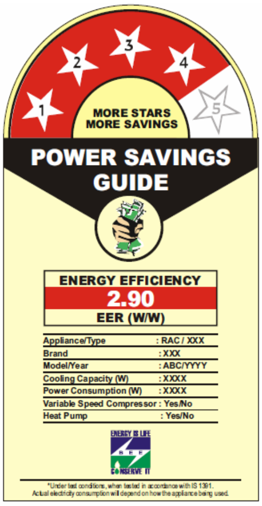

Figure 1. Energy Efficiency Label adopted for AC appliances in India (Jose, 2011)

Objective

Foster the commercialization of more efficient equipment and inform consumers about the efficiency of appliances and energy systems, by applying in air conditioner performance and endorsement labels, and defining MEPS.

Programme description

Management

Bureau of Energy Efficiency (BEE) of India, with support of the National Standards Body, responsible for the formulation and implementation of National Standards, including production and quality system certification, and the laboratories accredited by National Accreditation Board of Laboratories, educational institutions, manufacturers and manufacturing associations and consumer organizations.

Sponsor

Government of India

Mode of intervention

To implement the labeling and MEPS program, aiming to reach the energy savings target, BEE developed a detailed plan, starting from the basic aspects until the final evaluation, assuming that a full cycle of actions could take up to 12 years. The main steps of this plan are: 1) Decide whether and how to implement Energy Efficiency Labels and Standards, 2) Develop a testing capability, 3&4) Design and implement a Labeling program and analyse and set Standards, 5) Design and implement a communication campaign, 6) Ensure program integrity and 7) Evaluate the program, in line with the CLASP recommendations (Wiel and McMahon, 2001).

The most common capacity of air conditioners in India is 3.5 kW (12,000 Btu/h),

	which represent more than 78% of sales; with an average efficiency (EER) of 2.6 (W/W) (McNeil et al., 2005). It was estimated by these authors that an increase of efficiency to 2.76 (W/W) implies a 7.2% reduction in energy consumption, reducing annual use from 1,191 kWh to 1,105 kWh. In this assessment, the authors assumed that the regions in India where AC is common (North) have a six months cooling season.

As an outcome of the labeling program, the participation of more efficient equipment has increased, displacing the less efficient ones, as indicated by Figure 2. Thus, the average value of ERR for 2009-2010 reached 2.72 (W/W), rising about 2% per year after the start of the labeling program (Jose, 2011).

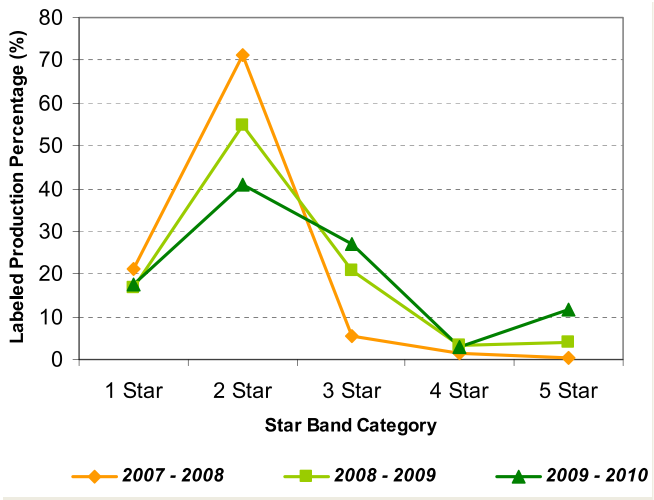

Figure 2. Market evolution for star rated air conditioners in India (Jose, 2011)

An important differential of the Indian labeling and MEPS program with regards to similar programs is the emphasis in educational and awareness aspects. A massive and monitored communication campaign has been promoted, oriented to the different group of consumers, including short courses, mass media advertising and distribution properly designed material: posters for shops, “Promoter Cards” (pocket book for show room salesmen to explain labeling to customers, including estimates of benefits in electricity bill and payback) and “Piggy Leaflets” (with the essential parts of Promoter Cards, to be given for costumers) (BEE, 2010). Very possibly, the good results obtained are associated to this concern with interaction with consumers. According to a Public Opinion survey, labeling in air conditioners is the more noticed among other appliances and good efficiency is one of three more relevant factor to take into account when purchasing air conditioners, after long life and appliance price.

