UNIVERSITY OF CALGARY

Urban Energy Management in Quito: A case Study

by

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A Masters Degree Project submitted to the Faculty of Graduate Studies in partial Fulfillment of the Requirements for the Degree of Master of Science in Sustainable Energy Development

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CERTIFICATE OF COMPLETION OF INDIVIDUAL PROJECT

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MASTER OF SCIENCE DEGREE IN SUSTAINABLE ENERGY DEVELOPMENT

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, the Individual Project Report entitled *"Urban Energy Management in Quito: A case Study"* submitted by Paula Sánchez in partial fulfillment of the requirements for the degree of Master of Science in Sustainable Energy Development.

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ABSTRACT

This study aims to analyze an energy efficiency program on the demand-side for the residential sector of Quito. The study considers the importance of energy efficiency programs and international experiences, and it covers technical aspects like the load characterization, tariff aspects, and identification of the energy efficiency measures, estimated savings for lighting, refrigeration and water heaters, and benefits for residential consumers and Electric Power distributors of Quito.

The study includes a legal framework and strategic management tools that could be used during the development of an energy efficiency program for the residential sector.

In addition, the study develops a sequence of environmental implications including CO_2 emission reductions due to electricity generation and other concerns like air pollutants emitted to the environment.

ACKNOWLEDGEMENTS

First, I would like to express my gratitude to my father who gave me the support and the initiative to start this Masters program and to my husband for being understanding and encouraging me to continue during this period.

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DEDICATION

To my husband and parents for their support

Paula

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CHAPTER ONE: INTRODUCTION

1.1 Purpose of the Research

The purpose of the research is to suggest an energy efficiency (EE) program for a targeted sector which is going to consider the energy saving potential of the residential sector in the city of Quito and relevant aspects within a program for a target sector such as technical, economical, environmental and legal implications.

Additionally, the study will propose an EE program based on those appliances that consume the most and where the saving potential is higher. For those existing programs like the substitution of light bulbs, the research will be limited to depict current results and improvement opportunities. In the case of the residential sector, it is important to analyze the demand-side management by existent appliances in the market and compare them with efficient appliances to build an EE scenario.

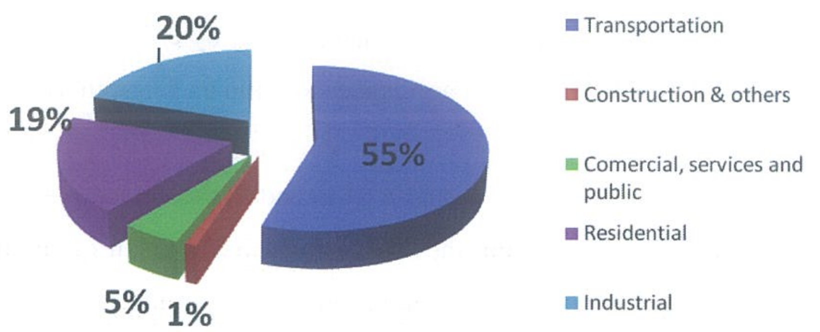
According to the energy matrix of Ecuador, the demand- side could be modified to reduce energy consumption; these reductions could result on environmental benefits by reducing greenhouse gases emissions and economic benefits by decreasing operational costs in those power facilities that provide energy to the residential sector (Ministerio de Electricidad y Energia Renovable, 2008).

Furthermore, the proposed study is going to analyze accurate information about stratified electricity consumption sectors compared to household income to assess the efficiency of household appliances that must be introduced in the residential sector according to existing social distribution and energy consumption. Finally, legal and strategic management implications on which the EE program is going to be sustained will be addressed to assess a legal and regulatory framework for EE products that are currently in the market.

1.1.1 Importance of energy efficiency programs in Ecuador

According to the energy matrix of Ecuador, Figure 1 shows that the residential sector covers 19% of the energy consumption in Ecuador. This sector is third on energy savings potential after the industrial sector, which represents an opportunity for EE programs to model the demand-side in the energy matrix of Ecuador (Ministerio de Electricidad y Energia Renovable, 2008)

Figure 1: Structure of energy consumption by sector in Ecuador (2006)



***SOURCE:** (Ministerio de Electricidad y Energía Renovable, 2008)*

In addition, the energy intensity in the Latin American and Caribbean region could not be compared with the variation in energy specific consumption of the residential sector of Quito, due to the concept of energy intensity that indicates the energy consumption resulting from a wide range of production and consumption activities.

In specific economic sectors and sub-sectors, the ratio of energy use to output or activity is the "energy intensity" (if the output is measured in economic units) or the "specific energy requirement" (if the output is measured in physical units such as tonnes or passenger-kilometers) (United Nations - Department of Economic and Social Affairs, 2008).

In this way, the residential sector is not considered a productive activity to be included in the GDP, thus the variation of the specific energy consumption of Quito's energy utility users will lead to the energy efficiency productivity of this sector.

Table 1: Growth rate of the energy intensity

Subregion / Year	2000 – 2005
Mexico	-0.40%
Central America	0.70%
Caribbean	1.00%
Andean Region	0.20%
Southern Region	0.20%
Latin America and Caribbean Region	0.30%

SOURCE: *Energy-Economic Information System OLADE (SIEE)*

Table 2: Growth rate of the specific consumption of Quito's Residential Sector

RESIDENTIAL SECTOR	
Specific consumption (kWh/user)	
2000 - 2005	**VARIATION %**
1690	
1692	0.1
1732	2.3
1785	3.0
1831	2.5
AVERAGE	2.0

For instance, table 1 depicts the growth rate of the energy intensity in the Andean Region as 0.20%, which refers to the productivity of a region.

On the other hand, table 2 shows 2% growth rate of specific energy consumption in Quito's residential users, which indicates the comfort of a specific sector (Poveda, 2007).

1.2 International experiences with EE programs

Nowadays greenhouse gases emissions are global concerns adopted by international agreements that are seeking mitigation measures in order to reduce emission; for instance, in the article "Energy Efficiency: an Unexploited Resource", regarding energy efficiency the author exemplifies these mitigation measures 85% of what the European countries consumed. They have specialized institutions in energy efficiency that have been considered as an instrument to achieve a reduction of CO_2 emissions, since less fossil fuel is required to generate electricity.

To illustrate, a clear European approach to ensure a reasonable energy consumption has been depicted by energy intensity rates (energy consumption per Gross Domestic Product unit), with decreasing rates of 0.9% annually between 1990 and 2002, in contrast Latin America and the Caribbean countries have shown a decreasing rate of 0.5% annually. With this in mind, European efforts to reduce energy consumption have been supported by government decisions that established institutional framework for energy efficiency development (Poveda, 2007).

Brazil implemented the National Program for Electric Energy Conservation (NPEEC, with its acronym in Spanish - PROCEL) in 1986; the program was managed by the company Electrobras and granted a shared fund that included national resources of the company, Global Reserve Fund of Reversion (GRR), and international resources such as the Global Environmental Facility (GEF). In 2005, the initiatives allowed energy savings of 2,158 GWh together with a rationalization program (CONPET) that reduced diesel consumption, encouraged new technologies for household appliances and rationalization concepts (Poveda, 2007).

Mexico is a good example of energy efficiency programs ever since the National Commission for Energy Savings (CONAE) started. Moreover, the program (PEMEX) estimated natural gas savings for more than 100 thousand million cubic feet. Additionally, reductions of 1,962 million kWh in electricity consumption with an approximated cost of US$ 78 million were found during the program application (Poveda, 2007).

Ultimately, the EE Mexican program included the summer schedule that consists in reduction of peak hours by moving one hour ahead of night time energy demand and taking advantage of natural light in the morning (The Electric Energy Saving Trust Fund, 2008). The results of these measures have shown savings of 1,200 kWh in energy consumption during 2007. These savings are equivalent to the annual energy consumption of Baja California Sur or Colima (The Electric Energy Saving Trust Fund, 2008).

OLADE (Latin America Energy Organization) in the article Designing energy-efficiency programs, collected past experience data in the region, the information shows 42.2% of energy consumption in the residential sector in 21 of 47 countries compared with industrial, commercial and other sectors. According to this data the residential sector plays an important role in EE programs not only for its share, but residential players are likely to accept the EE schemes where a good education (technical support), communication and advertising considerations are required for a successful program (Vieira de Carvalho, Poveda-Almeida, & Zak, 1996)

Furthermore, prospects for improved energy efficiency in the UK residential sector have mentioned that "energy use by households is one of the most pressing areas needing to be addressed. Over a quarter of the CO_2 produced in the UK comes from energy used at home, and technical estimates suggest that up to 25% of these emissions could be saved cost-effectively" (McEvoy, Gibbs, & Longhurst, 1999)

For instance, the Commission of the European Communities published a green paper called "A European Strategy for Sustainable, Competitive and Secure Energy" in which the European Union (EU) considers energy efficiency programs as one of the measures to accomplish the goal of saving 20% of the energy that the EU would otherwise use by 2020. The idea of including energy efficiency programs in the region does not mean sacrificing comfort or production, instead it means improving competitiveness. In fact, making cost-effective investment to reduce bad usage of energy, saving money for consumers and using price signals are the means that could represent a more responsible, economical and rational use of energy in the region (Commission of the European Communities, 2006)

Rebate programs for EE in the United States have been successfully implemented. For example, the California Statewide Multifamily Energy Efficiency Rebate Program

(MEERP) promotes energy efficiency by providing equipment rebates to owners and tenants of multifamily properties. The program offers property owners rebates up to $1500 for energy efficiency products and improvements. The MEERP is still in place and from 2004 to 2005 it achieved power savings of 17,572 kW (Compendium of Champions, ACEEE, 2008)

In summary, energy efficiency programs are established to reduce greenhouse gas emissions and achieve savings on energy throw measures to improve efficient use of energy and analyzing consumption patterns on the demand-side management.

1.3 Energy efficiency programs in the residential sector of Quito

Since 2007, the Ecuadorian government has done some efforts to achieve energy efficient projects such as the PROMEC (Modernization Project of the Electric Sector, Communications, and Rural Services), which started bidding and operations in 2002 and 2005 respectively. On regards to the energy sector, the project aims to cover the Ecuadorian territory especially rural areas with energy services (CONATEL, Consejo Nacional de Telecomunicaciones, 2006).

Although the project does not include energy efficiency measures, the government takes into account this initiative as an attempt for energy efficiency development. Besides, the Ecuadorian government tried to implement the project by selling 2 million energy saving light bulbs at reduced prices at the distribution points, and the donation of 150,000 efficient light bulbs in the entire Ecuadorian territory. In spite of these efforts, the results have been poor with only 25,000 light bulbs sold. (Ministerio de Electricidad y Energia Renovable, 2008).

The conclusion of these valuable approaches to implement energy efficiency projects is that people with scarce resources are not able to buy these appliances and the best way to get to them is through its direct donation. (Ministerio de Electricidad y Energia Renovable, 2008)

Currently, the Ministry of Electricity and Renewable is running the project to replace incandescent light bulbs with energy saving bulbs. The purpose of the project is to replace 6 million incandescent light bulbs in the residential sector that has an average energy consumption of 130 kWh in the highlands and 150 kWh in the coast. (Ministerio de Electricidad y Energia Renovable, 2008)

Until April 29th, 2009 the project has substituted 3,896,707 energy saving light bulbs and they have been distributed as illustrated in Figure 2.

Figure 2: Distribution of Energy Saving Light Bulbs in the Residential Sector

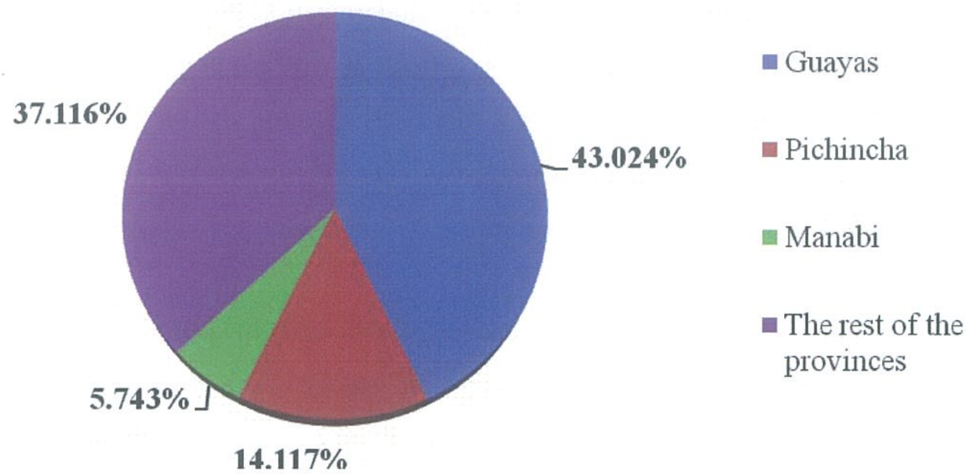


Figure 2 shows that Pichincha (Quito's province), represents only 14% while Guayas represents 43% of energy saving light bulbs distribution (Ministerio de Electricidad y Energia Renovable, 2008). The baseline of the project estimates that 24% of the energy consumption in the residential sector is for lighting; however, 50% of this consumption is intended during maximum peak hours between 18 and 22 hours (Gobierno Nacional de la Republica del Ecuador, 2008).

The current replacing program has six strategies (Gobierno Nacional de la Republica del Ecuador, 2008):

- Make a contact network, Ministry agreements, and technical requirements for the acquisition and implementation of light bulb substitution.
- Plan, analyze and structure warehouse facilities, transport, custody, and assign energy saving light bulbs to beneficiaries.
- Design processes, guidelines and policies according to the value chain which include imports, transport and warehouse, distribution, evaluation and monitoring of energy saving light bulbs.
- Implement security, mechanic and environmental quality terms.
- Train coordinators of electric companies, executing committee – CEFEN on distribution procedures and substitution of energy saving light bulbs.
- Promote and advertise the national campaign of energy saving light bulbs through local radio stations, television and writing press.

The energy saving light bulbs program will be monitored through the following indicators (Gobierno Nacional de la Republica del Ecuador, 2008):

- Number of replaced light bulbs
- Number of energy saving light bulbs imported

- Number of users benefitted
- Energy saved in peak hours (MW)
- Invested Resources (USD $)

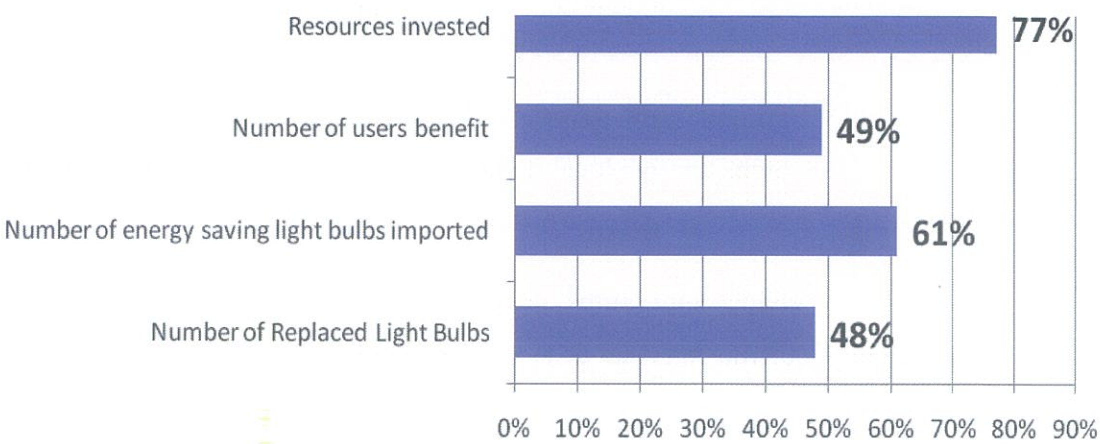
The initial results that have been monitored in the replacing program are reported in table 3, and % of completion is depicted in figure 3:

Table 3: Light bulbs substitution program – Indicators and Results

INDICATORS	UNITS	2007	2008	TOTAL	ESTIMATED	COMPLETION
Number of Replaced Light Bulbs	light bulbs	150,000.00	2,414,140.00	2,564,140.00	5,366,628.00	48%
Number of energy saving light bulbs imported	light bulbs	150,000.00	3,600,000.00	3,750,000.00	6,150,000.00	61%
Number of users benefitted	users	62,000.00	1,050,278.00	1,112,278.00	2,289,586.00	49%
Resources invested	USD $	6,798,000.00	1,496,927.00	8,294,927.00	10,703,445.00	77%

SOURCE: *(Gobierno Nacional de la Republica del Ecuador, 2008)*

Figure 3: Indicators completion of the light bulbs substitution program



According to the CENACE (National Center for Energy Control), the use of energy saving light bulbs has generated a benefit for the Treasury of USD $3 million between September and December 2008. The CENACE reported that the replacment program resulted in a reduction of power consumption equivalent to 65 Megawatts during this period. (CONELEC - Consejo Nacional de Electricidad, 2008). On the other hand, the SIGOB (Information System for the Democratic Governability) reported power savings of 152 MW. for the year 2008, (Gobierno Nacional de la Republica del Ecuador, 2008).

According to Mentor Poveda - OLADE'S energy efficiency expert, the 152 MW of power saved do not represent the real savings due to diversity; since not all the light bulbs are turned-on at the same time. As a result, only an estimated 50% of the power reduced by the substitution is the amount to be shown-up in the electric power peak therefore only 76 MW are the real savings from the light bulbs substitution program. On regards to the efficiency of a thermoelectric power plant of 14 kWh/gallon, the CENACE calculated fuel savings of 2.8 million gallons of diesel. (CONELEC - Consejo Nacional de Electricidad, 2008). Finally, CENACE mentioned in its report that since August 2008 the Ministry of Electricity and Renewable Energy gave 2.5 million light saving bulbs in the whole Ecuadorian territory, representing 45% of the 6 million planned units. (CONELEC - Consejo Nacional de Electricidad, 2008)

1.3.1 Goals and objectives of the research

The goal of the study is to propose an EE program for the residential sector of Quito after a partial analysis of the OLADE's methodology for structuring EE programs. (Vieira de Carvalho, Poveda-Almeida, & Zak, 1996). According to the goal, the main objective is to do an adequate selection of the program based on a previous analysis. Specific objectives for the suggested EE program are:

- Collect accurate information from secondary data sources to identify the energy consumption and end-use share for load characterization.
- Identify household appliances that provide significant energy efficiency impacts.
- Evaluate technical and economic parameters for EE household appliances available in the market.
- Analyze a cost-benefit scenario with EE household appliances for the program.
- Recognize legal requirements and educational programs that should be used as mechanisms to apply the EE program for the residential sector of Quito.

1.4 Methodology

The study considers a quantitative and qualitative methodology depending on the issue to be addressed; at first, load characterization requires data of consumption per appliance usage time and electricity pricing to be obtained from secondary data, such as the existing EE programs of the Ministry of Electricity and Renewable Energy. Data collected should be analyzed to correlate the variables and define the appliances with highest conservation potential for the EE scenario. As a result, the technical aspects will be analyzed through existing information of load characterization from past years (1991 – 1992) from INECEL (Ecuadorian Institute of Electrification) studies. In order to update the information it is necessary to correlate data from those appliances that are not present in previous studies such as vampire appliances and import trends of other appliances that might be not visible on these earlier studies.

The variables of cost and energy in household appliances need a quantitative analysis in order to obtain a cost-benefit and cost- effectiveness scenario. The economic analysis requires the information from current stratified electricity prices, and includes the costs of existing appliances in market.

After the predicted scenario, the study will be conducted with a qualitative methodology from secondary data sources, which is going to address the issues of the program, that fits the best for energy efficiency purposes and compare them with existing programs due to strategic management and legal mechanisms.

For legal implications, it is necessary to find or suggest policies required to implement the program. Finally, the methodology suggested for environmental issues, consider the energy savings and the amount of pollutants produced by the electricity generation sector.

1.5 Limitations of the research

The study gathers information or correlates previous data for load characterization with current information that could be correlated. However, the collection of secondary data does not allow the researcher to have control of the final results of the developed experiment of measuring the load characterization and consumption end-use. The assumption within secondary data that includes the load curve (1991) remains the same and is the baseline for this study.

The scope of the study is very limited and only some issues on regards to policies are going to be addressed, but will may not be possible to study all of them.
The study is limited in the way that surveys for load characterization were done by INECEL only in 1991. Starting this year, there have not been studies or surveys to identify the energy consumption by appliance and their behavior during 24 hours to determine peak hours of consumption. Additionally, the INECEL study did not included the stand-by power which is very important for load characterization.

Other limitations appears at the moment of analyzing tariff aspects which still maintain cross subsidies that do not incentive EE measures.

In addition, the methodology to build EE programs used by the *Program for the Demand-Side Management and Rational Use of Electricity in Ecuador* (AD&UREE) and by OLADE will be partially covered because this methodology explained in chapter 2, takes into account the entire energy sectors while the aim of this study is to focus electric power sector on the residential sector of Quito.