Follow-up	The outcome of this program has been regularly studied and assessed by independent researchers (see References).

Impact/evaluation

Ex-post evaluation	Based on a reference air conditioner operation, considering performance levels before and after MEPS adoption and the sales fraction affected by MEPS, it was estimated the annual and accumulated energy saving and the avoided generating capacity. The annual operating time was estimated considering the degree.days data for 23°C as the reference temperature.
Market transformation	Estimated that 30% of sales of are replaced by efficient equipment (MEPS or more efficient)

Energy savings	For replacing low efficiency air conditioners with MEPS equipment: 72 GWh in 2010 and due to the accumulated effects, 289 GWh in 2022, corresponding to a saved installed capacity of 59 MW. For replacing low efficiency air conditioners with air conditioners of more efficient class in labeling: 167 GWh in 2010 and due to the accumulated effects, 668 GWh in 2022, corresponding to a saved installed capacity of 137 MW.

Lessons and conditions of replication

An experienced management team	Very important, due to necessity of undertake certification tests considering the local conditions and the experience abroad, in permanent dialog with conditioners manufacturers and traders, consumers representatives, academy and universities, and government institutions.
Develops a market for energy efficiency	By informing properly consumers about the better equipment models and creating a demand for these models, and particularly in this case, taking into account the information of consumers about the correct selection and operation of air conditioners.
Conditions of applications	It is essential the availability of expertise and a good system for performance certification of AC systems, as well as a good system of monitoring and consumers information.

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Wiel, S., McMahon, J.E., Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting, Collaborative Labeling and Appliance Standards Program (CLASP), Washington, 2001.

Mexico

Context

Mexico deserves attention not only because has been developing AC systems labeling and MEPS programs (Sanchez et al., 2007), but particularly because the Mexican institutions has been also implementing relevant programs of incentives for scrapping old air conditioners, made possible exactly due to the existence of such labeling and MEPS programs.

Electricity consumption in Mexico is expected to grow at fast pace (3.6% annual growth rate) during the 2009-2024 period, to reach in the end of this period a total consumption of 333,000 GWh, which means a 60% increase compared to 2008 levels (SENER, 2009 apud Praz, 2011) and expanding the generation capacity at this rate is challenging. Besides the elevated capital costs, the Mexican electricity market is largely subsidized and costs exceed electric tariffs for all segments except for the commercial and industrial sector. Given the large participation of residential consumption and the low price/cost ratio of this segment, 75% of the total electricity subsidies go to the residential sector.

Although energy efficiency savings have been not systematically considered in the planning process of Mexican electricity infrastructure, energy efficiency is now one of the nine guiding axes of energy policy in Mexico. The National Energy Strategy, published in 2010, set the objective of reducing total energy consumption by an average of 280 TWh until 2024. This achievement would represent a 1% reduction in the annual total primary energy consumption growth rate. It is expected that 30% will come from the reduction of electricity consumption at final use (SENER, 2010 apud Praz, 2011).

In Mexico, where air conditioning is used, it accounts for approximately 25% of residential electricity consumption. Currently only about 20% of Mexican have AC systems but there is an increase in their penetration, thus it can be projected a large expansion in energy consumption associated to this final use, that could represent an incremental consumption in 2030 equal to three times residential electricity use in 2005 (Johnson, Alatorre, Romo, & Liu, 2010 apud Praz, 2011) To address this consumption growth, the Mexican government main strategy is twofold: to update air conditioner MEPS and building codes, and to accelerated the substitution of already installed inefficient air-conditioners. In this direction, in 2006 a revised Mexican standard for energy efficiency evaluation of air conditioners was approved (SENER, 2006).