The measures for the EE program are going to consider the appliances with more EE potential, with this in mind, this study is going to analyze household illumination, refrigerators and water heaters.

The projection for number of subscribers to Quito´s Electricity Utility (EEQ) was calculated considering data from 1990 to 2007, which implies that the sample is not representative, unless the study considers 30 years of analysis instead of 18. Therefore, the lack of information about number of subscribers for more than 30 years has been an obstacle in presenting accurate projections and this study has consider the data for the information gathered during 18 years.

CHAPTER TWO: TECHNICAL ASPECTS

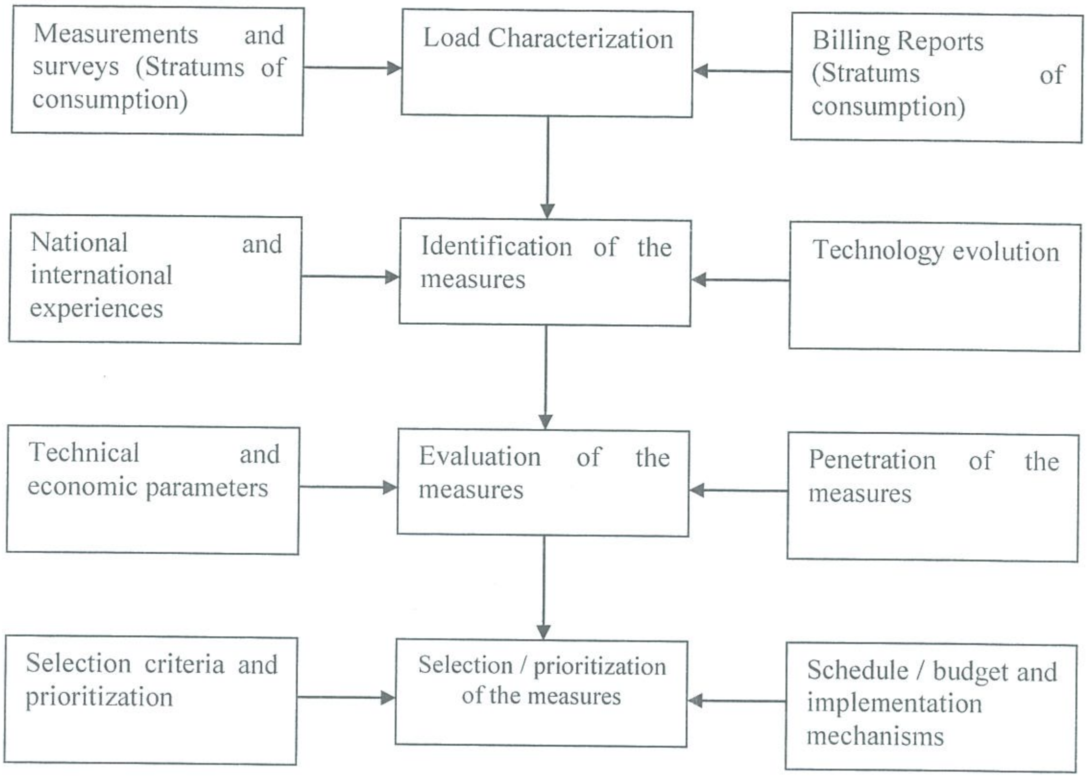
This chapter will focus on the technical aspects such as end-use sharing, load characterization, identification of measures, and evaluation of measures and selection of the measures for the program of the residential sector of Quito. First, it is necessary to identify the average load curve per household during 24 hours (day hours) in order to see the energy efficiency improvements after using efficient appliances with a certain program. Second, it is important to assess an energy efficiency scenario to finally estimate the energy savings in terms of consumption per household.

Moreover, the consumption per final usages should incorporate the social class and consumption stratums by which the electricity consumption has been classified to benefit consumers with scarce resources.

The data collected (secondary information) to analyze the structure of energy consumption per final usages in the residential sector has been taken from a previous study done by the Ecuadorian Institute of Electrification (INECEL), as the first approach to a EE program done in 1993.

According to the INECEL, the data collected help to establish a ***Program for the Demand-Side Management and Rational use of Electricity in Ecuador*** named with its acronym AD&UREE. (INECEL, 1994). The objective of the AD&UREE was to assess the INECEL staff in order to establish an action plan for the development of specific measures for short, medium and long term for different targets and consumption stratums, the identification of the costs and benefits for different AD&UREE's stakeholders such as: the electricity sector, electricity consumers and those who may not adopt the measures, and the society in general (INECEL, 1994). The methodology of technical – economic evaluation of AD&UREE's program is established as follows

Figure 4: Methodology of Technical – Economic Evaluation of AD&UREE's Program



SOURCE: *(INECEL, 1994)*

The methodology was taken from OLADE in order to develop energy efficiency programs in Latin America (Vieira de Carvalho, Poveda-Almeida, & Zak, 1996, p. 25)

2.1 Load characterization and end-use sharing

The last studies done by INECEL in 1991 for load characterization and electricity end-use were the last approach to establish measurements for energy efficiency. At that time the INECEL did a research with representative samples of electricity subscribers of the Quito Electric Utility (Empresa Electrica Quito – EEQ) and the ex – EMELEC.

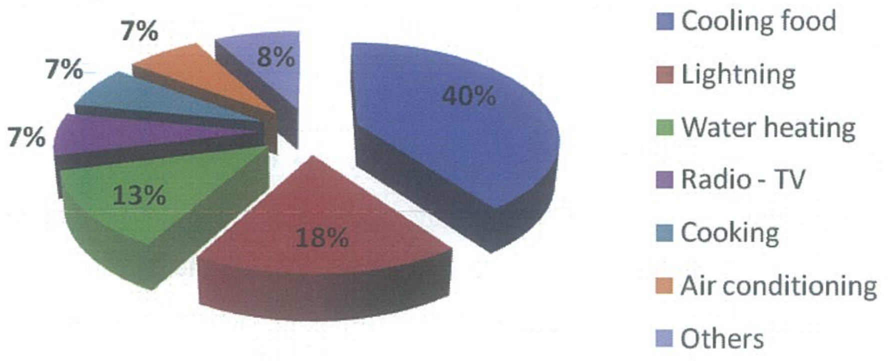
(Ministerio de Energia Renovable y Eficiencia Energetica, 2008). As a result, the INECEL categorized the end-use of electricity per stratified consumption sectors including the residential sector of Quito. (Ministerio de Electricidad y Energia Renovable, 2008).

The inefficient use of energy is given by the load factor which in the case of the Ecuadorian system has a value of 56% due to the important participation of residential sector. This factor implies the important use of energy during peak hours from residential sector and the consequences to power facilities that have elevated marginal costs.

Ecuadorian load characterization has peak hours between 18 and 22 hours with the highest peak between 19 and 21 hours. Additionally, the day of maximum demand is Wednesday where the maximum demand of energy increases during peak hours due to the residential and commercial energy consumption which represents a minimum of 400 MW (Ministerio de Electricidad y Energia Renovable, 2008).

In order to identify the allocation of the measures for an EE program it is necessary to set up the end-use consumption per appliance. The study done by INECEL in 1991 in the Ecuadorian territory mentions that the electricity consumption behaviours in the residential population are expressed as a weighted national average, and they are presented in Figure 5 as follows:

Figure 5: Electricity End-use in the Ecuadorian Residential Sector



SOURCE: *(Ministerio de Electricidad y Energía Renovable, 2008)*

The issue regarding the end-use distribution is that during the last 14 years there have not been studies about the electricity end-use in the residential sector. Probably, increases on TVs, computers and the displacement of electric water heaters and electric stoves for gas appliances have modified the end-use distribution.

Moreover, the gas subsidy has contributed for changes in the consumption behaviour of residential users (Ministerio de Electricidad y Energia Renovable, 2008).

The INECEL study did not included "vampire appliances" which consist of appliances that continuously consume energy even if they are switched off or if they are not performing their primary function (Science Daily, 2002).

According to studies done by the Lawrence Berkeley National Laboratory (USA), the International Energy Agency (France), and the ADEME (France), the stand-by power is a global concern because it is about 2% of the total electricity consumption of OECD Countries[1] .

On regards to power generation, standby represents 1% of its carbon emissions and the replacement of existent vampire appliances with those having lower standby could minimize the total standby power consumption by over 70% (Lebot, Benoit et al., 2000).

To continue, Figure 6 demonstrates how the load curve is distributed during 24 hours in a day and the peak hours mentioned above.

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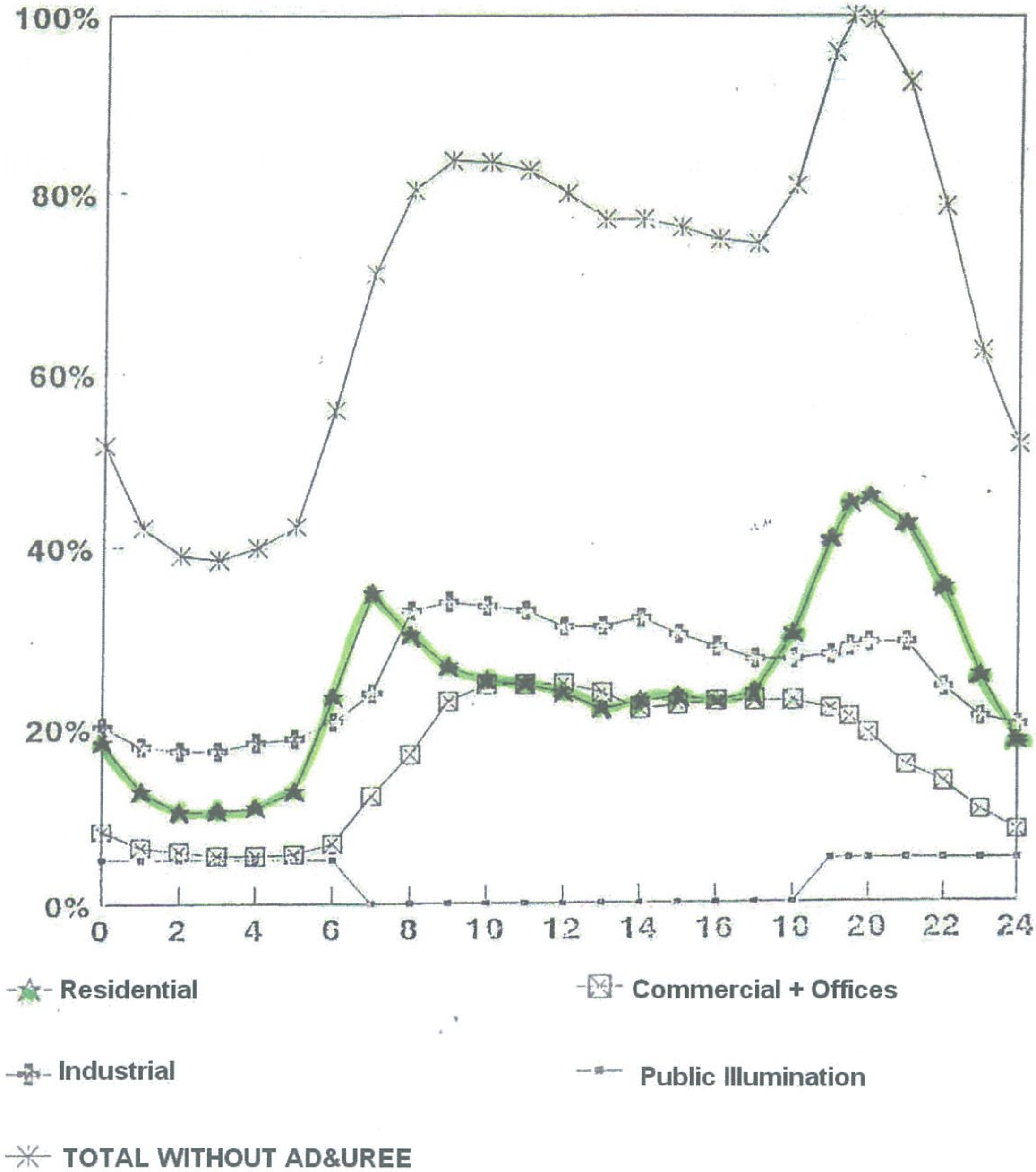
[1] OECD countries are members of the Convention on the Organization for Economic Co-operation and Development. The following countries have ratified in the OECD convention: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States (Organization for Economic Co-operation and Development, 2005).

Figure 6: Sector Load Curves – Highlands Region / Weekday (1991)



SOURCE: *(Ministerio de Electricidad y Energía Renovable, 2008)*

As depicted in figure 6, the residential sector load curve has high energy consumption during peak hours (6 a.m. – 8 a.m. and 6 p.m. – 8 p.m.). The first peak occurs because of water heating and the second is due to lightning appliances that function during these hours. However, water heating appliances might have changed due to water heaters that operate with subsidized liquefied gas.

2.2 Social Distribution[2] and Energy Consumption

During the INECEL study in 1993, the Minister distributed the residential users by social segments and energy consumption, this distribution is showed in Table 4.

Table 4: Social Distribution and Stratified Residential Energy Consumption (Ecuador)

SOCIAL DISTRIBUTION	ENERGY CONSUMPTION (kWh / month)
Low	0 – 50
Medium – Low	51 – 200
Medium	201 – 500
Medium – High	501 – 1000
High	More than 1000

SOURCE: *(Ministerio de Electricidad y Energía Renovable, 2008)*

[2] In the INECEL study of 1991, the social distribution is based on the energy consumption, classifying the social stratum per amount of energy consumed. Nevertheless, it is important to understand that the demand for energy is basically a derived demand that depends on the following factors: Prices of energy and the cost of energy using device, technology and related variables defining the efficiency of use; and incomes of consumers, and other actors in the system. Additionally, changing lifestyles and cultural preferences are also important factors to analyze at doing a social distribution for electricity consumption (Reddy, 2004).

In addition, the stratification of energy consumption has been used by the government to identify the segment where subsidies could be applied. Nevertheless, this stratification represents a tool to identify the segments where energy efficiency programs could be applied in the future.

As it was mentioned before, the current social distribution in Ecuador presents some problems on regards to some factors that are missing in the analysis of distribution. For instance, the current lifestyle in urban areas is characterized by the small amount of time spent at homes compared to the amount of time spent at work or out of home. If we classified the social distribution by energy consumption, then it will be the same to have a poor household whose members use 0 to 50 kWh / month and a wealthy family that spend most of the time out of home and consume the same amount of energy.

This is the reason why it is important to consider income aspects and other factors before doing a social distribution analysis, as well as the environmental responsibility that a wealthy family has for using more appliances that should be efficient to reduce emissions to the atmosphere. This study suggests that for future applications of social stratums and distributions it is necessary to include all the factors mentioned before to avoid biases, however, the study will continue with the current social distribution applied by INECEL.

The data available was taken from a study done by the Minister of Electricity and Renewable Energy which included the social distribution of residential electricity consumption for June 2007 in the Highlands region as shows Table 5.

Table 5: Social Distribution of the Residential Electricity Consumption

(Highlands Region – June 2007)

Social Segment by consumption	Stratum (kWh / month)	Subscribers	% of subscribers	Consumption (MWh)	% of Consumption	Billing (Thousands USD$)	% of Billing
High	up to 1000	4345	0.3%	8454	4.9%	778	4.7%
Medium - high	501 to 1000	19,616	1.3%	12,840	7.4%	1168	7.1%
Medium	201 – 500	207,741	13.8%	58,624	33.9%	5208	31.6%
Medium - low	51 – 200	739,322	49.0%	83,955	48.6%	7793	47.4%
Low	0 – 50	538,262	35.7%	8973	5.2%	1509	9.2%
TOTAL		**1,509,286**	**100%**	**172,846**	**100%**	**16456**	**100%**

SOURCE: *(Ministerio de Energía Renovable y Eficiencia Energética, 2008)*

Therefore, the data shown in Table 5 is the basis to calculate the distribution of the residential electricity consumption for the city of Quito as follows:

Table 6: Social Distribution of the Residential Electricity Consumption

(Quito – 2007)

Social Segment by consumption	Stratum (kWh / month)	% of subscribers	Quito's Subscribers	% of Consumption	Consumption (MWh)	% of Billing	Billing (Million USD$)
High	More -1000	0.3%	1,735	4.9%	56,073	4.7%	311
Medium - high	501 to 1000	1.3%	7,833	7.4%	85,164	7.1%	466
Medium	201 – 500	13.8%	82,958	33.9%	388,837	31.6%	2080
Medium - low	51 – 200	49.0%	295,236	48.6%	556,850	47.4%	3112
Low	0 – 50	35.7%	214,946	5.2%	59,515	9.2%	603
TOTAL		100%	602,708[3]	100%	1,146,439[4]		6571

[3] This data was gathered from the current indicators Quito's Electricity Company for current subscribers in 2007.(Empresa Electrica Quito, 2007)

[4] This data was gathered from the current indicators Quito's Electricity Utility for current consumption in MWh in 2007.((Empresa Electrica Quito, EEQ 2007)

According to Table 6, the segment with more energy saving potential is the medium-low segment with monthly electricity consumption of 51 – 200 kWh and 48.6% of energy consumption.

This table also shows that even if the 85% of subscribers are located in the medium-low and low segments, the application and importance of the energy efficiency program will be addressed to the medium and medium-low segments that represent the 82.5% of energy consumption in Quito.

2.3 Tariff Aspects

Electricity prices are important at the moment of analyzing an EE program. In the case of Latin America, electricity prices have not encouraged energy efficiency measures due to cross subsidies (Vieira de Carvalho, Poveda-Almeida, & Zak, 1996).

However, it is necessary to analyze the tariff structure that in the case of Quito's residential users has the following characteristics:

The residential tariff is applied to residential users independently of the load connected. The charges for billing are USD$ 1.414 which includes commercialization and is independent from energy consumption.

Energy consumption is charged per consumption block (kWh) as table 7 shows:

Table 7: Electricity Pricing for Residential Users – (30th June 2009 – Quito)

Consumption Block (kWh)	Charges for consumption (US$)
0 – 50	0.068
51 – 100	0.071
101 – 150	0.073
151 – 200	0.080
201 – 250	0.087
251 – More	0.089

SOURCE: *(Empresa Electrica Quito, 2009)*

Additionally, the electricity tariff for Quito's residential users has a cross subsidy, a solidarity subsidy and the dignity tariff subsidy. The cross subsidy consist in the reduction of US$2.10 on the final electricity consumption bill for those users who consume between 1 to 130 kWh per month. The solidarity subsidy is a 10% discount in the electricity bill for users that consume more than 161 kWh because of their contribution to the cross subsidy before mentioned. The last subsidy corresponds to the Executive Decree No. 452-A which mentions that residential users that consume up to 110kWh/month will pay $US 0.04 /kWh of consumption and $US 0.7 per month for commercialization. This subsidy is shown in the electricity bill as an independent concept.

2.4 Identification of the Measures and Technology Evolution

The identification of measures is going to be analyzed for three appliances: light bulbs, refrigerators and water heaters based on the tenure percentage from the INECEL study of 1991 including stratification of electricity consumption per household.

2.4.1 Light bulbs

According to the light bulbs' substitution program, the total amounts of incandescent light bulbs replaced are 6,000,000. In 2008 the progress of light bulbs substitution reported in the Highlands region was 2,982,312 out of 6 million light bulbs (Gobierno Nacional de la Republica del Ecuador, 2008). If in 2007 the number of clients connected to the electricity grid in the highlands region were 1,509,286, and the number of clients of Quito's Electricity Utility was 602,706[5] for that same year. Therefore, the light bulbs replaced for Quito's residential users are 1,192,925 that represent 40% of the total light bulbs replaced in the highlands region.

According to Mentor Poveda, the energy saved from replacing incandescent light bulbs for Compact Fluorescent Light Bulbs (CFL's) is 0.045 kW/ lamp which multiplied by the estimated number of light bulbs replaced in Quito will give a previous result of 53,682 kW[6].

This number represents the total no coincident where 50% of real savings is 26,841 kW (26.8 MW) for Quito's residential sector. In order to transform the power demand of energy the number of hours that these appliances will work is required.

According to peak hour's demand in the highlands load curve, which will be assumed to be similar to Quito's load curve (See figure 9), from 6 p.m. to 8 p.m. is the peak, where illumination has the greatest influence. Therefore, the energy saved in peak hours is 71,576 kWh.

As figure 9 shows, the residential load curve could be modified by the energy savings generated from substituting incandescent bulbs by CFLs.

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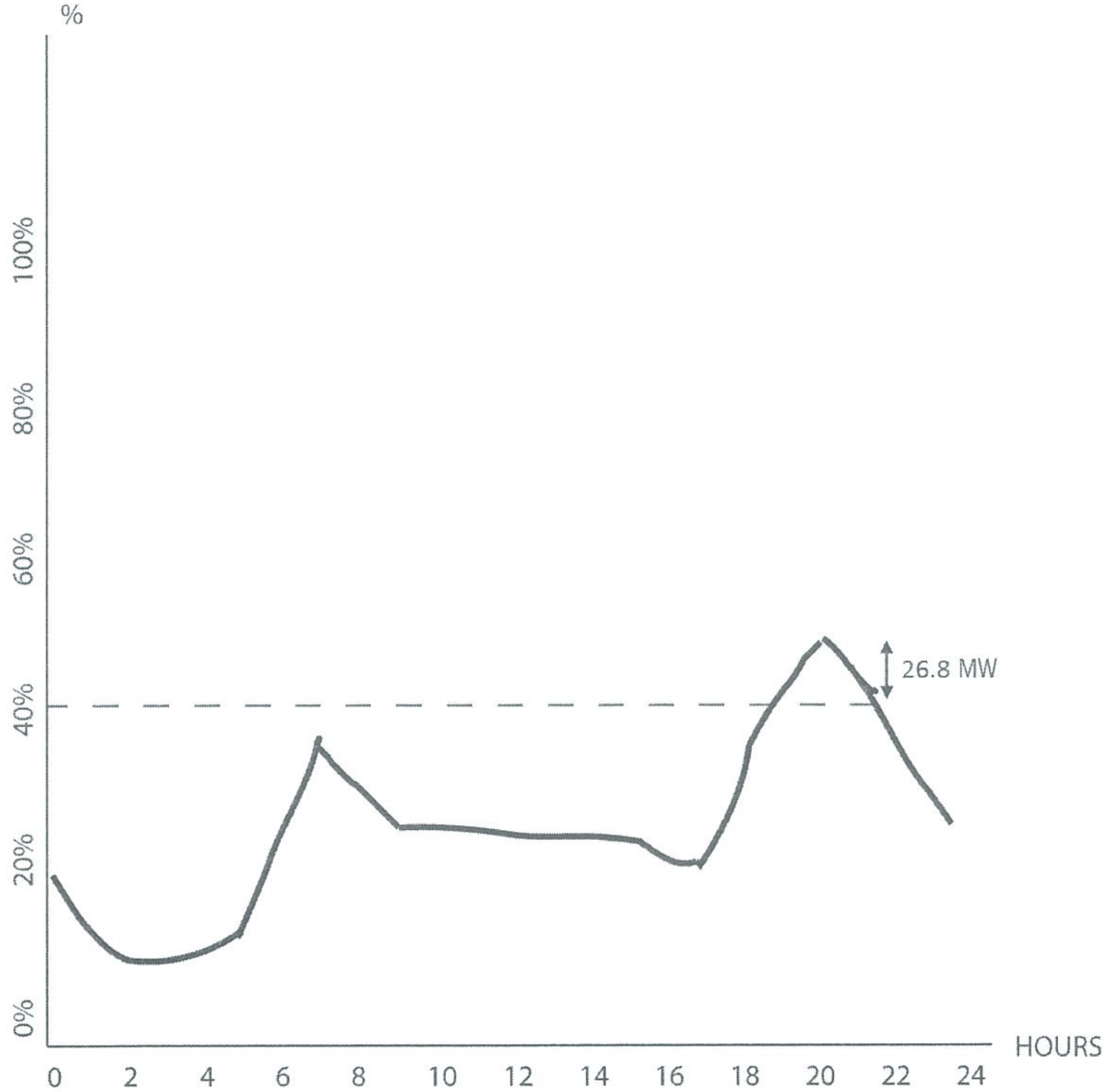
[5] Retrieved from: (Empresa Electrica Quito, 2009) – Number of clients.
[6] 1'192924.8 lamps * 0.045 kW/lamp = 53682 kW

Figure7: Power reduced in the residential load curve



The technological evolution of light bulbs is given by the improvements on wattage reductions and increasing in hours of consumption. For instance, lighting consumption is determined by assuming certain wattage per lamp bulb, where the most common in surveys is 60W for incandescent lamps, 15W for CFLs, and 36W for fluorescent tubes (McNeil, Letschert, & de la Rue du Can, 2008). The saving potential of CFLs is 60% and 80% less energy consumption than the incandescent lamps. In addition, the compact fluorescent light bulbs have a longer life time, between 6000 and 15,000 hours compared to 1000 hours of the incandescent lamps (Dunn, 2008).

According to Yépez the energy-saving potential with CFLs technology could be big, due to the wattage reduction from using this technology. For instance, Yépez compared wattages from incandescent and CFLs as table 10 shows:

Table 8: Comparison between incandescent and CF lamps wattage for similar light level service (Finn & Ouellete, 1992)

Incandescent Wattage	CFL Wattage
25	5
50	9
60	15
75	20
100	25
120	28
150	39

SOURCE: *(Yepez, 2003)*

The energy consumption of fluorescent lamps depends on the lamp efficacy and losses in the lamp ballast[7]. According to McNeil et al. the energy saving potential of a 36W fluorescent tube can be replaced by a 15% less consuming tube, representing 25% improvement compared to the standard electromagnetic ballast. (McNeil, Letschert, & de la Rue du Can, 2008). In this case, the energy efficiency scenario will take into

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[7] Lamp efficacy refers to amount of light output per unit input energy of a lamp or lamp-fixture system (McNeil, Letschert, & de la Rue du Can, 2008).
The ballast is the element on the light bulb that control the current and voltage applied to the lamp (Yepez, 2003)

account the replacement of incandescent lamps of 60W for CFLs of 15W, representing an average power saving potential of 45W.

2.4.2 Refrigerators

The characteristics of refrigerators vary between countries depending on the size of the cabinet, freezer compartment configuration and added features, such as automatic defrost, ice makers, etc. Nevertheless, Energy Efficiency Standards & Labels (EES&L) most often regulate this product motivating manufacturers to be more efficient. (McNeil, Letschert, & de la Rue du Can, 2008). In the case of refrigerators and refrigerator – freezers, the international efficiency and unit energy consumption (UEC) is more broadly available, compared to other appliances due to its high share of household electricity consumption.

Therefore, the baseline to analyze this product is to consider data from the study "Global Potential of Energy Efficiency Standards and Labeling Programs" by the Berkeley National Laboratory and Ernest Orlando Lawrence that includes some basic assumptions for the Latin American region based on current Mandatory Energy Performance Standards (MEPS) in Mexico and Brazilian labeling program.

Additionally, the study assumes the feasibility of aggressive targets for refrigerators for 2020 reaching the current 'A+' level. According to this study the optimistic scenario is given by two reasons:

"There exists a wealth of understanding of refrigerator efficiency technology (compressor design and insulation), with high efficiency being a requirement in some markets already for decades." (McNeil, Letschert, & de la Rue du Can, 2008, pp. 43).

"There is a trend towards internationalization of major white goods, and a large number of successful EES&L programs in many countries, providing ample opportunity for alignment to best practices." (McNeil, Letschert, & de la Rue du Can, 2008, pp. 44)

As a result, the study mentioned above depicts refrigerators' energy consumption of 261 kWh/year for 2010 and 216 kWh/year for 2020, assuming 39% improvement in Brazil by 2010, harmonizing Mexican standards with U.S. by 2010 and reaching A+ European Union level by 2020.

The scenarios for refrigerators mentioned above could be related to Ecuador, since the Minister of Electricity and Renewable Energy is restricting the imports of inefficient refrigerators. On July 9th , 2009 the Minister signed a ministerial agreement No. 05 – 879 that modified the first one signed on November 8th ,2005, the last modification was published in the Official Record No.153 (Instituto Ecuatoriano de Normalizacion, 2009). This agreement does not allow commercial establishments to import equipment that do not count with energy saving technology. The agreement is under the resolution No. 118-2008 of Ecuadorian Institute of Normalization (INEN – Spanish acronym), which implies that only those refrigerators that have A and B labeling in the energy efficiency scale will be allowed to enter the country (CONELEC - Consejo Nacional de Electricidad, 2009).

The Ministry Alecksey Mosquera said that the Ecuadorian industry currently produces around 40,000 refrigerators per year that meet the technology required to save 50% of energy, and that 300,000 are imported from Mexico, Japan, Korea, Europe and China, which do not necessarily comply with the energy labeling approved. For instance, an inefficient refrigerator of 400 liters that is at the level "F" or "G" consumes around 800 kWh/year.

While, an efficient refrigerator at the level "A" or "B" will consume around 400 kWh/year, thus, it will be saving half of the annual consumption (CONELEC - Consejo Nacional de Electricidad, 2009).

The purpose of the government is to achieve the replacement of appliances by 2017, which will allow power savings of 200 MW by that time. In order to achieve this objective, Mosquera said that they will implement a scrapping program for refrigerators such that old appliances will be replaced by new ones.

Additionally, the government estimates that the imports restrictions will encourage national manufactures to cover 60% of the national demand of the appliances type A and B, therefore the measure will an incentive to the local industry and it will generate sources of labor (CONELEC - Consejo Nacional de Electricidad, 2009).

According to the Ecuadorian Technical Regulation RTE INEN 035, the Ecuadorian Institute for Normalization (INEN) is establishing mandatory parameters for energy efficiency in household refrigerating appliances, energy consumption, test methods and labeling. This regulation aims to set up the procedures and requirements to report the values of Reference Energy Consumption and the ranges of energy consumption that will allow the classification of the appliances. Additionally, it specifies the content of the label of energy consumption for all types of household appliances for refrigeration with the objective of health prevention, security and environmental risks and practices that could lead to non-efficient energy consumption for final users (Instituto Ecuatoriano de Normalizacion, 2009).

In order to summarize this regulation, this study will take into account the type 4 refrigerators from 11 types existing in the RTE INEN 035. Type 4 is a freezer – refrigerator which consists in a combination of a refrigerator with a freezer mounted on top, automatic (defrost), it can have separated controls for the freezer and for the food compartment. Also, it does not include the service of water/ice through the front door, but it includes all the refrigerators with automatic defrost.

The INEN regulation includes the energy consumption analysis for two regions, tropical and subtropical regions, which in this case the subtropical region is the one that will be applicable for Quito. Therefore, the National Energy Consumption (NEC), according to the type of weather, type 4 refrigerator has $m_n = 0.78$ and a $Ce_{on} = 305$, where:

m_n is the slope of the curve of the CERn

- CERn is the Reference Energy Consumption expressed in kWh/year, and the way to calculate it is: $CERn = (m_n * VA) + Ce_{on}$
- Ce_{on} is the energy consumption expressed in kWh/year for an adjusted volume of zero.
- VA is the adjusted volume in liters

The adjusted volume of the refrigerators is calculated by the following formula:

VA = Gross volume of the fresh food compartment (liters) + [Gross volume of the low temperature compartment * Adjusted factor]

After considering and measuring all these aspects of the National Energy Consumption the regulation establishes the ranges of Reference Energy Consumption as follows:

Table 9: Ranges of Reference Energy Consumption

Range	Upper limit including %[8]	Lower limit (%)
A	67.5	0
B	77.5	67.5
C	92.5	77.5
D	107.5	92.5
E	122.5	107.5
F	132.5	122.5
G	α	132.5

SOURCE: *(Instituto Ecuatoriano de Normalizacion, 2009)*

From to the same INEN regulation, the requirements for labeling energy consumption in refrigerators are:

The energy consumption label must have the following characteristics (Instituto Ecuatoriano de Normalizacion, 2009):

Permanence: The label must be well pasted to the appliance in such way that it could only be removed after final purchase and user's convenience.
Location: The label must be located in a visible area for the consumer.
Information: The label must be readable and must at least contain the following information:

[8] The percentage is related according to the National Energy Consumption - CERn

> *A legend saying "ENERGY", registered brand, specification of the model, type of appliance (including its classification according to the product's design), indicate the range of energy consumption between A and G, specify the energy consumption in kWh/year including the legend saying that " The real consumption depends on the conditions of use and the location of the appliance". Additionally, the label should include the indicator of energy efficiency defined as the relation between energy consumption kWh/year and total net volume in liters, the type of climate (tropical –T or subtropical - ST). Finally, the label should specify the total net volume of the appliance, the net volume for the fresh food compartment and the net volume of the low temperatures compartment.*

The testing methods done by the INEN in order to approve and launch the refrigerators to the market will be mentioned further when implementation of the EE program will be analyzed.

According to Yépez (Yépez, 2007), the technological evolution in refrigerators has changed quickly in the last three decades. A typical new refrigerator of the type 4 mentioned before, with automatic defrost and top-mounted freezer uses less than 500 kWh/year. On the other hand, the models sold in 1973 used over 1800 kWh/year.

The difference of efficiency between the old and the new appliances is given by changes in more efficient compressors, improved insulation, better door seals, improved condensers and evaporators, and more precise temperature controls and defrost mechanisms. Therefore, energy-efficient refrigerators save energy by using less energy per unit volume cooled (Yepez, 2003).

Yepez also reported that OLADE has estimated energy savings from new efficient refrigerators with an average of 450 kWh/year/ appliance. At the moment of purchase many energy – efficient products could be more expensive than the normal ones, however, they will cost less to operate over the lifetime of the appliance. Another measure in refrigeration is related with maintenance and improvements of existent appliances. Better equipment position, internal and external cleaning, good sealing conservation, and thermostat adjustments (4°C for the refrigerator and -12°C for the freezer) are ways to achieve energy savings. Nevertheless, Latin American households are not known for the maintenance awareness in appliances and the best way to achieve energy savings is through the replacement of old refrigerators for new ones (Yepez, 2003).

2.4.3 Water heaters

According to McNeil et al. water heating efficiency depends on the technology used to heat water which could be done by electricity, natural gas or other fuels. The electric or gas-storage type water heaters are significantly used by owners that have instantaneous shower-type water heaters and these appliances can contribute more to household energy consumption than any other end-use, except perhaps space heating and lighting.

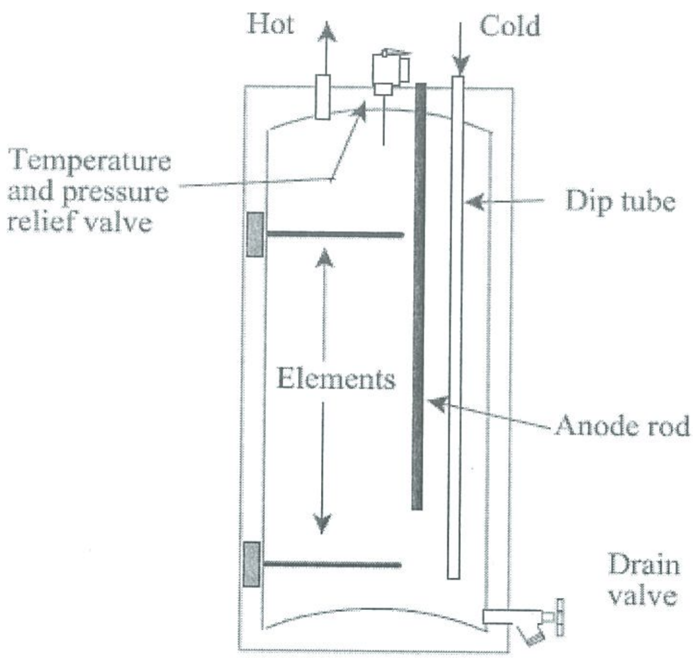
In addition, the consumption of these appliances depend on climate, size of households, the capacity of the device (tank size), and on cultural practices and preferences.

As a consequence, McNeil et al. estimated useful water heater energy (consumption) for Latin America of 955 kWh/unit with a fuel share of: Electricity 9%, Fuel 54%, and other 37%. According to McNeil et al. the 9% representing electric water heaters have a basic efficiency of 0.79 and will achieve 0.83 and 0.88 in 2010 and 2020 respectively (McNeil, Letschert, & de la Rue du Can, 2008).

A conventional, residential electric storage water heater consists of an insulated, glass-lined, steel hot water storage tank, corrosion protection (anode rod), hot and cold water connections, a temperature and pressure relief valve, and a drain valve as shown in figure 8. In order to heat the water, an electric water heater has two (upper and lower) electric resistance heating elements, each typically 4500 W.

The input power is controlled by thermostats mounted on one side of the tank where only one element operates at a time. The upper element operates when hot water has almost been emptied and the lower element for heating the bulk of the water in the tank (U.S. Department of Energy - Energy Efficiency and Renewable Energy, 2001).

Figure 8: Residential Water Heater



SOURCE: *(U.S. Department of Energy - Energy Efficiency and Renewable Energy, 2001)*

For instance, the efficiency of a residential water heater is expressed in terms of the energy factor (EF)

$$EF = \frac{\text{heat delivered (as hot water)}}{\text{the energy consumed}}$$

The EF accounts for recovery efficiency (RE) and standby losses, and the required minimum energy factor varies with the size of the tank. Typical 50-gallon electric water heaters have minimum energy factors of 0.54. The range of energy factors for electric water heaters currently on the U.S. market is 0.81–0.95. The range of energy factors is accounted for primarily by differences in the insulation effectiveness and in tank size

2.5 Penetration of the measures

In order to illustrate the penetration of different equipments in an EE program, the study done by McNeil et al. is the reference to obtain information about the relationship between the equipment penetration (lighting, refrigeration and water heating) and the income level of the country.

2.5.1 Lighting

According to McNeil et al. a penetration model for lighting uses energy intensity derived from three factors: efficiency of the ballast and the fixture, hours of usage, and penetration of equipment. In the case of Latin America, lighting intensity data is available for Argentina, Uruguay, Chile and Brazil as shows table 10.

Table 10: Lighting Intensity

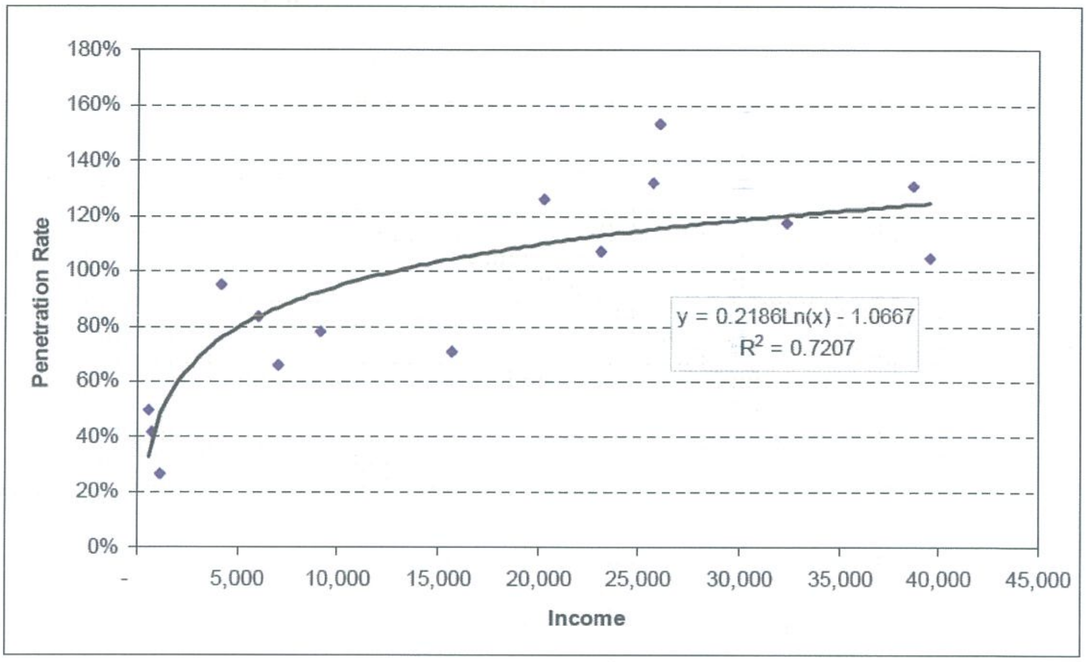
Country	kWh/m2	Source	Income	Efficiency factor assumption	Hours of use factor assumption	Penetration
Argentina	28.9	(Lutz, McNeil et al. 2008)	9132	0.81	1	0.78
Uruguay	37	(UTE, 1999)	7048	0.81	1.52	0.66
Chile	46.9	(Deirdre 1999)	6006	0.81	1.52	0.83
Brazil	53.5	(COPPE 2005)	4206	0.81	1.52	0.95

SOURCE: *(McNeil, Letschert, & de la Rue du Can, 2008, p. A-29)*

The penetration rates were then associated with income and used to develop a lighting equipment penetration model as represented in Figure 11

According to the National Institute of Statistics and Censuses (INEC), the Ecuadorian family income registered during 2008 in urban areas was around $380 monthly, which represents $4,560 yearly (INEC - Instituto Nacional de Estadisticas y Censos, 2009). This level of income allocates Ecuador (Quito and urban areas) in a similar position to Brazil regarding income level.