Objective

Accelerate the introduction and substitution of old air conditioners by more efficient equipment.

Programmes description

Management

FIDE and FIPATREM. FIDE is the trust fund for the savings of electric energy, created in 1990 by CFE (State owned main public utility) with support of the main Mexican business organizations. FIDE is a private institution, focused in promoting energy efficiency and operating aligned with Mexican government strategies. FIPATREM is another trust fund, older than FIDE, pushed by the federal government in the 1990's with the specific objective of providing electricity savings for the residential sector. FIPATERM began financing the thermal insulation installation and in 1997 the substitution of electric appliances such as air conditioners was incorporated as part of the FIPATERM ASI, operating in the states bordering the US (Baja California and Sonora), the tropical states of the Yucatan Peninsula plus Chiapas and Tabasco (Gomez Rodriguez, 2005 apud Praz, 2011)

Sponsors	Mexico Government, World Bank and KfW (Germany).
Mode of intervention	In recent times, two parallel but closely related programs were developed in Mexico to provide financing to residential users that wish to replace an old inefficient air conditioner for a new and more efficient unit: 1. The Program for the Financing of Electric Energy Savings (PFAEE) leaded by FIDE. 2. The Program for Systematic Savings (ASI), managed by FIPATREM. A third and more ample program for air conditioners replacement was implemented more recently. In 2009, in the framework of the Energy Reform Law, the Mexican government (with the support of the World Bank and of KfW) provided funding to be managed by FIDE to promote energy efficiency. Among other initiatives, the Program of Substitution of Electrical Appliances for Energy Efficiency (PNSEE) aimed to replace 1.9 million refrigerators and air conditioners by 2012, covering until 50% of acquisition cost of new units (SENER, 2012). Depending on the consumption level, the financial support to consumers can be given as direct subsidy and/or loan over 4 years reimbursed via the electricity bill. The PNSEE was managed by FIDE with rules and structure similar to those defined for the PFAEE program. Thus, the eligibility criteria for the participation in the air conditioning substitution were: – be a customer billed by electricity rates that apply to regions with summer minimum average temperatures equal to or greater than 30°C – have a old air conditioner functioning 10 or more year with a capacity of 0.75 TR (tons of refrigeration) to 5 TR. – the old air conditioner has to be delivered at the moment of receive the new one. – the size of the new equipment cannot exceed in more than 1 TR the capacity of the replaced air conditioner.
Follow-up	The outcome of this program has been regularly studied and assessed by independent researchers (see References).

Impact/evaluation

Market transformation	It informed that the PFAEE promoted from 2002 to 2006 the substitution of low efficiency 129,889 air conditioners in this period (PFIDE, 2009 apud Praz, 2011). According to Praz (2011), it is foresee that FIPATERM promoted the replacement of 100,268 window air conditioners between 1997 and 2010. Because of its origins and long operation time, FIPATERM actions were reported separately from the PFAEE's reports. The long experience of this program allows to observe two trends; the migration from window air conditioner towards split technology and an increase in cooling capacity of new AC systems versus replaced ones. Considering the weighted average, the replaced equipment capacity was 6.3 kW, while the installed new equipment is 7.3 kW, about 15% more, an important aspect to take into account to predict the results of investments in accelerated substitutions. It was estimated that the PNSEE program promoted an annual substitution of 85,171 air conditioners during the 2009-2012 period, which means a total of 340,648 units replaced (Praz, 2011).
Energy savings	It is estimated that together, the FIPATERM and FIDE PFAEE 2002-2006 programs achieved a saving of 2,371 GWh, while the estimated results from the PNSEE program are 4,710 GWh. This is equal to average annual savings of 482 GWh or 0.45% of annual residential electricity consumption in 2008 (Praz, 2011).