Figure 9: Lighting Equipment Penetration Model



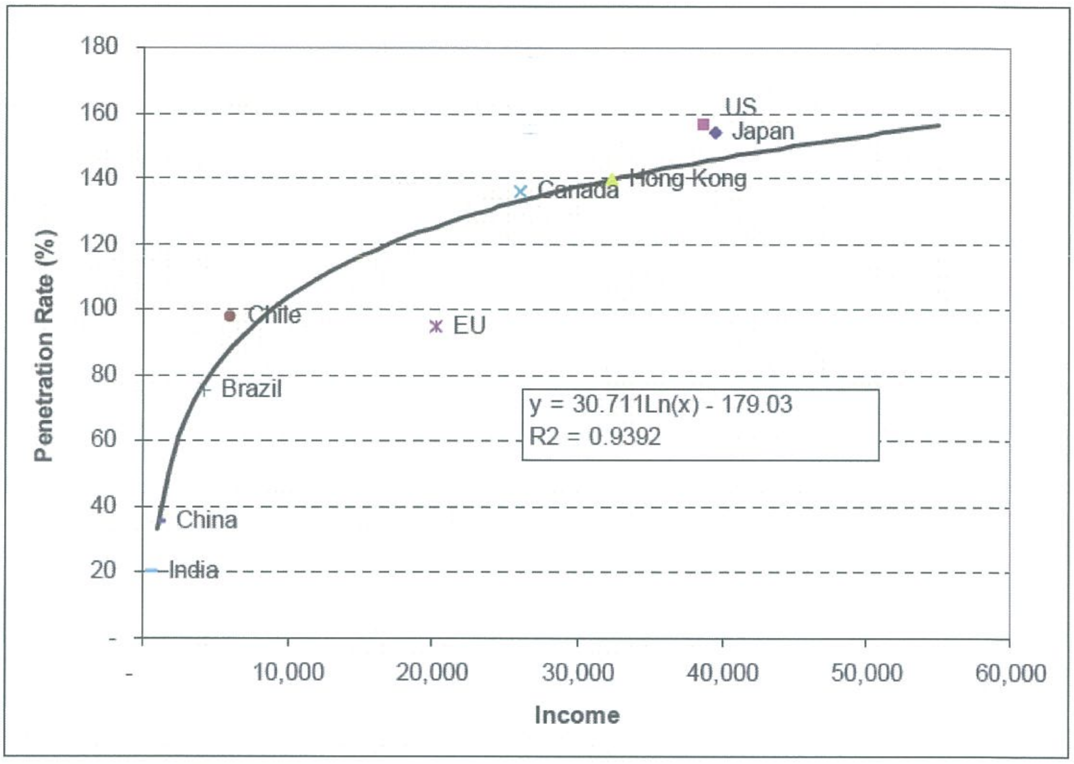
SOURCE: *(McNeil, Letschert, & de la Rue du Can, 2008, p. 34)*

McNeil et al. conclude that "The lighting intensity baseline for the countries mentioned above was calculated using the penetration derived from the equation shown in Figure 9 and from the assumptions of efficiency coefficient and hours of use" (McNeil, Letschert, & de la Rue du Can, 2008, p. 34)

2.5.2 Refrigeration

The penetration of refrigeration equipment has a similar model as cooling and lighting equipment penetration that drives energy intensity. According to Mc. Neil et al. the penetration for refrigeration will follow a similar path to space cooling equipment as represented in Figure 10.

Figure 10: Cooling Equipment Penetration by Income level



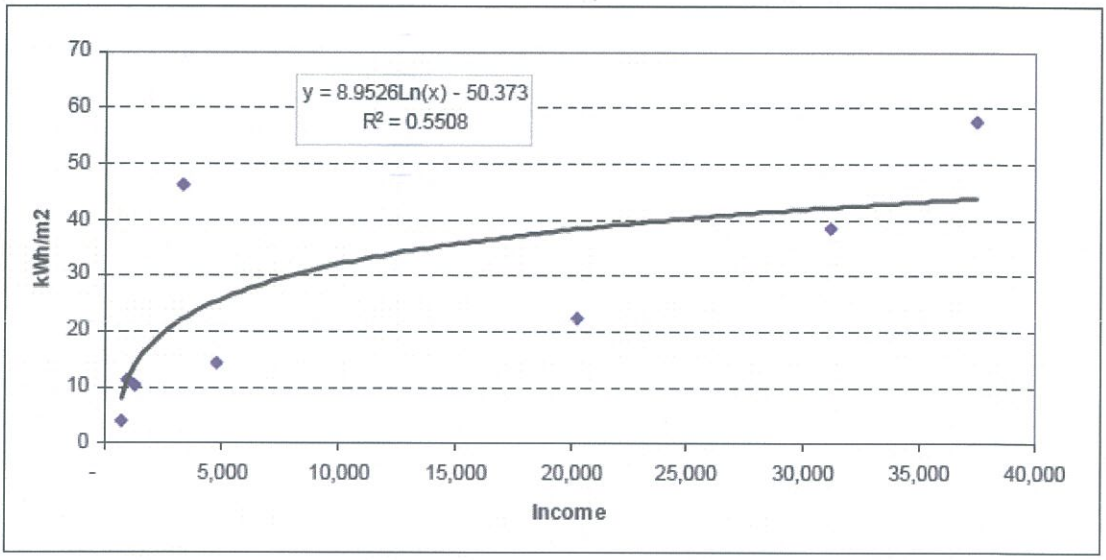
SOURCE: *(McNeil, Letschert, & de la Rue du Can, 2008, p. 36)*

As a result, the energy intensity for cooling from electric appliance in Chile and Brazil represent 12.20 kWh/m^2/year and 26 kWh/m^2/year respectively.

2.5.3 Water Heating

The penetration model is similar to the ones applied in refrigeration and lighting. Figure 11 shows the water heating intensity model for developing countries.

Figure 11: Water Heating Intensity Model for developing countries



SOURCE: *(McNeil, Letschert, & de la Rue du Can, 2008, p. A-31)*

2.6 Energy Efficiency scenario replacing household appliances

The energy efficiency scenario replacing household appliances considers a period of ten years starting in 2010 to 2020. In the case of lighting, the data was gathered from the Government´s replacement program that aimed to replace six million incandescent light bulbs in the Ecuadorian territory.

In order to estimate the growth of Quito's Electric Utility clients, the study has considered the data in Table 11 (Coyago Cruz, 2006).

The projection of clients from 2008 to 2020 was derived from a regression analysis. The model of number of subscribers taken from this analysis shows some issues as explained below:

Apparently, the correlation value (R^2) is close to 1 which is good for the model. "A value of 1 describes a relationship where an increase in one variable is accompanied by a predictable and consistent increase in the other" (Minitab Inc., 2007).

Nevertheless, there are other conditions for the accuracy of a model that have not been supported with the amount of data for subscribers per year available. In this case, a larger number of years is required to see the accuracy of the model. These other conditions are:

The model fails due to the number of subscribers. Also as figure 12 shows in the box plot, the data is not symmetric. It is possible to see that the model does not follow a normal curve or normal distribution as illustrated in Figure 13.

The residual plots of Figure 14 are used to examine the goodness of model fit in regression. These plots are helpful to determine if the value of R^2 is really met and if this regression will have unbiased coefficient estimates with the minimum variance (Minitab Inc., 2007).

In the case of the Histogram of the Residual, it is likely to see a skewed distribution due to the longer tail on the right side of the histogram. The normal probability plot should indicate a straight line if the residual is normally distributed (Minitab Inc., 2007). Some of the points come from a straight line; though the points at the left tail are separated from the line and may not show the normality assumption, thus may be invalid. The residual versus fitted values plot shows the dispersion of the data where the increasing of the residual values while increasing the fitted values should violate the constant variance assumption (Minitab Inc., 2007).

Table 11: Number of suscribers to Quito´s Electricity Utility (QEU)

YEAR	YEAR	NUMBER OF SUBSCRIBERS	SOURCE
1990	1	268,840	(Coyago Cruz, 2006)
1991	2	282,173	(Coyago Cruz, 2006)
1992	3	326,749	(Coyago Cruz, 2006)
1993	4	316,749	(Coyago Cruz, 2006)
1994	5	334,394	(Coyago Cruz, 2006)
1995	6	359,456	(Coyago Cruz, 2006)
1996	7	381,079	(Coyago Cruz, 2006)
1997	8	399,447	(Coyago Cruz, 2006)
1998	9	424,503	(Coyago Cruz, 2006)
1999	10	434,536	(Coyago Cruz, 2006)
2000	11	513,695	(Empresa Electrica Quito, 2007)
2001	12	536,634	(Empresa Electrica Quito, 2007)
2002	13	559,404	(Empresa Electrica Quito, 2007)
2003	14	581,394	(Empresa Electrica Quito, 2007)
2004	15	608,760	(Empresa Electrica Quito, 2007)
2005	16	641,136	(Empresa Electrica Quito, 2007)
2006	17	676,755	(Empresa Electrica Quito, 2007)
2007	18	709,449	(Empresa Electrica Quito, 2007)
PROJECTION			
2008	19	713,797	
2009	20	740,073	
2010	21	766,349	
2011	22	792,625	
2012	23	818,901	
2013	24	845,177	
2014	25	871,453	
2015	26	897,729	
2016	27	924,005	
2017	28	950,281	
2018	29	976,557	
2019	30	1,002,832	
2020	31	1,029,108	

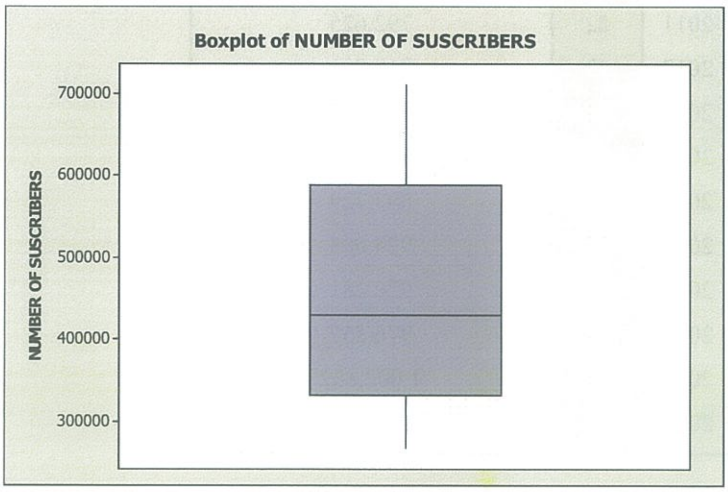
In this case, the model has a great dispersion in relation with the fitted values. As a consequence, the model violates the constant variance assumption. ¨ The residuals versus order of data is a plot of all residuals in the order that the data was collected and can be used to find non-random error, especially of time-related effects. This plot helps you to check the assumption that the residuals are uncorrelated with each other¨ (Minitab Inc., 2007, residuals plot). In this case, this plot shows that the data at the left side is uncorrelated with each other, while the other data shows correlation.

After analyzing the failures of the model, the main consequence of using it is that while going further in time, the error is bigger and it grows asymptotically.

Despite all this consequence and the innefectiveness and accuracy of the model, the study is going to assume that the variances are equal every year of analysis, and it will consider the results of the regression for future calculation of number of suscribers.

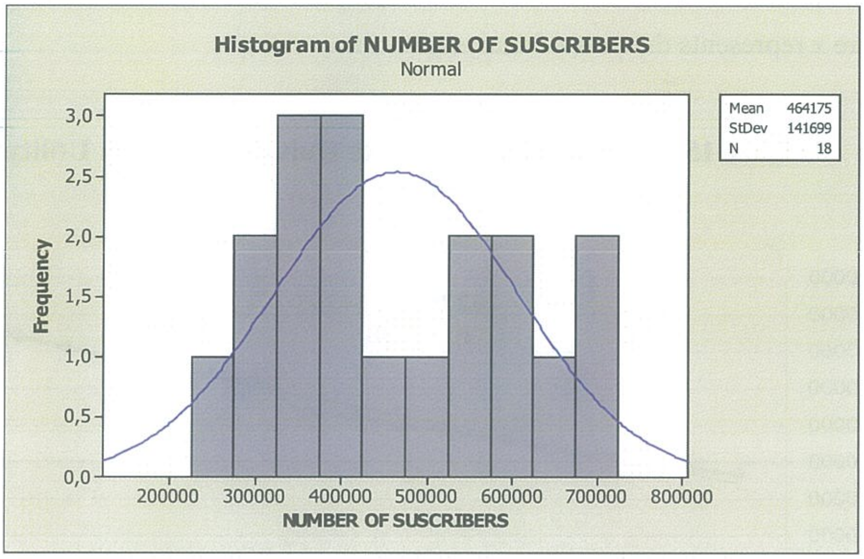
However, the advise for next studies is that the data sample of number of suscribers should be bigger or at least of 30 data, which has been an obstacle for this study.

Figure 12: Box plot of Number of Subscribers



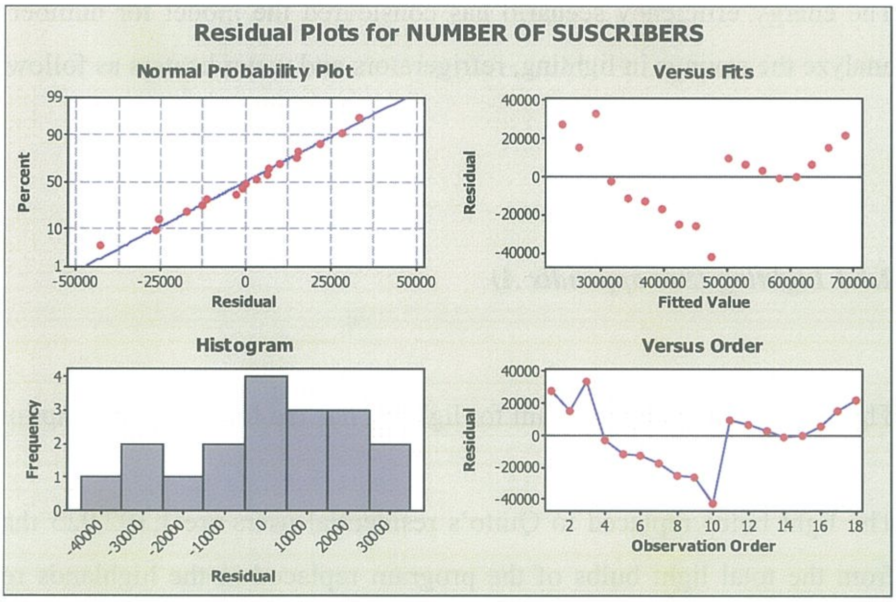
Source: *(Minitab Inc., 2007)*

Figure 13: Histogram of Number of Subscribers (Normal)



Source: *(Minitab Inc., 2007)*

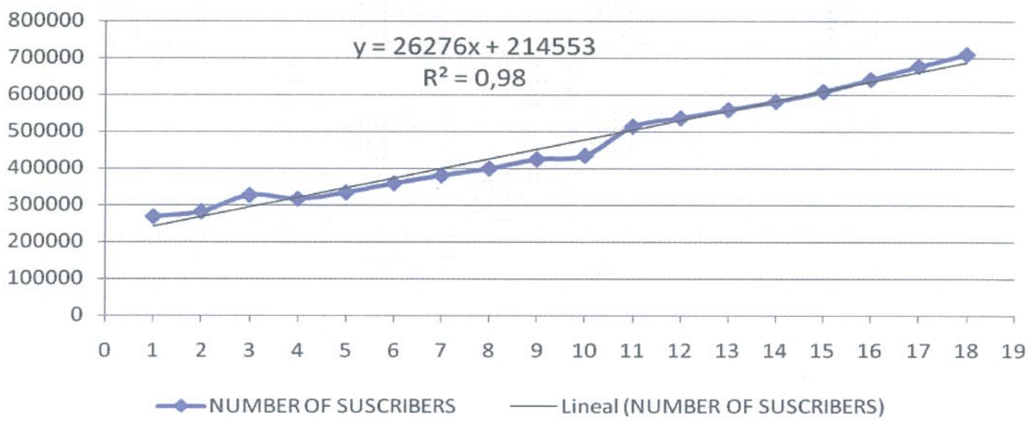
Figure 14: Residual Plots for Number of subscribers



Source: *(Minitab Inc., 2007)*

Considering the failures and validation of the model, Figure 15 depicts the trend of number of subscribers for Quito´s residential clients. As a conclusion, the equation derived from the graph for the future the projection of Table 11 is *26,276x + 214,553*, where *x* represents the year of analysis.

Figure 15: Number of suscribers to Quito´s Electricity Utility (EEQ)



The energy efficiency scenario has considered the model for number of suscribers to analyze the savings in lighting, refrigerators and water heaters as follows:

2.6.1 Lighting (See appendix A)

The energy efficiency program for lighting has the following assumptions:

The light bulbs replaced to Quito's residential users are 1,192,925 that represent 40% from the total light bulbs of the program replaced in the highlands region. (From the lightbulbs' replacement program). According to the Olade's expert Mentor Poveda, the number of light bulbs per subscriber is 6 in average. As a consequence, the total estimated number of light bulbs in Quito is 4,200,000. According to the growth for subscribers to the EEQ, the number of subscribers increasing each year is based on the equation *26,276x + 21,4553*, where *x* represents the year of analysis.

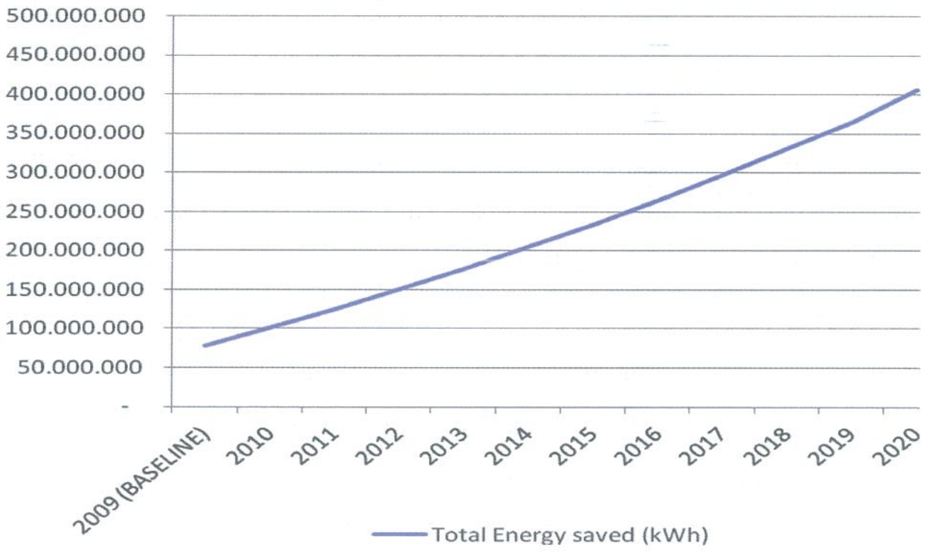
The Energy saved replacing incandescent lamps is 0.045 kW/ lamp, multiplied by the estimated number of light bulbs replaced in Quito: 53682 kW* 4 hours/day (average) * 365 days = 78,375,172.5 kWh /year.

Nevertheless, it is necessary for power to include the coincidence factor of 0.5 which is the ratio of the maximum demand of a group, class, or system as a whole to the sum of the individual maximum demands of the several components of the group, class, or system. As defined, coincidence factor can never be greater than unity (Progress Energy, 2003).

At the beginning the program started with a penetration of 28% derived from the No. of light bulbs replaced in the program 2008-2009 divided by the total number of light bulbs in the city. Second, from the Lighting Equipment Penetration Model that considers a yearly family income of $4560, the study assumes 75% for the fifth year, and the last year a penetration of 100% assuming that for the last years the legislation will be stricter than other years.

In this case, the energy efficiency scenario will take into account the replacement of incandescent lamps of 60W for CFLs of 15W, representing an average power saving potential of 45W. In the Appendix A it is possible to see the that the energy saved per client is constant with a value of USD$ 394,2 every year. The amount of money saved per year is constant because the purchase of the appliance is done once. In contrast Figure 16, depicts that the total energy saved from the replacement of incadencent lightbulbs increases with time, while the number of suscribers increases every year.