Lessons and conditions of replication

An experienced management team	Very important, due to necessity of undertake certification tests considering the local conditions and the experience abroad, in permanent dialog with conditioners manufacturers and traders, consumers representatives, academy and universities, and government institutions.
Develops a market for energy efficiency	By informing properly consumers about the better equipment models and creating a demand for these models, as well as financing the acquisition and replacement of low efficiency conditioners.
Conditions of applications	It is essential the availability of expertise and a good system for performance certification of AC systems, as well as a good system of monitoring and consumers information.

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Tunisia

Context

Tunisia government has been developing energy efficiency programs motivated by the economic growth and increasing energy demand, which have overloaded the Tunisia's electricity grid in recent years. In fact, due to limited natural resources, energy imports are increasing since 2000. The climate is mostly hot and arid, in the North also warm-temperate, imposing frequent use of air conditioning. In this context, the energy efficiency programs have focused buildings in the residential and tertiary sectors because currently they are jointly one of the most relevant energy consumers, forecasted to be the greatest consumer sector in 2020 (World Bank, 2012, apud bigEE, 2013).

The Ministry of Industry and Energy (Ministère de l'Industrie, de l'Energie et des Petites et Moyennes Entreprises, TMIE) is responsible for the national energy policy in Tunisia, particularly through its Directorate General for Energy. Founded in 1985, the Tunisian National Agency for Energy Management (Agency Nationale pour la Maîtrise del' Énergie, ANME) is in charge of implement the energy policy directives with regards to energy efficiency.

The Tunisian initiatives on energy efficiency have been developed within a broad planning framework, the Four-Year Energy Control Plan 2008-2011, with an objective of save 24% in primary energy intensity up to 2016 (Blanc, 2012).

Objective

Promote energy efficient building, by regionally defined setting standards for construction and appliance application, and developing demonstration projects.

Programme description

Management

Directorate General for Energy of the Ministry of Industry and Energy (Ministère de l'Industrie, de l'Energie et des Petites et Moyennes Entreprises, TMIE), acting by the Tunisian National Agency for Energy Management (Agency Nationale pour la Maîtrise del' Énergie, ANME) with technical support from the Tunis International Centre for Environmental Technologies (Centre International des Technologies de l'Environnement de Tunis, CITET.

Sponsor

Government of Tunisia, with backing support of PNUD and Agence Française de Développement (AFD).

Mode of intervention

Developed under the concepts indicated in Figure 1, the main action of the Tunisian government on energy efficiency is a mandatory minimum energy efficiency standards (MEPS) and energy labeling program for new buildings and extensions to existing buildings.

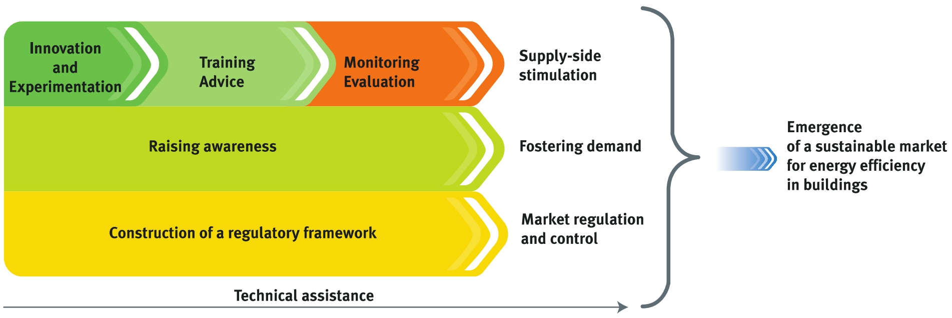

Figure 1. Tunisian building energy efficiency policy (ANME, 2012)

Minimum energy performance standards for buildings are especially important in countries like Tunisia, where the construction activity is very high. For new buildings in the public sector, thermal insulation is obligatory since April 2005 and according to the Law 2004-72 (revised 2009-7) new buildings and extensions to existing buildings are required to meet a minimum energy performance standards.