Figure 16: Total Energy Saved (kWh) from the replacement of incandescent lightbulbs

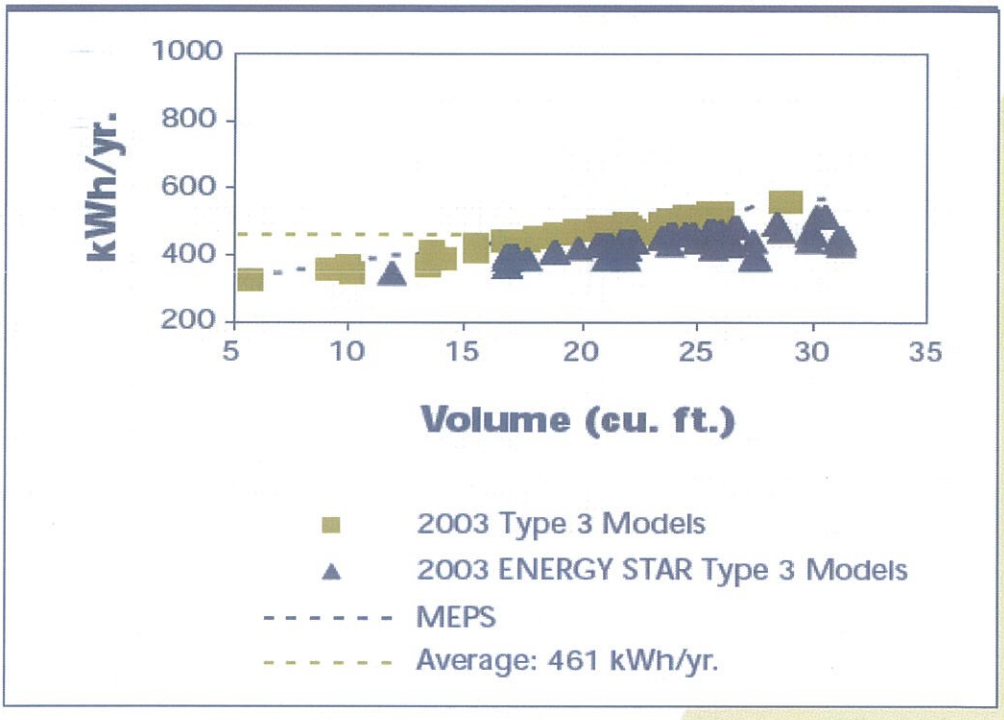


Source: (See appendix A)

2.6.2 Refrigerators (See appendix B)

According to a study done by Natural Resources Canada, a type 3 refrigerator accounts for the 68.2% of the ownership for household appliances. This type 3 refrigerator consists of refrigerator-freezers with automatic defrost, with top-mounted freezer and without through-the-door ice service, as well as refrigerators without freezers but with automatic defrost (Natural Resources Canada- Office of Energy Efficiency, 2005)

Figure 17: Energy Consumption of Type 3 Refrigerator – Models available in 2003



SOURCE: *(Natural Resources Canada- Office of Energy Efficiency, 2005, p.3)*

According to the Figure 17, the energy consumption of a 13 to 15 cubic feet refrigerator is 380 kWh/year.

Therefore, the program will take into account refrigerators of 13 cubic feet for the three lowest stratums of consumption and refrigerators of 25 cubic feet for the two highest stratums of consumption considering energy consumptions of 461 kWh/year.

In order to analyze the trend of clients, it is necessary to separate this number of clients into stratums as shown in table # 12. This table shows the clients per stratum in the Highlands region. However, it is possible to estimate the number of clients per stratum considering that for 2009 the number of clients is 740,073.

Table 12: Stratums of Energy Consumption in the Residential Sector

(HIGHLANDS REGION - JUNE 2007) [9]		%	QUITO'S CLIENTS - 2009
STRATUM	**CLIENTS**		
1000 - >	4,345	0.3%	2,131
501 -1000	19,616	1.3%	9,619
201 - 500	207,741	13.8%	101,865
51 - 200	739,322	49.0%	362,524
0 - 50	538,262	35.7%	263,935
TOTAL	**1,509,286**	**100%**	**740.072,77**

In the case of Ecuador, the efficient refrigerators do not include those with the Energy Star labeling because this is the next step to the replacement of old refrigerators, which is the difference with Canada and other developing countries that include Energy Star as the efficient scenario.

According to the penetration rate model for cooling equipment, the assumption is that Ecuador will have a penetration rate of 65% after changing refrigerators. In 2010, the program starts with 0% of penetration of efficient appliances until it achieves the 65% for the last year.

Mentor Poveda mentioned that in Costa Rica, a country with less poverty, the ownership of refrigerators is 85%, so it has sense for Ecuador that at the end of the program, 65% of Quito's residential users will have refrigerator at home.

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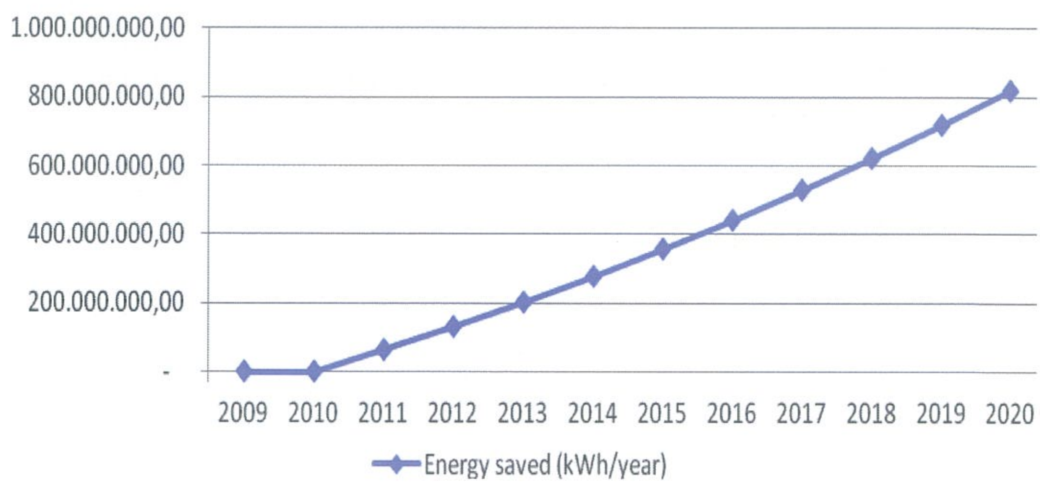
[9] (INECEL, 1994)

According to Mentor Poveda, the total power savings are derived from the Load Factor equation that is *kW*8760 hours in a year*load factor = kWh*. For instance, the equation to obtain power applied to inefficient refrigerators is: *1,800 kWh/ 8760hours /0. 30 = 0.68kW.* According to the Olade's expert, Mentor Poveda, the assumption for this case is that for inefficient refrigerators the load factor is *0,35*; while for efficient refrigerators is *0. 30.*

Appendix B shows the scenario with the replacement of inefficient refrigerators. Therefore, Figure 18 shows the total energy saved per year. In the case of refrigerators, the savings per clients is constant as happened with light bulbs depicting a value per year of USD$ 1222,7.

Figure 18: Total Energy saved (kWh/year) replacing inefficient refrigerators



2.6.3 Water Heaters (See appendix C)

In order to calculate the energy savings from the installation of timers in water heaters, the study has considered the following assumptions:

In the INECEL study of 1991, the usage of electric showers in the lowest stratums is high as illustrated in table 13, so the efficient measures for water heating will be applied in the two highest stratums of energy consumption due to the ownership percentage that in the case of water heaters the stratum that consumes 501 -1000 kWh has 91.43 ownership % and the stratum of 1000 kWh and more has 90 ownership %.

Table 13: Ownership of Electric Showers in Quito´s Residential Sector

STRATUM (kWh)	% OWNERSHIP	No. of appliances (working)
0 - 50	5.26	1,570
51 - 200	32.03	37,176
201 - 500	35.44	18,384
501 -1000	11.43	2,079
1000 - >	0	

Source: (INECEL, 1994)

In 2000, the U.S. Department of Energy reported energy consumption for electric domestic water heaters of 3,460 kWh/year.

The opportunity to save energy in an electric water heater is through the installation of a timer that turns it off at night when most people do not use water and/or during the utility's peak demand times. The range percentage of savings from installing timers is 5% to 12% (U.S. Department of Energy, 2009).

According to the Olade's expert, the percentage for Quito should be 12%, due to hot water consumption behavior that is affected by weather temperatures between 10°C and 22°C in the Highlands region. These temperatures allow people to use hot water just for one shower a day, thus increasing the effectiveness of timers.

From the previous data of 3,460 kWh/year for electric domestic water heating, it is possible to have savings of 415.2 kWh/year from the installation of timers to save energy.

For the penetration of efficient water heaters, the assumption will be to have the same penetration as refrigerators. The first five years of 65% and the last five years of the program a penetration of 100%.

The coincidence factor for water heating used to calculate the power is 0.4 (Bonneville Power Administration, 1991)

Figure 19 depicts the total energy savings from installing timers. The graph has the same behavior as the other residential appliances increasing the total benefit. In addition the benefit for consumer is constant and the money savings per year from the installation of water heaters represents USD$ 319.2. The total energy savings achieved by installing timers could be a great opportunity to improve the technology of water heaters including this feature.

Figure 19: Total Energy saved per year (kWh) from installing Timers

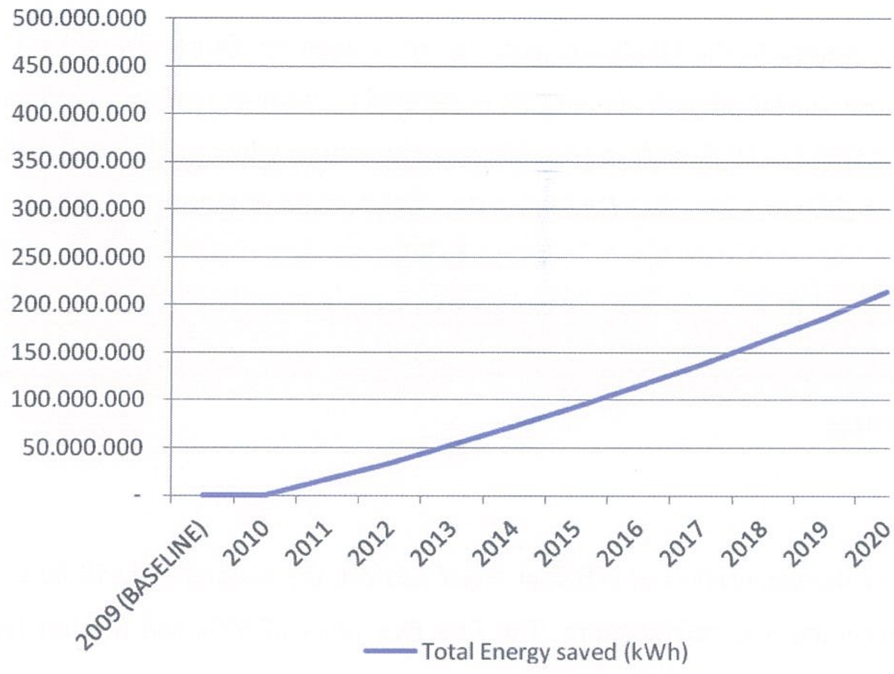


Figure 20 indicates the total and individual savings after implementing the EE program. This figure shows that the biggest savings are obtained from replacing inefficient refrigerators. Therefore, this behavior is useful for consumers at the moment of prioritize their purchases.

On the other hand, it is important to calculate the biggest power savings in order to prioritize the program for producers. In this case, Figure 21 depicts the biggest power savings which is lighting during the first 5 years of the program, followed by refrigeration which increases during the last 5 years of the program, and finally water heaters.

Figure 20: Total Energy Savings (kWh/year) for Lighting, Refrigerators and Water Heaters Applying the EE Program

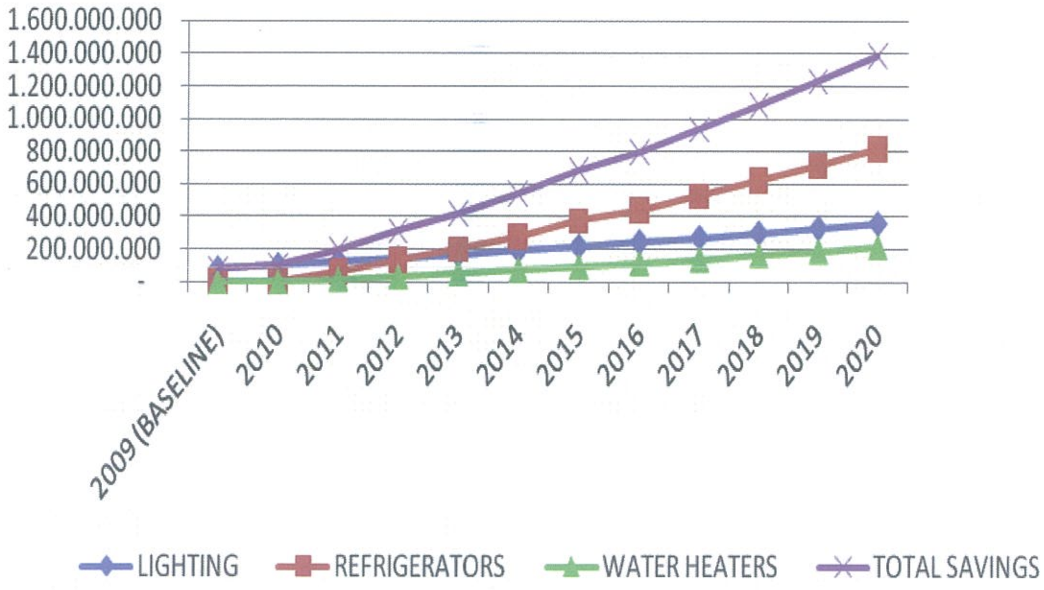
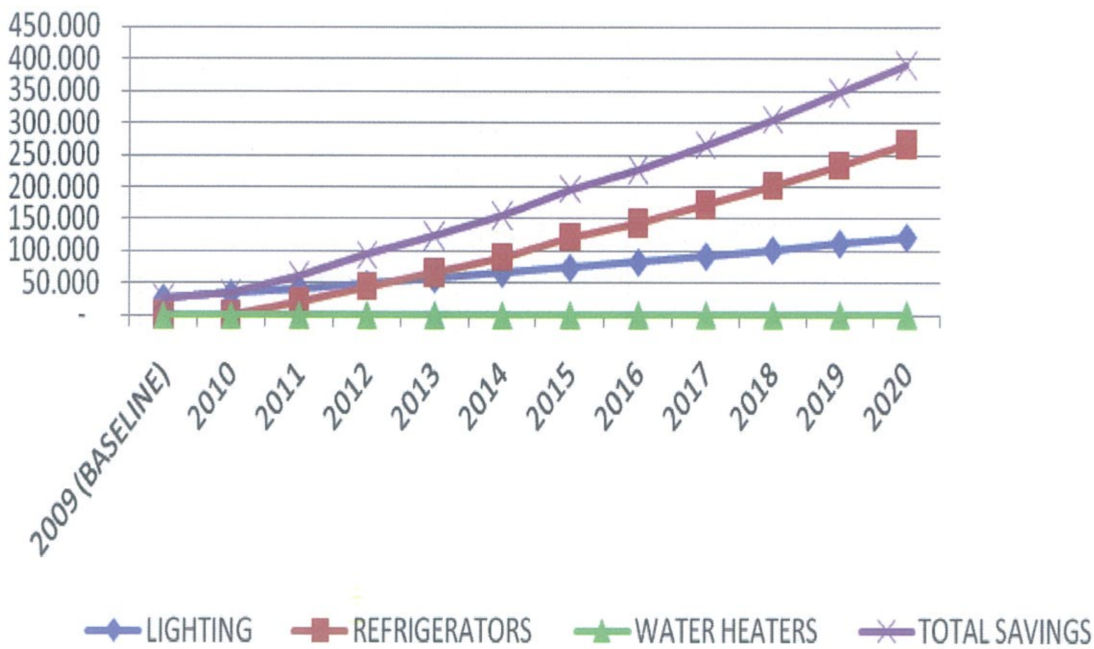


Figure 21: Total Power saved (kW) for Lighting, Refrigerators and Water Heaters Applying the EE Program



2.7 Economic benefits for consumers

In order to analyze the economic benefits from the EE program, it is required to mention the prices of electricity per stratum as shows Table 14.

Table 14: Monthly Tariffs for Residential EEQ´s clients, per Stratum

RANGE OF CONSUMPTION CATEGORY	ENERGY (USD/kWh) RESIDENTIAL	MARKETING (USD/consumer)	
		MONTLY	10 YEARS
0-50	0.068	1.414	14.14
51-100	0.071	1.414	14.14
101-150	0.073	1.414	14.14
151-200	0.080	1.414	14.14
201-250	0.087	1.414	14.14
251-300	0.089	1.414	14.14
301-350	0.089	1.414	14.14
351-400	0.089	1.414	14.14
Superior	0.089	1.414	14.14
AVERAGE	**0.082**		

SOURCE: *(CONELEC - Consejo Nacional de Electricidad, 2008)*

Figure 22: Economic savings from the replacement of inefficient appliances per client, per year in $USD

In the case of lighting, Figure 22 [10] shows the economic savings from the replacement of inefficient appliances per client, per year. The figure shows that the savings are constant. At the beginning the investment of the appliances should be recovered, but after recovering the investment the savings are all for the client.

2.7.1 Real Savings: Net Present Value (NPV)

In order to analyze the real savings for consumers, it is necessary to calculate the purchase cost, replacement and maintenance of the appliances. Second, the savings must be brought to present value to estimate the amount saved at present time.

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[10] See appendix D

2.7.2 NPV for lighting

Modern CFL's typically have a life span of between 6,000 and 15,000 hours, whereas incandescent lamps are usually manufactured to have a life span of 750 hours or 1000 hours. The lifetime of any lamp depends on many factors including manufacturing defects, exposure to voltage spikes, mechanical shock, frequency of cycling on and off and ambient operating temperature, among other factors (French Agency for the Environment and Energy Management, 2007).

According to Mentor Poveda, the replacement of incandescent light bulbs will be done 5 times after the initial purchase, since the incandescent light bulbs´ life span is 1000 hours in average, and represents one year of usage, compared to 6000 hours of CFLs that correspond to 6 years of usage. Table 15, shows the cost of the appliances and their net present value during the life span period which has been considered 6000 hours average for CFLs and 1000 hours average for incandescent light bulbs.

This scenario considers as an opportunity cost the social rate of return, which is defined as an indicator of social return of a project. Therefore, it allows the evaluation of the social impact, and the measurement (%) of each unit of monetary benefit that is invested on community projects (Universidad de Málaga, 2005).

Another important aspect to consider is the savings, which in this case is the money that the customer could save at the beginning to see if the savings pay the initial purchase of the appliance. In the case of lighting, the energy saved per year is giving by 0.045kWh/lamp*6lamp*4h/day*365d/year=394.2 kWh/year, considering an average price for the average stratum of consumption (kWh) of USD$ 0.073. As a result the monetary savings per year is *USD$ 28. 78.*

In the first scenario, Table 15 has considered a social rate of return selected from an energy efficiency program in Chile that aims to replace light bulbs and other appliances

(Allamand, 2008). The 8% rate is affecting the first scenario, in the way that the NPV of incandescent light bulbs is USD$ -2.81 and USD$ -2.5 for CFLs. Therefore, the NPV that should be chosen is the CFL value. It is possible to see that the efficient appliance is paid in less than a year due to the saving value of USD$ 28 for every year.

On the other hand, Table 16 depicts the changes on NPV, if the social rate of return decreases to 6%. It will be beneficial for customers to buy CFLs because its NPV is still $-2.5 and for incandescent is $-2.96.

Additionally, there is another factor that influences the NPV of this appliance. If the technology becomes cheaper with time, CFLs will have a benefit for consumers at the moment of purchase.

For instance, Table 17 assumes a cost of USD$ 1.5 for one CFL maintaining the social rate of return of 8%. Therefore, the consumer would still see a convenient NPV for CFLs which is $1.50 and $2, 81for incandescent.

In conclusion, there are two variables to take into account at the moment of analysis of the Net Present Value, the social rate of return, and the cost of new technology of appliances.

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Table 15: Comparison of purchase cost and NPV of incandescent and CFL light bulbs

	Incandescent Lightbulbs	CFLs	SOURCE
UNITARY COST ($USD)	0.5	2.5	Mentor Poveda
LIFE SPAN (Hours)	1000	6000	Mentor Poveda

YEARS	0	1	2	3	4	5	6
INCANDESCENT 60W (USD$)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
CFL 15W (USD$)	-2.5	28.7	28.7	28.7	28.7	28.7	28.7

NET PRESENT VALUE (COST FOR CONSUMERS)	
INCANDESCENT (USD$)	($ 2.81)
CFL (USD$)	($ 2.50)
OPPORTUNITY COST	8%

Table 16: NPV Changing the Social Rate of Return

YEARS	0	1	2	3	4	5	6
INCANDESCENT 60W (USD$)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
CFL 15W (USD$)	-2.5	28.7	28.7	28.7	28.7	28.7	28.7

NET PRESENT VALUE (COST FOR CONSUMERS)	
INCANDESCENT (USD$)	($ 2,96)
CFL (USD$)	($ 2,50)
OPPORTUNITY COST	6%

Table 17: NPV Reducing the Cost of CFLs

YEARS	0	1	2	3	4	5	6
INCANDESCENT 60W (USD$)	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
CFL 15W (USD$)	-1.5	28.7	28.7	28.7	28.7	28.7	28.7

NET PRESENT VALUE (COST FOR CONSUMERS)	
INCANDESCENT (USD$)	($ 2,81)
CFL (USD$)	($ 1,50)
OPPORTUNITY COST	8%

2.7.3 NPV for refrigerators

In the case of refrigerators, the social rate of return is the 8% of the Chilean program (Allamand, 2008), and the purchase cost of efficient and inefficient refrigerators comes from simple observations of prices to consumers in two of the biggest appliances stores in Quito.