Based on 43 successful demonstration projects, ANME develop seven guides oriented to professionals directly involved with building design and construction, and focusing at low-cost interventions that would add less than 10% to the cost of the building. These interventions are basically oriented to six points (ANME, 2010): architectural design, wall and roof insulation, choice of materials, use of high-quality glazing in terms of optical and thermal performance, use of renewables and use of energy-efficient lighting in buildings.

Temperature requirements in buildings depend on the location of the building. Thus, ANME sub-divided Tunisia in three zones, in order to facilitate the proper design of heating and air-conditioning equipment as well as temperature optimization in buildings. The thermal insulation regulation is combined with PROMO-ISOL, a promotional program for insulation, and PROSOL, a program for solar water heaters (RCREEE 2010, apud bigEE, 2013).

A label indicating comfort and energy performance of buildings was implemented; its main elements are depicted in Figure 2. Such building labeling program is backed by (FEEM et al. 2010; Saheb 2012, apud bigEE, 2013):

- a set of capacity building activities, such as training courses in construction techniques, methodologies and software for temperature simulations; e-learning program set up to orient architects in the design of energy efficient buildings; tools to aid the design of low energy buildings made available to construction professionals, technical guides covering buildings for different purposes (housing with or without equipment, hotels, hospitals, shops, offices and teaching establishments), guides to climate zones and capacities evaluation for heating and air conditioning equipment, and temperature simulation tools;

- an extensive communication program including television, radio and newspaper advertisements, as well as a dedicated web-site for the several types of people potentially interested (RCREEE, 2010, apud bigEE, 2013).

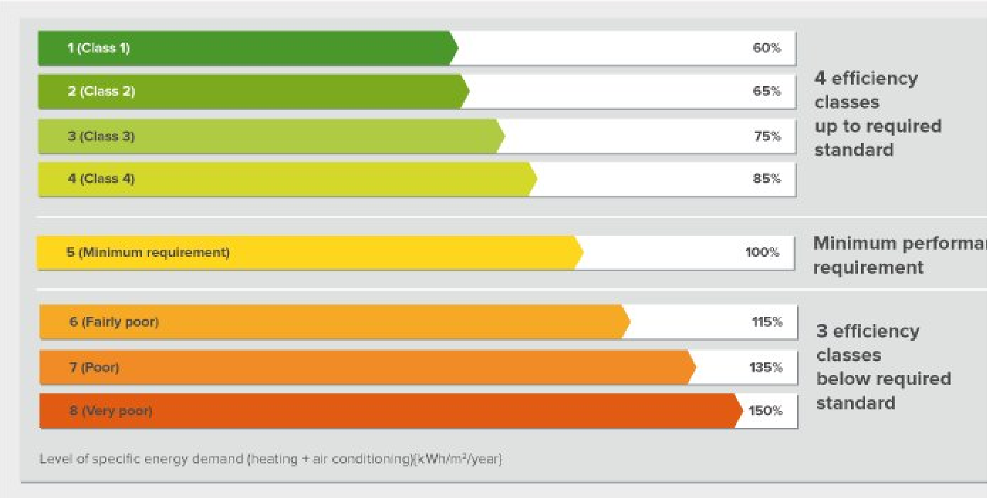

Figure 2. Tunisian building energy efficiency label main elements (FEEM et al. 2010; Saheb 2012, apud bigEE, 2013)

Impact/evaluation

Energy savings	Considering the successful demonstration projects implemented, it was expected savings from 10% to 40%, at low cost (ANME, 2010).

Lessons and conditions of replication

An experienced management team	Very important, due to necessity of developing energy efficiency standards for building and appliances, in permanent dialog with construction, equipment manufacturers and traders, consumers representatives, academy and universities, and government institutions.
Develops a market for energy efficiency	By informing properly consumers about the better architectural concepts and designs, as well as creating a demand for these models and buildings.
Conditions of applications	It is essential the availability of expertise and a good system for performance certification of buildings and appliances, as well as a good system of monitoring and consumers information.