According to a market study done in Quito, the biggest appliances stores are "Artefacta" and "Creditos Económicos" (Alvarez Dulcey & Centeno Alava, 2005). The observations gathered from these two stores, show the most popular brands and their prices, considering the volume of refrigerators as is presented in Table 18. This study only takes into account the average price of the 15 cubic feet refrigerators to analyze the NPV as indicated in Appendix E.

According to Yepez (2003), the difference in cost that the owner has to pay for buying an efficient refrigerator instead of buying a normal one, could be smaller than $100 in average. Note that the cost per year of running inefficient versus efficient refrigerators is $168 and $62, respectively (California Municipal Utilities Association, 2009).

The net present value has considered an average life expectancy of 17 years for refrigerators and 14 years for water heaters (Seattle City Government, 2004)

Table 18: Brands and Prices of efficient refrigerators in Quito

BRAND	PRICE		STORE
	13 cubic feet ($USD)	15 cubic feet ($USD)	
Indurama	913.23		Artefacta
Indurama	725.00		Creditos Economicos
Mabe	902.14		Artefacta
General Electric		1,041.35	Creditos Economicos
Smart Fresh		1,239.00	Artefacta
AVERAGE	**846.79**	**1.140,18**	

In this case, the savings of the efficient refrigerators were obtained from the difference of kWh/year consumed by an inefficient refrigerator (1800 kWh/year) and a 13 cubic feet efficient refrigerator that consumes 380 kWh/year. As a result, 1420 kWh/year * USD$ 0.073 kWh =USD $104 / year saved from the replacement of inefficient refrigerator.

Appendix E shows that the Net Present Value of an efficient refrigerator is USD$-771, while the NPV for an inefficient one is USD$ -2,527. As a consequence the replacement shows a better NPV value for the efficient refrigerator.

At the moment of purchase, it will be more convenient for the customer to start an energy efficiency measure by lighting followed by refrigeration, due to the savings, that in the case of lighting the appliance is paid in less than a year compared to efficient refrigerators where savings pay the appliances in more than a year.

2.7.4 Water Heaters

In the case of water heaters, there is information about the purchase cost of the tank and the timers including the installation. Table 19 shows the costs that the consumer should pay at the beginning for water heaters. However, it was not possible to locate information about the running costs of Water heaters.

Water heater timers can be purchased at building supply stores for about $35 and generally require an electrician to install with the average cost running about $65. This makes the total cost about $100 (Great Lakes Home Performance, 1993)

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Traditional tank systems run about $100-$600 ($350 average). Installation runs about $200-$400 ($300 average) for a traditional tank model depending on size, existing set-up, fit and other factors (Costhelper.com, 2006)

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Table 19: Cost of a water heater with and without timer

	WITHOUT TIMER	WITH TIMER
Purchase cost of the electric tank (USD $)	350	350
Installation of the tank (USD $)	300	300
Purchase and installation of timer (USD $)		100
TOTAL COSTS (USD $)	650	750

2.8 Benefits for Distributors (Quito´s Electricity Utility)

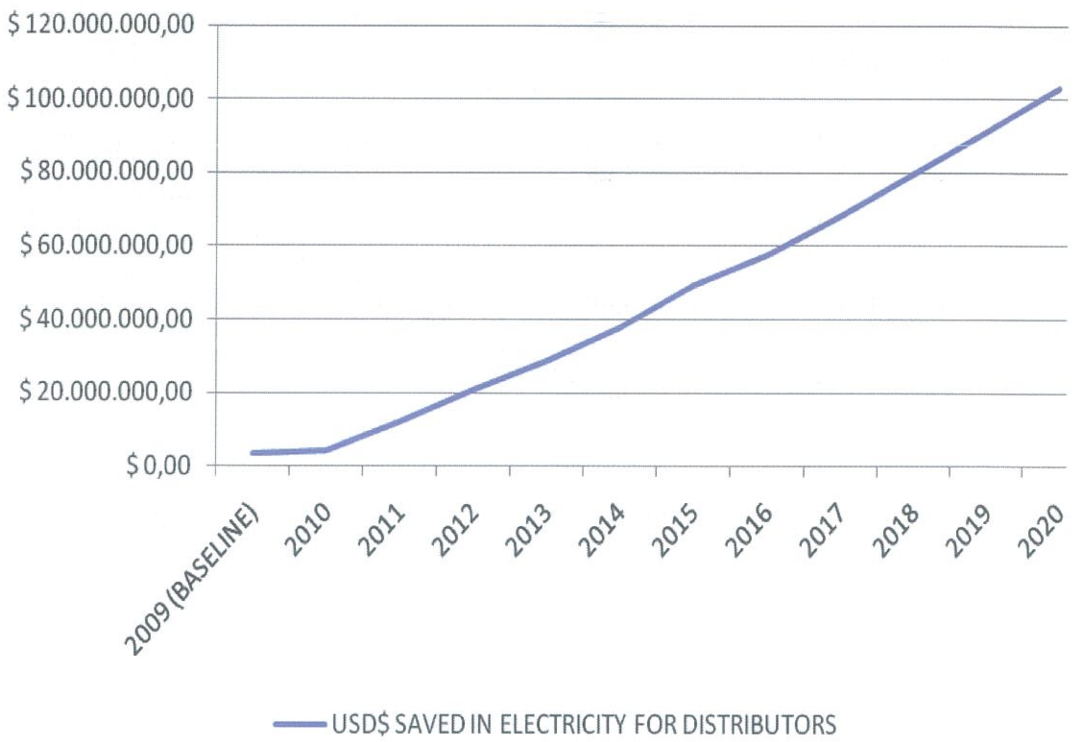
According to the Olade´s expert, Mentor Poveda, the benefits for distributors are:

- Savings in energy purchases (kWh, kW)
- Released capacity (kW)
- Reduce losses in the transmission grid.

2.8.1 Savings in energy purchases (kWh, kW)

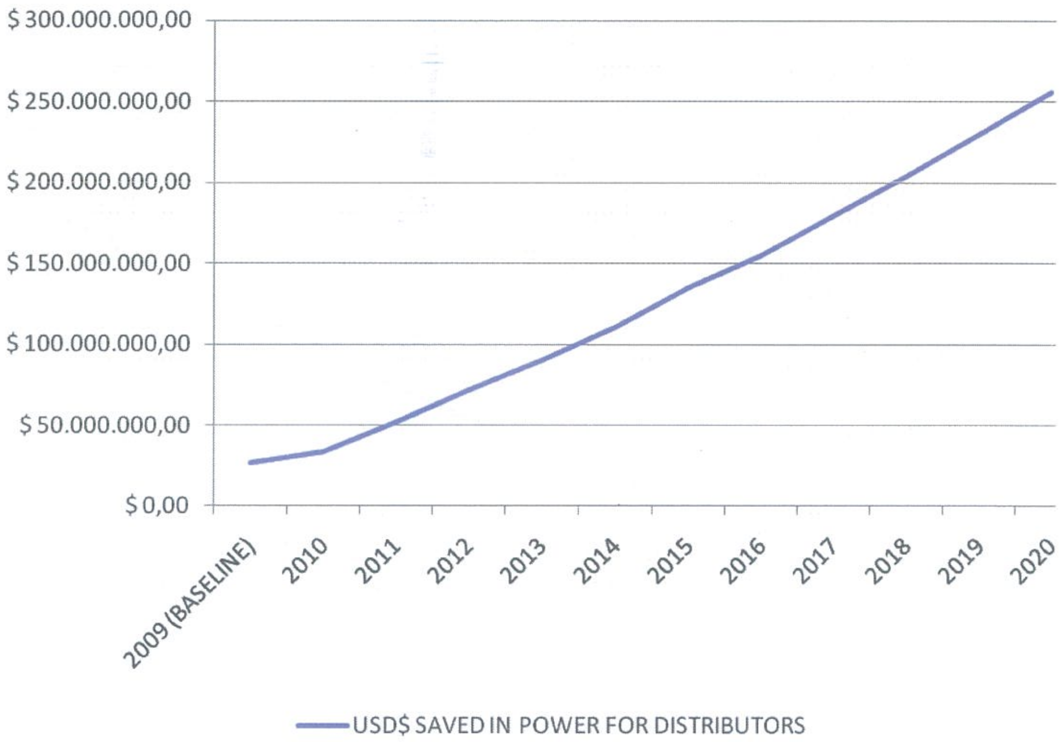
The National Institute of Pre-investment in Ecuador, has considered an average total cost of energy for distribution of US 8, 53 cents/kWh. Therefore, Figure 23 indicates the total economic savings from the implementation of the EE program.

Figure 23: Total Economic Savings for Distributors in electricity (USD$) Implementing the EE Program



On the other hand, the economic savings in power costs for Quito´s Electricity Utility have been calculated considering an annual power cost of $ 500 USD (Coyago Cruz, 2006). In consequence, Figure 24 depicts the economic power savings from the implementation of the EE program during the 10 years.

Figure 24: Total Economic Savings for Distributors in power (USD$) Implementing the EE Program



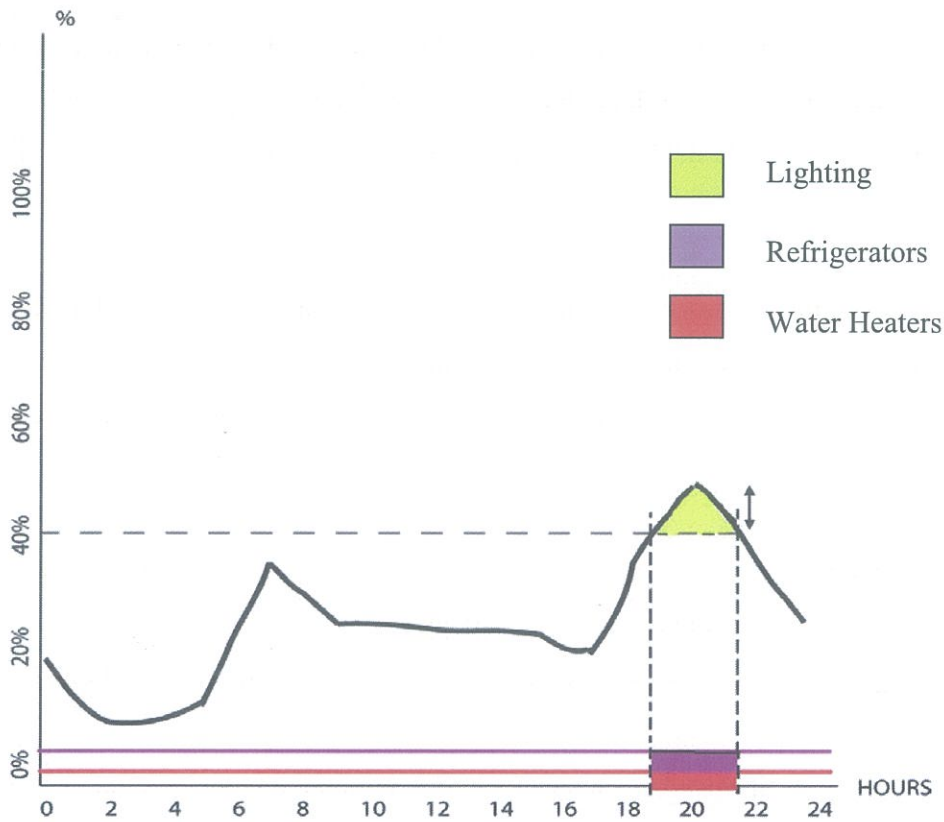
2.8.2 Released capacity

According to Mentor Poveda, the implementation of EE programs is an opportunity to release capacity in the load curve from power savings as shows Figure 25. For instance, Appendix G shows the values for power savings per year, where for 2020 the savings in MW for lighting will be 122 MW; for refrigerators 266 MW and for water heaters will be 1,2 W. According to Poveda, there are two costs for the distribution company: The cost for buying power and the cost for buying electricity, which in the case of Quito´s Electricity Utility is $USD 5,7 cents the kW per month and $USD6 cents for kWh.

These savings in cost will be considered as reductions to take into account in the effective energy capacity. For example, the effective energy capacity in Ecuador is 4354

MW (Instituto Nacional de Preinversión, 2007), and the savings in 2011 from lighting, refrigerators and water heaters will be free from generation, transmission and distribution systems of the country.

Figure 25: Reductions in the residential load curve implementing the EE program



In addition, Poveda says that the released capacity will help to reduce the need for new thermal projects for generation, as well as, take advantage of power savings to avoid the expansion of transmission lines, or use the capacity for transmission lines for new subscribers of Quito´s Electricity Utility. On the other hand, the economic savings for distributors could be use to invest in any projects required by the company.

According to Mentor Poveda, Quito´s Electricity Utility has economic losses for the sale of energy due to the reduction of kW consumed by refrigerators and water heaters. However, the power consumed by lighting is more beneficial than the energy itself.

2.8.3 Reduce losses in the transmission grid

According to Mentor Poveda, the 122 MW saved for lighting in 2020 mean a reduction of the demand. Therefore, this means a reduction in technical losses. For instance, a reduction of 1% in demand indicates a reduction of 2% in losses in the transmission grid.

Mentor Poveda mentioned that the demand for 2007 was 589.7 MW, and for 2008 was 615.3 MW; from where a growth rate in demand of 4%[11] could be obtained As a consequence, the estimated demand for 2009 is 640 MW[12]. Considering 26 MW of saving for lighting in 2009, Poveda illustrated the following:

640 MW – 26 MW = 614 MW ⟶ 614MW/ 640MW = 95.94% of reductions

100% - 95.94% = 4.06% of reductions

Thus, $(95.94\%)^2 = 92\%$ ⟶ 100% - 92% = 8% reductions in technical losses.

As a result of Poveda´s calculations, it is possible to conclude that 4.06% of reductions in demand result on 8% reductions in technical losses.

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[11] 589.7 MW / 615.3 MW = 4%
[12] 615.3 MW *4% = 640 MW

2.9 Environmental Implications from the EE Program

The energy demand savings contribute to carbon dioxide mitigation through the reductions of energy consumed in the system (McNeil, Letschert, & de la Rue du Can, 2008). Therefore, a number of measures have been implemented to mitigate world emissions, one of which has had a direct effect on Latin America and the Caribbean due to the promotion of more environmentally friendly projects, through the Kyoto Protocol's Clean Development Mechanism (CDM). In October 2008, the world had 919 on–going projects, while the region had implemented a total of 345 projects (37 %), preventing the generation of 260 million tons of CO2, and 55 % of these projects pertained to the energy sector. (Organizacion Latinoamericana de Energía - OLADE, 2008).

Despite the efforts of the Latin American Region to achieve CO_2 reductions, Table 20 shows that Ecuador has not registered projects of Energy Efficiency under the Kyoto Protocol's Clean Development Mechanism (CDM). In contrast, Argentina, Brazil, Chile and Mexico have registered energy efficiency programs accounting CO_2 emission reductions (Mton CO_2) of 1.04 ; 1.24; 0.02; and 2.61 respectively.

Table 20: World Emission Reduction by CDM Projects until October 2008 (Mton CO_2)

5.11 REDUCCIÓN DE EMISIONES MUNDIALES BAJO PROYECTOS MDL HASTA OCTUBRE 2008 (Mton CO2)
WORLD EMISSIONS REDUCTION BY CDM PROJECTS UNTIL OCTUBER 2008 (Mton CO2)

REGIONES/ TIPOS DE PROYECTOS *REGIONS / TYPE OF PROJECTS*	Número de Proyectos Registrados* / *Number of Registered Projects**												Emisiones Reducidas *Reduced Emissions Mtons CO2*
	Agricultura *Agriculture*	Biogas *Biogas*	Biomasa *Biomass*	El. Energética *Energy Efficiency*	Cambio Combustible *Fuel Switching*	Reducción HFCs *HFCs Reduction*	Hidroeléctricidad *Hydropower*	Gas Rel. Sanitarios *Landfill Gas*	Reducción N2O *NO2 Reduction*	Energía Eólica *Wind Energy*	Energía Geotérmica *GeothermalEnergy*	Total Proyectos *Total Projects*	
AMERICA LATINA Y EL CARIBE *ILATIN AMERICA AND CARIBBEAN*	104	34	55	5	9	2	70	47	5	14	2	345	274,8
ARGENTINA	1		2	1		1		7		1		13	35,1
BOLIVIA							1	1				2	1,6
BRASIL / BRAZIL	37		40	2	6		26	16	2	4		133	116,2
COLOMBIA			1		1		4	2	2	1		11	8,6
COSTA RICA			2				2	1		1		6	2,7
CHILE	4		4	1	1		6	8	1			25	29,3
ECUADOR	3		1				6	1		1		12	3,7
EL SALVADOR			2					1			2	3	1,8
GUATEMALA		1					5					6	2,2
GUYANA			1									1	0,3
HONDURAS		3	2				9					14	2,2
JAMAICA										1		1	0,5
MEXICO	59	29		1		1		8		4		102	60,5
PANAMÁ							5					5	0,8
PERÚ		1			1		6	2				10	8,1
REPÚBLICA DOMINICANA										1		1	1,2
ASIA & PACÍFICO *I ASIA & PACIFIC*	0	13	137	114	11	9	113	20	6	130		553	1247,4
BANGLADESH								2				2	1,2
BHUTAN							1					1	0,004
CHINA		1	11	26		4	59	13	2	69		185	838,74
FIJI							1					1	0,2
INDIA		10	126	88	10	4	43	3		57		341	298,3
NEPAL		2										2	0,7
COREA DEL SUR / SOUTH KOREA					1	1	5	2	4	4		17	107,2
SRI LANKA							4					4	1,1
EUROPA Y ASIA CENTRAL *IEUROPE & CENTRAL ASIA*	1						2	1				4	1,4
ARMENIA													
AFRICA SUB-SAHARA *ISUB-SAHARAN AFRICA*		2	2	2	2			2	4			14	19,9
SUD AFRICA / SOUTH AFRICA													
AFRICA DEL NORTE Y MEDIO ORIENTE / *NORTH AFRICA & MIDDLE EAST*								1		2		3	2,4
MOROCCO													
MUNDO / WORLD	105	49	194	121	22	11	185	71	15	146	2	919	1545,9

* Proyectos registrados ante la Junta Ejecutiva del MDL hasta octubre 2008/ *Registered Projects in the CDM Executive Board until octuber 2008.*
FUENTES / *SOURCES*: UNFCCC, UNEP RISOE (CD4CDM)

SOURCE: *(Organizacion Latinoamericana de Energía - OLADE, 2008)*

In order to see the environmental benefits of the EE program, it is necessary to explain the current situation of the pollutants in the environment by electricity generation.

According to Environmental Defense in United States, besides CO_2 there are other pollutants produced by electricity generation (Environmental Defense, 2002):

- 62. 6% of sulfur dioxide emissions that contribute to acid rain.
- 21.1% of nitrous oxides emissions that contribute to urban smog.
- 40% of carbon emissions that contribute to global climate change.

The Latin American Energy Organization has interesting data about the evolution of these pollutants in the environment. For this reason, this study has extracted the information about Ecuador in order to give an idea of the current situation of air pollution, followed by CO_2 emissions by electricity generation in Ecuador, including the calculations of emissions reduction by the program, and finishing with total benefits from the application of this specific energy efficiency program.

2.9.1 Emission of Pollutants in the air: Ecuador

Table 21 and Figures 26 and 27; show an increasing behavior of air pollutants emissions in Ecuador. The biggest difference between CO_2 and the other pollutants is the amount emitted to the environment. As Figure 26 shows, total CO_2 emissions are between 10 and 27 Mton, compared to the other emitted pollutants that oscillate between 0,0003 and 0,76 Mton during the last 29 years.

Figures 29 and 30 depict a big difference between CO_2 and the other pollutants. Therefore, this study will analyze the CO_2 emissions in the Residential Sector, and CO_2 emissions due to electricity generation.

Table 21: Evolution of Air Pollutants Emissions in Ecuador (Mton)

YEARS	1978	1983	1988	1993	1998	2003	2006	2007
TOTAL PRODUCTION OF CO_2 EMISSIONS (Mton)	9,86	12,30	13,30	13,68	18,54	19,50	26,78	27,77
TOTAL SOx EMISSIONS (Mton)	0,0003	0,0005	0,0004	0,0004	0,0006	0,0006	0,0007	0,0008
PRODUCTION OF CO EMISSIONS (Mton)	0,36	0,41	0,47	0,49	0,52	0,55	0,76	0,75
PRODUCTION OF NOx EMISSIONS (Mton)	0,07	0,10	0,11	0,10	0,14	0,15	0,23	0,23

SOURCE: *(Organizacion Latinoamericana de Energía - OLADE, 2008)*

Figure 26: Total Production of CO_2 emissions in Ecuador (Mton)

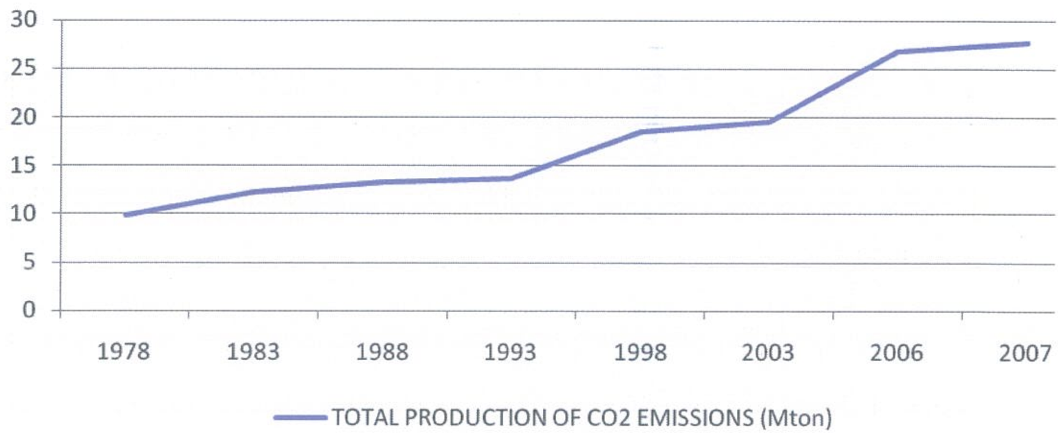
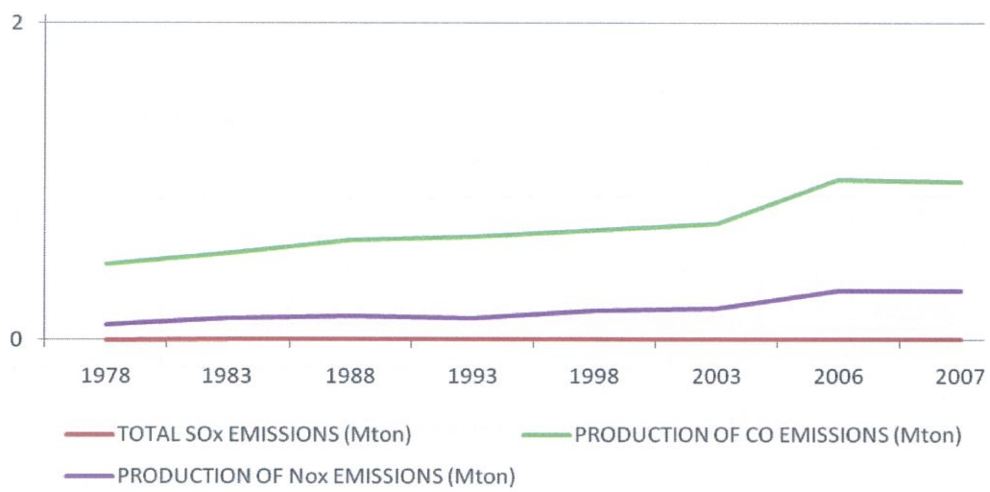


Figure 27: Total Production of Air Pollutants in Ecuador (Mton)



2.9.2 CO_2 emissions growth in the Ecuadorian Residential Sector (Mton)

Table 22 and Figure 28 show that CO_2 emissions in the Ecuadorian Residential Sector are increasing every year. Specially, the last years where the growth rate (%) indicates that between 2006 and 2007 the rate was almost the same as the ten years of the 1988 – 1998 period.

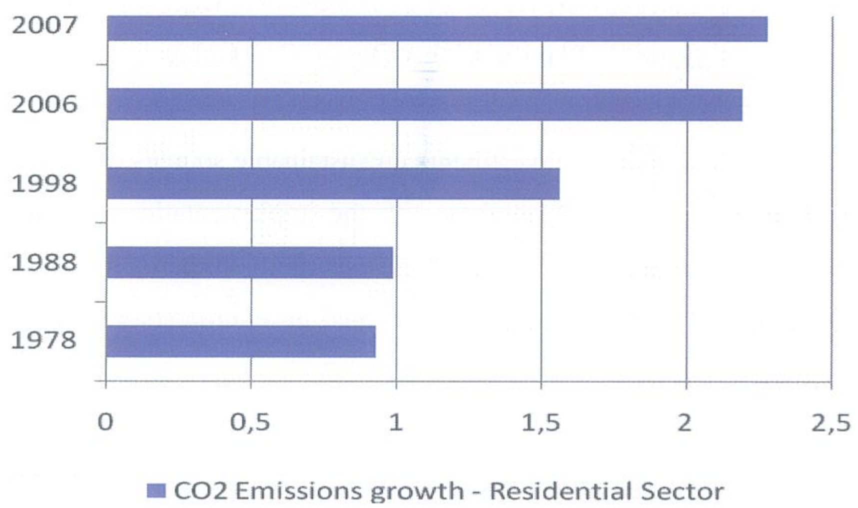
As a consequence, energy efficiency programs become more important in order to reduce CO_2 emissions and mitigate the air pollution occurred by an increased of electricity consumption and usage of old technologies.

Table 22: CO_2 emissions growth in the Ecuadorian Residential Sector (Mton) and Growth Rate (%)

						GROWTH RATE (%)			
YEARS	1978	1988	1998	2006	2007	1978 - 1988	1988-1998	1998 - 2007	2006 - 2007
CO_2 Emissions growth - Residential Sector	0,93	0,99	1,56	2,19	2,28	0,57	4,66	4,34	4,16

SOURCE: *(Organizacion Latinoamericana de Energía - OLADE, 2008)*

Figure 28: CO_2 emissions growth in the Ecuadorian Residential Sector (Mton)



2.9.3 CO_2 Emissions growth – Electricity Generation (Mton)

Table 23 and Figure 29, show that in the case of the Ecuadorian electricity generation sector, the CO_2 emissions have been reduced between 2006 to 2007. Nevertheless, the Ecuadorian energy matrix has shown the opposite behavior (Secretaria Nacional de Planificacion y Desarrollo - Gobierno del Ecuador, 2009). During the last years the thermal energy has increased significantly. For instance during 1991 the thermal sources of energy represented 27%, while in 2006 it was 47%. On the other hand, hydroelectricity went from 73% to 44% in the same period. These changes in the energy matrix have the following implications (Secretaria Nacional de Planificacion y Desarrollo - Gobierno del Ecuador, 2009)

Between 1997 and 2006 the energy demand was duplicated. Therefore, this increase represents more than the population growth. If the electricity coverage increased to 94%, the consequence was an increase in the total energy demand consumed in homes (Secretaria Nacional de Planificacion y Desarrollo - Gobierno del Ecuador, 2009).

Ecuador stopped making investments on sustainable sources of energy and replaced the electricity demand growth at first with the implementation of thermal power plants. Second, the Government increased the electricity imports from Colombia, which in 2006 were 1,570 GWh (Secretaria Nacional de Planificacion y Desarrollo - Gobierno del Ecuador, 2009).

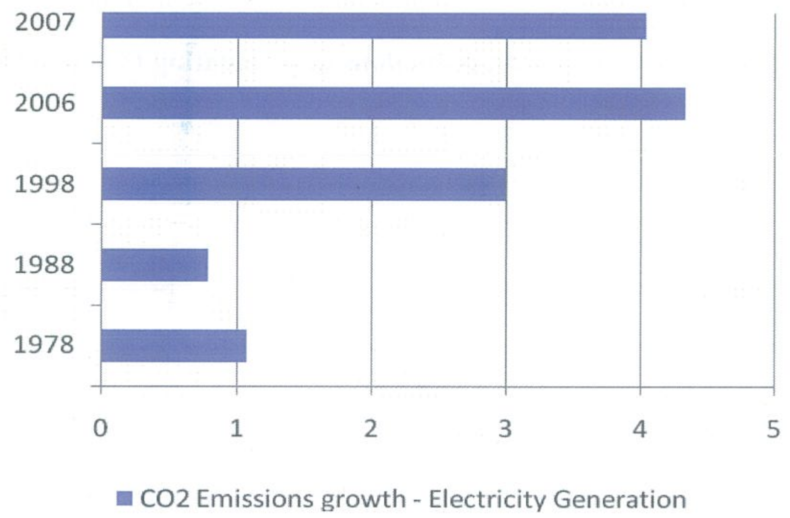
The electricity generation produces environmental impacts that are not considered in the prices structure, or in investments of the energy sector. The increase in CO_2 emissions that have as a baseline the thermal sources is significantly increasing (Secretaria Nacional de Planificacion y Desarrollo - Gobierno del Ecuador, 2009).

Table 23: CO_2 emissions growth in Electricity Generation in Ecuador (Mton) and Growth Rate (%)

						GROWTH RATE (%)			
YEARS	**1978**	**1988**	**1998**	**2006**	**2007**	**1978 - 1988**	**1988-1998**	**1998 - 2007**	**2006 - 2007**
CO_2 Emissions growth - Electricity Generation	1,07	0,78	3	4,33	4,04	-3,07	14,36	3,37	-6,53

SOURCE: *(Organizacion Latinoamericana de Energía - OLADE, 2008)*

Figure 29: CO_2 emissions growth in the Ecuadorian Electricity Generation Sector (Mton)



2.9.4 CO2 reductions implementing the EE program

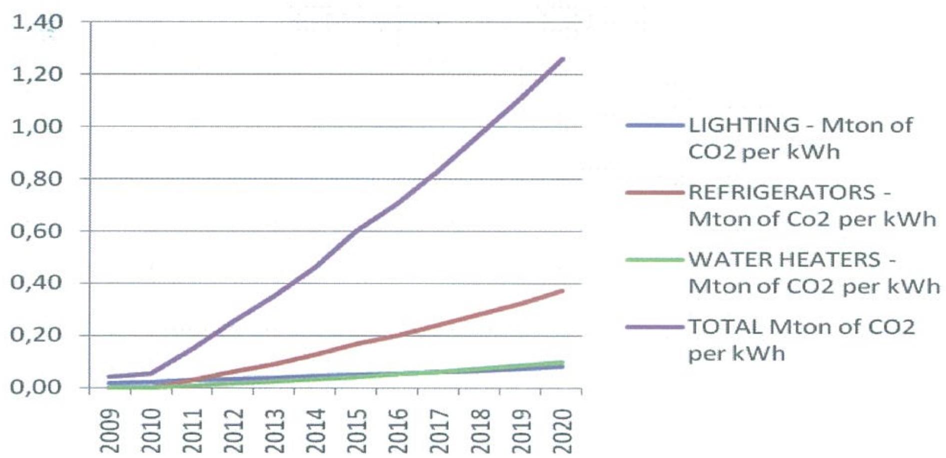
In order to calculate the CO_2 emission reductions from the EE program, it is required to know the amount of CO_2 emmited by the generation per kWh.

According to Barnwell in his article "Your Contribution to Global Warming", that appeared on page 53 of the February-March 1990 issue of *National Wildlife*, the magazine of the National Wildlife Federation, assumed that the CO_2 emissions coming from electricity produced by thermal sources have a coefficient of about 2.3 lb CO_2 per kilowatt-hour of electricity (Carbon Dioxide Information Analysis Center, 2003).

Therefore, Appendix I and Figure 30 depict the CO_2 emission reductions during the EE program period. It is possible to achieve CO_2 reductions of 1,2 Mton by 2020, which implies a great environmental benefit.

According to Figure 30, the biggest CO_2 reductions are achievable through the replacement of inefficient refrigerators, while water heaters and lighting have similar results of CO_2 reductions and could be replaced simultaneously.

Figure 30: CO_2 emission reductions implementing the EE program (Mton)



CHAPTER THREE: LEGAL MECHANISMS OF ENVIRONMENTAL PROTECTION IN ENERGY EFFICIENCY PROGRAMS

Energy Efficiency is a matter of concern due to its energy savings potential. Nowadays, efficiency in energy systems in industrialized countries is less than 15 percent; however, energy efficiency can be improved by avoiding losses and improving energy services including technology evolution of household appliances (United Nations Development Programme, 2000). In this context, in order to increase energy efficiency potential it is necessary to look over the theoretical potential which aims to minimize or avoid losses in the system; the technical potential that consists on replacing the technology available for improving efficiency and the market trend potential related with market's behavior and conditions such as energy prices, consumer preferences and energy policies. In this brief study the approach of energy efficiency improvements will be addressed through market's conditions on regards to policies and legal instruments that could be applied in the residential sector.

3.1 General Legal Aspects

3.1.1 Principles

In the case of energy efficiency the principle applicable is the ***prevention principle*** through which energy efficiency could reduce the risk of harm from CO_2 emissions produced from electricity production in electricity facilities that fired their systems with fossil fuels (United Nations Development Programme, 2000). Additionally, energy consumption from human activities related to buildings, including the use of appliances, equipment, and lighting, accounts for 34% of the total energy consumption (Wiel & McMahon, 2001). According to this approach, energy efficiency has a great potential for CO_2 emissions and energy consumption reductions. In this way, the prevention principle could be applicable to energy efficiency measures in the residential and industrial sector through some legal instruments such as emission limits, product standards, the use of best available techniques (BAT), and other similar techniques (United Nations Environment Programme, 2005). Pollution prevention techniques for energy efficiency should be encouraged to the industry and final consumers in order to have best results on emission reductions. In the case of energy efficiency in the residential sector another principle does not apply because legal instruments for residential measures could not have the command-and-control approach, but should include economic incentives or other required instruments (United Nations Environment Programme, 2005).

3.1.2 Legal Rules applicable to Energy Efficiency in Ecuador and other countries: Brief comment

According to the 3rd International Conference on Energy Efficiency in Domestic Appliances and Lightning for the Andean Community, the legal rules applicable to energy efficiency for the residential sector are standards and labeling national programs.

Since 1990, energy efficiency has been a policy issue in the Andean Community composed by Bolivia, Colombia, Ecuador, Peru and Venezuela. In the case of Ecuador it has been initiated an energy program and a bill is also under preparation by the National Energy Institute (INE). The framework for energy efficiency legislation often makes reference to energy efficiency labeling and standards for energy using equipment. This initiative started in Venezuela and Colombia with programs on labeling and standards; however, there is a regional initiative in the Andean Region which in the case of Ecuador is managed by the National Energy Institute (INE), the Institute of Nuclear Science and Alternative Energies (INEA) in Colombia, the Center of Energy Conservation and Environmental (CENERGIA) in Peru, and the Energy Efficiency

Division of the Ministry of Energy and Mines of Venezuela (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003). .

This was an attempt to develop programs to encourage renewable and energy efficiency measures in the region together with institutional setting required to do so, including a sustainability criteria.

Therefore, the integration of national programs in the Andean region has been called the Andean Program of Energy Integration (PAIE) which aimed to develop standards and labeling to achieve energy efficiency in the region. With this in mind, the PAIE got into force from 1995 to 1996 through a co-operative program the *Junta de Acuerdo de Cartagena* (JUNAC) that proposed to developed energy efficiency standards and labeling for tradable goods in the Andean Region through the related Ministers as a mean to achieve the regional goal (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003). .

Unfortunately, the PAIE stopped working in 1996 and standardization for tradable goods lost continuity, nevertheless, Peru and Colombia got some results as technical energy efficiency standards for domestic refrigerator, freezers and lamps; and international ISO/IEC standards respectively (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003).

According to the Academy of Environmental Law Research Studies, the existence of a soft law or non-binding regulation for energy efficiency measures at international level includes the ***Energy Charter Treaty*** which comprises international energy trade and investment and it has the weakness of managing environmental objectives through economic considerations. On the other hand, the ***Protocol on Energy Efficiency and Related Matters*** is legally binding but it does not impose enforceable obligations on parties to take specific measure.

In addition, the ***UN Framework Convention on Climate Change (UNFCCC)*** and the ***Kyoto Protol*** enhance measures to reduce Green House Gases (GHGs) emissions through the implementation of energy efficiency programs covering the supply and demand side mangement; but, it has been difficul to put into force these instruments (IUCN Academy of Environmental Law Research Studies, 2003).

On the other side, a succesful Multilateral Environmental Agreement (MEA) included in the ***Montreal Convention*** ratified in short order, demonstrates how international community can possitively react global environmental issues (IUCN Academy of Environmental Law Research Studies, 2003).

3.1.3 The concept of Clean Development Mechanisms related to energy efficiency on the demand-side management.

Under the UNFCCC, there has been developed some Clean Development Mechanisms (CDM) projects which include energy efficiency for the supply and demand side management. For instance, projects on energy demand account 1% with 21 projects of the total portfolio (2110) of projects developed under this mechanism (United Nations Framework Convention on Climate Change, 2009).

The CDM includes project in developing countries to earn certified emission reduction credits (CER) which are equivalent to one tonne of CO_2. The CERs are tradable with industrialized countries to meet part of their emission reduction targets under the Kyoto Protocol. The CDM encourages sustainable development and emission reduction through limitation targets for industrialized countries (United Nations Framework Convention on Climate Change, 2009)..

Therefore, the process of projects qualification is rigorous and must be approved by the CDM Executive Board after a deep analysis. The CDM has been operating since 2006 through more than 1000 project resulting in CERs of more than 2.7 billion tones of CO1 equivalent in the first commitment period of the Kyoto Protocol, 2008-2012 (United Nations Framework Convention on Climate Change, 2009)

3.2 Policy measures for Energy Efficiency in the Residential Sector

The current situation of residential energy consumption in Latin America has changed during the last years, where switching firewood and charcoal for fossil fuels is the trend. For instance, the use of liquefied petroleum gas and natural gas has increased due to their efficiency. During 1990-95 per capita residential electricity use increased by 4-5 % year in Brazil and Mexico. While electricity use increases, the importance of energy efficiency programs is shown by the economic energy efficiency potential which account 20 to 40 % from 2010 to 2020 for the residential sector in Latin America (United Nations Development Programme, 2000).

The greatest potential for efficiency improvements could be achieved through electrical end use of lighting, air conditioning and refrigerators. The implication for energy efficiency policies for the residential sector is based on the end-use sharing of each country that differes from one country to another due to the appliances technology available and conditions of the energetic matrix. However, the energy efficiency potential for this sector could be achived through technology transfers which includes efficient appliances (United Nations Development Programme, 2000).

3.2.1 Barriers for Policy measures in the Residential Sector

According to the United Nations Development Programme, the obstacles to end-use efficiency change from one country to another because differences on technical education and training, entrepreneurial and household traditions, the availability of capital, and exiting legislation. Besides, there are market imperfections such as subsidies, external costs of energy use, traditional legislation and rules, motivations and decision-making in households (United Nations Development Programme, 2000).

In addition, political interests are also involved as an obstacle, because energy efficiency investments remain invisible and do not help to public image improvements (United Nations Development Programme, 2000).

In the case of developing countries, which still lack an effective energy efficiency policy at the national level this problem could exist because most of the supply energy companies are owned by the Government and have rigid hierarchical structures where the decision-making process takes longer and implies more consensuses (United Nations Development Programme, 2000).

Another obstacle in developing countries is the lack of awareness of potential benefits of energy efficiency. This issue rises from the limited media interests to communicate the advantages of energy efficiency measures, not only at individual level but also industry level where manufactures should communicate or educate customers to use energy efficient appliances and which are the benefits from it (United Nations Development Programme, 2000).

According to Mentor Poveda, in the case of Ecuador the big obstacle is given by inappropriate energy pricing and cross-subsidies which are related with political difficulties to quit these measures. Finally, the obstacle to be analyzed in this study deals with inefficient equipment in the market. This problem addresses the absence of efficient labeling and standards for energy efficient appliances.

Some proposed policy measures for the residential sector could be (United Nations Development Programme, 2000):

- Energy labeling for electric appliances
- Financial incentives by government and utilities (at purchasing appliances)

- Change of laws, standards, and regulations
- Change of tariff structures
- These policy measures are not generic; they could widely vary from one country to another according to the conditions of the energy matrix structure, market conditions, and consumer's behavior.

3.3 Standards & Labels

"Energy efficiency standards are procedures and regulations that prescribe the energy performance of manufactured products, sometimes prohibiting the sale of products that are less energy efficient that the minimum standard" (Wiel & McMahon, 2001, p. 8) With this in mind, standards could be defined as protocols or laboratory procedures to obtain an accurate energy performance to be compared with other models or standards could be also useful to target limits on energy performance which includes maximum and minimum efficiency based on a specified test protocol.

"Energy-efficiency labels are informative labels that are affixed to manufactured products and describe a product's energy performance (usually in the form of energy use, efficiency, or energy cost) to provide consumers data with the necessary for making informed purchases" (Wiel & McMahon, 2001, p. 7-8)

3.4 Types of Energy Efficiency Standards and Labels

According to Wiel & McMahon, the energy efficiency standards are classified as follows:

- **Prescriptive standards:** Special feature or device to be installed in a new product.

- **Minimum energy performance standards (MEPS):** The maximum energy consumption that manufactures should include in each product excluding technology and design details of the product.

- **Class-average standards:** Indicate the average efficiency of a manufactured product.

Labels could be divided as (Wiel & McMahon, 2001):

- **Endorsement labels:** Are seals of approval in accordance with specific criteria.
- **Comparative labels:** Comparison labels due to performance among similar products.
- **Information-only labels:** Provide information of product performance.