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United States of America

Context	In the United States, a great energy consumer, there is at governmental level enough awareness about the relevance and potential of energy efficiency. Consolidate programs towards the introduction of more efficient equipment and good practices have been developed at federal and state level. Mature programs as the endorsement label Energy Star, largely adopted to promote efficient products and several governmental and non governmental agencies, leaded by the Department of Energy's Office of Energy Efficiency and Renewable Energy establishes a comprehensive framework to deal with energy efficiency information, involving national laboratories, public utilities, environmental protection agencies and non-profit organizations. There are multiples and reliable sources of information at sectorial level or final use level, and a group of qualified laboratories operate under Department of Energy support and guidance. Thus, the classic tools to face the challenge of promoting energy efficiency are sufficiently well known in US. However, the elevated energy consumption and energy intensity, in this country indicate that there is an ample room for promoting energy efficiency in order to reach effective results. In order to explore different measures for promoting energy efficiency in different contexts, the American case selected with regards air conditioning takes into account the economics incentives developed to promote inefficient air conditioners replacement and operation. This kind of incentive have been developed in US in federal and state level, and a large diversity of programs were or still are in operation, but following essentially the same rules (Energy Star, 2012).
Objective	Provide economics incentives developed to replace inefficient air conditioners in existing homes.

Programme description

Management	Office of Energy Efficiency and Renewable Energy of the Department of Energy, in co-operation of Environment Protection Agency and other private institutions.
Sponsor	US Government.
Mode of intervention	At federal level, as part of the Energy Policy Act of 2005 and subsequently amended and extended several times the US government launched the Federal Tax Credits for Consumer Energy Efficiency, oriented to finance energy efficiency improvements, including the installation of highly efficient AC systems. In line with this program, the Tax Incentives Assistance Project (TIAP), sponsored by a coalition of public interest non profit groups, government agencies, and other organizations in the energy efficiency field (such as Alliance to Save Energy, American Council for an Energy-Efficient Economy, California Energy Commission, Vermont Energy Investment Corporation, Energy Foundation, DoE, EPA, among other), was created in 2005, aiming to give consumers and businesses information they need to access the federal income tax incentives for energy efficient products and technologies (TIAP, 2012). In the last amendment, this program, with the title of was set to operate until the end of 2013, under the framework of the American Recovery and Reinvestment Act. This program finance homeowners who want install energy efficient equipment in their existing homes, under the following rules with regards to AC

systems (for the 2012&2013 period) (Energy Star, 2013):

- equipment to be used should be awarded with the Energy Star label.
- credit rate of 10% of cost up to $300 or a specific amount from $50–$300, to be applied diverse improvements such as adding insulation, install energy efficient exterior windows and energy-efficient heating and air conditioning systems.
- must be an existing home and the principal residence of taxpayer, new construction and rentals do not qualify.

The table below presents the energy performance requirement for an air conditioning equipment be qualified as Energy Star one and access the Federal Tax Credits for Consumer Energy Efficiency.

Table 1. Energy efficiency limits for air conditioners access the Federal Tax Credits for Consumer Energy Efficiency (Energy Star, 2013)

AC system	**Efficiency Requirements** (W/W)
Split system central air conditioners	SEER > 4.69 and EER > 3.81
Packaged central air conditioners	SEER > 4.10 and EER > 3.52

Impact/evaluation

Energy savings

The program Federal Tax Credits for Consumer Energy Efficiency has been systematically assessed and its energy impact has been evaluated (Meyers et al., 2008), however data on the specific impact of efficient AC systems introduction was not found in the available literature, that indicates generic energy savings between 4% to 8% resulting from standards in the commercial and residential sectors.

Lessons and conditions of replication

An experienced management team

Very important, due to necessity of developing energy efficiency standards for air conditioning appliances, as well as able to establish effective mechanisms for public information and the required bureaucracy for implementing and monitoring special financing lines.

Develops a market for energy efficiency

By informing properly consumers and promoting sales of efficient equipment, a demand is created.

Conditions of applications

It is essential the availability of expertise and a good system for performance certification of buildings and appliances, as well as a good system of monitoring and consumers information.

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