In order to build Government policies for energy efficiency and GHGs emission reduction programs, labels and standards are good instruments to apply. They can be useful in increasing energy saving potential and they are cost effective at limiting energy growth without interfering economic growth (Wiel & McMahon, 2001). Obviously, the market's curve for household appliances shifts when standards and labeling are introduced, increasing the position of more efficient appliances and displacing those less efficient. Consumer's decision-making process seems to be assisted by labeling information which encourage manufactures to design products with high ratings rather than with minimum standards (Wiel & McMahon, 2001).

The benefits of standards and labels could be summarized as follows (Wiel & McMahon, 2001):

- Reduce capital investment in energy supply infrastructure
- Enhance national economic efficiency by reducing energy bills
- Enhance consumer welfare
- Strengthen competitive markets.

- Meet climate change goals, and
- Avert urban/regional pollution

In the case of Latin America, since October 3rd 2001, Colombia introduced the program for standards and labeling procedures for household appliances (Lutz, W. F., Garcia, V., Inocente, I., Palacios, M., Valles, C., & Waide, P. , 2003). The National Program for Rational Use of Energy and Energy Efficiency is supported by the law on the Rational use of Energy and the Program of Standardization called *Programa Colombiano de Normalizacion, Acreditacion, Certificacion y Etiquetado de Equipos de Uso Final de Energia.* The program has the objective of optimize the energy performance of end-use equipment in different sectors to promote energy efficiency awareness among Colombian citizens (Lutz, W. F., Garcia, V., Inocente, I., Palacios, M., Valles, C., & Waide, P. , 2003)..

In the case of Ecuador, the Minister of Renewable Energies and Energy Efficiency should establish legal and institutional frameworks for standardization, labeling, accreditation of laboratories, certification and evaluation of the equipments that are going to be introduced in the market. The standards for energy consuming equipment are planned to be developed under mandatory official energy efficiency standards (*Normas de Eficiencia Energetica Oficiales – NOE*) through a participatory process and involvement of manufacturers, consumers, research institutes, professional associations, chambers of industry and commerce and the Government (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003).

In this context, the Ecuadorian Standardization Institute (INEN) has been in charge to develop the energy efficiency standards and testing for domestic cooling and refrigeration equipment that until now is the only one applied to energy efficiency standards (Instituto Ecuatoriano de Normalizacion, 2009). This Ecuadorian Technical Regulation RTE – INEN 035 has been explained chapter two, identification of measures for refrigerators.

Moreover, educational tools to familiarize the public with purchase option and use of efficient equipment and systems (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003)

The legal framework supported by the new Ecuadorian Constitution (2008), in the fifth section: Biosphere, urban ecology and alternative energies, the ***article 413*** says: "The State will promote energy efficiency, the development and use of clean and healthy practices and technologies, as well as renewable, diversified, and low impact energies, that will not place at risk food sovereignty, ecologic equilibrium of ecosystems, nor water rights"

The Ecuadorian Law of Environmental Management and the Regulations for Prevention and Control of Environmental pollution (Ley de Gestión Ambiental y del Reglamento a la Ley de Gestión Ambiental para la Prevención y Control de la Contaminación Ambiental) of the Unified Text of the Environmental Normative establishes the competence of the national environmental authorities to reinforce this law. In the same way, this law indicates national and regional competences that must be developed in order to achieve prevention and control measures to protect water, soil and air. These competences include:

Dictate local or regional policies of environmental protection to prevent and control the pollution of resources: air, water and soil. Besides, the strategies to apply the environmental policies under a national environmental policy (Ministerio del Ambiente - Gobierno del Ecuador, 2009).

a) Elaborate the local Plan or Program for Prevention and Control of Environmental Pollution. This plan should be part of the Ecuadorian Environmental Plan.

b) Issue and apply technical norms, methods, guidelines and parameters of environmental protection applicable for national and regional jurisdictions framed in the current national technical norm. In order to issue the technical norms, there should be previous studies on social, technical and economic aspects that justified the applicability of the norms under this law.

c) To have available control and monitoring systems to verify the accomplishment of the present regulation and technical norms in the jurisdictional area.

Under these current legislations, it is necessary to include the energy efficiency standards and labeling to reinforce the existent Ecuadorian law of environmental prevention and control.

3.4.1 Assessing Existing Institutional Capacity

The Ecuadorian Standardization Institute (INEN) is the institution in charge of the development and ratification of Ecuadorian Technical Standards. This is the one that should develop the energy test procedures to support these programs, but there is a lack of test laboratories in the country capable of conducting the required testing (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003).

On the other hand, a positive insitutional change under the last Governemnt (2008) was the institutionalization of the Minister of Reneweable Energies and Energy Efficiency which in other government periods was subject to work inside the Minister of Hydrocarbons and Mines. Nowadays, it is easy to identify the responsabilities of energy efficiency management in the Government and this is helpful to implement new programs in the way that there is an entity which will be resposible of the whole process of designing and implementation (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003).

The assessment of the technical potential of labels and standards which in this case could be done by INEN should take into account the following (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003):

- Current levels and forecast trends for efficiency of products in the marketplace
- Expected level of efficiency possible
- Existence and characteristics of domestically manufactured products, and
- Existence and levels of standards in other countries.

The institutional activities and skills that must be carrying out in order to develop and maintain capacity are (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003):

- Test energy consumption, performance, and energy efficient levels
- Develop, issue, and maintain labels and standards regulations;
- Monitor compliance;
- Enforce regulatory requirements; and
- Evaluate program implementation and impacts

3.4.2 Administration, Monitoring, Enforcement and Evaluation

Administration should be followed by a Government entity being careful to duplicate label and standards activities. For example, there have been cases were complains for control of the programs have occurred due to a division of resources where two institutions issue separated energy/environmental endorsement labels, comparative energy labels, or "eco labels". The lack of a single institution that manages all the skills to coordinate energy efficiency programs lead to assist the process through external experts that may solve complaints (Wiel & McMahon, 2001).

Monitoring is applied in two ways, the first deals with testing energy performance and the second makes sure that the labels are exposed at the points of sale. The programs should include clear systems of procedures and penalties in order to succeed with monitoring issues (Wiel & McMahon, 2001)..

Enforcement is even more difficult especially in developing countries where it is harder to find the budget and staff to carry out institutional enforcing. So, resources should be designated to achieve the goals of the program. Independent agencies for administration and evaluation of the program should be required, as well as good trained researchers that will conclude with objective reviews (Wiel & McMahon, 2001)..

3.4.3 Establishing Political Legitimacy

Political legitimacy is an issue that involves government and industry consensus to support social objectives of society's development. Maybe, a case will arise where the industry will be in opposition to the establishment of mandatory labels and standards. In this case, minimum energy-efficiency standards will be the only way to gain political consensus with the industry. As a result, manufacturers could design, manufacture and market more efficient products (Wiel & McMahon, 2001).

This legitimacy will determine not only the design but the operation of the whole program. It has been demonstrated that legitimacy is widely recognized as reflecting a social consensus that is supported by top political leaders and are supported in binding legislation or decrees (Wiel & McMahon, 2001). The role of political authorities should be framed on:

- Strength their political determination,
- Objectives of the programs
- Institutional structure for program's authority

- limits for program interventions,
- Transparency and openness processes for programs designs
- Relationships with other relevant energy and non-energy policies.

3.4.4 Legal aspects

Framework legislation for energy efficient standards and labeling is the main legal constraint in these programs. This legal framework could be linked with the technical details to specific product and it is important to include the institution that is going to reinforce the product-specific regulations. Stakeholders, roles and responsibilities with respect to law should be considered to issue product-specific minimum efficiency standards (Wiel & McMahon, 2001).

"Two good examples of framework legislation are the European Union Directive establishing a framework on energy labeling (92/75/EC) and the U.S. National Appliance Energy Conservation Act (NAECA) of 1987, updated in 1988. The EU Directive gives authority to the European Commission to issue product specific energy labels following approval from a national panel of appointed specialists. The NAECA legislation empowers and obligates the U.S. Department of Energy (DOE) to issue minimum energy efficiency standards for energy intensive tradable equipment when a specific set of criteria are met. For a fuller discussion of framework legislation see Waide 1998". (Wiel & McMahon, 2001, p. 37)

According to Wiel & McMahon , these framework legislations or decrees should provide:

- Defined program objectives
- allowed types of intervention (mandatory standards and/or voluntary targets)
- criteria to know products that will be covered,

- criteria for technical intervention (based on consumer payback time, life-cycle costing criteria, or harmonization with trading partners),
- an implementation time frame,
- process rules and deadlines, and
- Evaluation report on the program's impact, including effects on manufacturers, consumers, and the nation.

CHAPTER FOUR: Strategic Management for Energy Efficiency Programs in the Residential Sector

This chapter consists on a theoretical review of the management strategy that best fits to implement energy efficiency (EE) programs in the residential sector. First, Institutional theory is addressed in order to understand its influence in the design and implementation of this kind of programs.

Besides, this theory will assess the institutional pressures and standardized norms that make it possible to implement the programs with similar practices worldwide. These standardized practices raise the idea of isomorphism in EE programs which makes government to adopt same methods to introduce the programs and influence society towards energy efficiency concerns.

Second, different experiences in Latin America are discussed as they could be an opportunity to improve current EE programs in the residential sector.

Finally, this chapter will conclude with what may be a management strategy for an EE program in the residential sector.

4.1 Institutional Theory applied to EE programs in the residential sector

Institutional theory is based on institutional pressures that organizations face on their environments comprising interactions among key stakeholders who produce powerful and complex set of norms that lead organizations to adopt similar practices and structures defined as "institutional isomorphism". Institutional isomorphism is the progressive convergence through imitation (Mintzberg, Ahlstrand, & Lampel, 2005).

In this study, institutional theory addresses the residential sector as the unit of analysis instead of company level and has identified key stakeholders enclosed in EE programs as government (strong player), citizens, industry and sellers. In this way, the theory gives a framework of the institutional pressures that drive the adoption and implementation of EE programs.

In addition, the theory has identified three types of isomorphism that will be analyzed through different EE programs in the residential sector to see the trend for adoption and implementation.

4.1.1 Coercive

Coerciveness is known as the pressure applied through standards, regulations, and the like (Mintzberg, Ahlstrand, & Lampel, 2005). EE programs in the residential sector are usually supported by a regulatory framework to make them applicable. For instance, standards and labeling for EE appliances are incorporating a regulatory framework to comply with the levels of standardization on energy consumption. This is the case of the Brazilian EE program (PROCEL) which included a legal framework for EE measures, based on two laws (Cruz, 2006):

> Law no. 9.991 – Energy Efficiency Programs of Distribution Utilities: Encourages electricity distribution utilities to invest 0.25% of their revenues in energy efficiency programs that could be applied in the residential sector, public sector, commerce and services, low-income consumers, industries, etc.
>
> Law no. 10.295 – Energy Efficiency Law: Includes minimum energy performance standards for equipment and buildings, as well as regulated equipment (short-term regulations for refrigerators, freezers, air conditions, stoves and ovens due to the fast technological changes of these appliances).

Another example of EE legal framework is illustrated in chapter 5, where the Chilean Government instituted the Law for Rational Use of Energy (Ley de Uso Racional de Energia) and it has similar characteristics as the PROCEL legal framework. This Law for Rational Use of Energy is a trend in the Latin American region and some other countries like Colombia, Peru and Ecuador have included or are going forward with this legal framework to develop their energy legislation (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003)

The implications of legal and regulatory frameworks to improve energy efficiency programs in the residential sector in Ecuador are not only concerns of the demand-side management. On the contrary, supply-side management must provide choices for cost-effective energy efficient appliances. Nevertheless, both (supply and demand sides) require innovation-friendly regulations that will lead to have a wide range of alternatives for efficient appliances in the market. Porter and van der Linde, in their article "Green and Competitive" (1995) mentioned the implications of having a good environmental regulation that encourage the industry to be more competitive and innovative with the purpose of having better outcomes, not technologies.

In the case of the residential sector, household appliances producers must focus on their products' energy efficient characteristics (outcomes) through innovation instead of having the "best available technologies" that will discourage improvements. A green and competitive industry will give more alternatives and best quality on energy efficient products or improved product yields to consumers. This innovation-friendly regulation could have the following characteristics (Porter & van der Linde, 1995:

- "Focus in outcomes, not technologies
- Enact strict rather than lax regulation
- Regulate as close to the end user as practical, while encouraging upstream solutions

- Employ phase-in periods
- Use market incentives
- Harmonize or converge regulations in associated fields
- Develop regulations in sync with other countries or slightly ahead of them
- Make the regulatory process more stable and predictable
- Require industry participation in setting standards from the beginning
- Develop strong technical capabilities among regulators, and
- Minimize the time and resources consumed in the regulatory process itself" (Porter & van der Linde, 1995, p. 124)

4.1.2 Mimetic

Mimetic isomorphism is the result of imitation of the competitors' successful practices (Mintzberg, Ahlstrand, & Lampel, 2005). Mimetic isomorphism probably is less evident in EE programs for the residential sector, because as we have seen in chapter 2 the methodology to design an EE program for the residential sector requires the study of the sector's energy consumption characteristics per household appliances and end-use share.

These characteristics and electricity pricing schemes vary worldwide and it is hard to assess the same EE program for sectors with different characteristics in each region (Mintzberg, Ahlstrand, & Lampel, 2005).

4.1.3 Normative

Normative isomorphism results from the strong influence of professional expertise (Mintzberg, Ahlstrand, & Lampel, 2005). This normative isomorphism appears to be the most influencing element for standardization and labeling programs for energy efficiency appliances.

Nowadays, it is likely to see labeling programs such as the ENERGY STAR® program that helps consumers to save money and protect the environment through energy efficient practices and appliances (U.S. Environmental Protection Agency and the Department of Energy).
Moreover, in the Andean region the need for expertise to measure and control appliances' efficiency is required in order to develop standards for a regional market.

After considering the different ways of isomorphism that could be present in EE programs for the residential sector, it is possible to describe the institutional sources of formal structure that were built in order to manage the residential EE programs in different countries.

The article "Formal Structure as Myth and Ceremony" of Meyer and Rowan (1977) discusses the fact that in modern societies formal structures are reflections of social reality and not only a result of the social organization. These formal structures comes from institutional forces that identify various social purposes as technical ones and use a rule-like way as the appropriate mean to pursue technical purposes.

The authors also argue that institutional isomorphism promotes the success and survival of organizations due to the involvement of internal and external participant of the company through legitimated formal structures. Therefore, these depict how institutional theory is seen as the interaction with external environment (Meyer & Rowan, 1977).

For instance, in the case of EE residential programs institutional isomorphism tends to involve the participants through legitimate formal structures as the authors mentioned above. In the case of Ecuador, the government created the Ministry of Electricity and Renewable Energies to develop improvements on the Ecuadorian energy matrix to have a continuous monitoring and planning the energy system.

Therefore, the responsibility of the current program of substitution of incandescent light bulbs for efficient CFLs is given to this Ministry. The institutionalized management of EE programs is part of the Ecuadorian government strategy to develop the new energy matrix. Appendix J shows the institutional isomorphism for EE programs in the residential sector in some countries.
With this example, it is possible to capture similarities of EE programs and the involvement of the population in general though incentives such as long payment periods for saving light bulbs as it is the case of the ILUMEX program in Mexico, while in Ecuador there is a similar incentive for consumers by a reduced price of energy saving light bulbs. In the case of Chile and Colombia, the normative isomorphism is essential to building standards and labeling programs because of the technical expertise required to test domestic appliances.

These examples support the following Meyer and Rowan argument: "Environments and environmental domains which have institutionalized a greater number of rational myths generate more formal organization. This thesis leads to the research hypothesis that formal organizations rise and become more complex as a result of the elaborated state and other institutions for collective action" (Meyer & Rowan, 1977, p. 360).

Energy efficiency in the residential sector appears to be the issue-based field through which countries have developed their institutions to aim energy consumption reductions on their energy matrix. The use of legal instruments to develop EE programs are the channels to connect or interact with different institutions in a national EE program. Organizational fields were analyzed in the U.S. chemical industry where field membership was emerged from legal processes that ended up in determining institutional norms regarding environmentalism (Hoffman, 1999).

As a similar case, emerging institutions for EE programs development in the residential sector have determined institutional norms regarding environmentalism such as the ILUMINEX program or the program of substitution of incandescent light bulbs in Ecuador, where the necessity of an institution to manage those programs was evident.

For instance, in the case of Mexico, institutions like the FIDE and the CONAE were required to build these kinds of programs (Dufour, 2006) Ecuador's case is even more illustrative where the government saw that these energy efficiency programs could be part of the past Ministry of Energy and Mines where the hydrocarbons sector could be together with electricity and renewable energies initiatives.

Hoffman (1999) also describes in his article the evolution of institutions to connect different pillars of the institutionalize theory. He mentioned the changed from normative, cognitive and regulative institutions that could change through time. Probably, the evidence of the "CONOCE" program in Colombia could be evidence of this transformation. In 2001, the Colombian government instituted the Law for Rational Energy Use (URE- 697) as the first step to develop EE programs as a regulative measure, however after this year the trend of the programs is to be based on the normative pressure of standards defined after testing appliances and labeling them.

A similar behavior happens in Ecuador where there has not been normative pressures to drive the EE program (substitution of incandescent light bulbs), but the trend to standardize appliances in the region is to establish the same standards and labeling procedures (Lutz, Garcia, Inocente, Palacios, Valles, & Waide, 2003)

4.2 The strategy behind institutional theory

EE programs in the residential sector are characterized by a constant interaction with the environment. The idea of institutional theory is to examine the cultural and institutional systems of which EE programs are part (Hoffman, 1999). Therefore, the approach to a management strategy could be a mixture of institutional forces and experiences acquired through the designing or implementation of these programs.

Appendix K depicts some international experience for domestic lighting in some countries. These experiences where done with involvement of manufacturers where they played the main role. However, DuPont refers to standards and labeling programs design as a process that must include input from marketing experts, testing experts, manufacturers and consumers and this process must require periodic recalibration of label scale (ratcheting), evaluation of label effectiveness and revision of label design (DuPont, 2000).

In general, the trend in EE programs for the residential sector seems to be addressed to standards and labels, thus normative isomorphism is part of the strategy. If programs are taken as initiatives to reduce energy consumption without a legal framework such as the Ecuadorian program for light bulbs substitution, it tends to go from coercive to normative isomorphism to educate consumers all over the commercial channels and not only to an specific target (low-income) consumers.

CHAPTER FIVE: Conclusions and Recommendations

5.1 Conclusions

The EE program is an opportunity to save economic resources for the development of critical investments in the energy sector. The government could find in an EE program a tool to help people with scarce resources and teach them how to take advantage of new technologies to pay less in the monthly electric bill.

Power savings suggest that the government should initiate energy efficient measures with the replacement of incandescent light bulbs, followed by refrigerators and ending with the installation of timers in water heaters. On the other hand, the benefit for consumers suggest that costumers could get more benefit for energy efficiency measures replacing first inefficient refrigerators, followed by the replacement of incandescent light bulbs and ending with the installation of timers in water heaters.

The study concludes that the energy efficiency measures for lighting could be applied at short term to obtain a benefit, because at long term, or after the first 5 years the EE program gives more saving benefits to refrigerators, and then for lighting.

It is important to differentiate and identify the savings in power and energy, because the savings in power will give the parameters to develop the program to benefit the distribution of electricity, while the savings in energy show a benefit for the consumers.

The appliances analyzed have delivered good results in the way that the load curve for the residential sector shows the biggest reduction in peak hours due to lighting efficient appliances, while for refrigeration and water heaters the reduction behavior in the load curve does not affect peak hours, but it consists in a reduction of energy and power consumption.

Environmental benefits from the EE program are achievable. For instance, by 2020 the program estimated savings of 1,2 Mton, which compared to the CO_2 emissions of 2007 that were 4, 04 Mton by electricity generation, the program represents the 30% of CO2 emission reductions. This behavior could mitigate the environmental impact caused during past periods that any energy efficiency measure was taken.

In order to calculate the CO_2 emission reductions, this study has assumed that the entire electricity generation is made through thermal power plants, which may affect the final result and may drop the CO_2 emission reductions. As a consequence, it is required for further analysis to estimate the CO_2 produced by hydroelectric power plants.

This study also has shown that a great consensus between government, industries and society in general should be part of the program's design which will affect the final results of energy efficiency.

5.2 Recommendations

Labeling and standard programs are a good alternative to reduce energy consumption without affecting consumer's comfort. In addition, it is a good strategy to accomplish the objectives of a protocol or an agreement because it is possible to reduce GHGs emissions and achieve the sustainability goals where energy-intensity in country's energetic matrix could be displaced.

It is important to take into account legal features and existent regulations in which energy efficient labeling and standards programs are going to be developed. This will help to understand the role of the environmental agencies or the institutional responsibilities in the program.

Political legitimacy is the result of a good elaborated legal framework that must reinforce the standards and labeling programs.

Legal issues and frameworks are the most important tools to apply and monitor, especially through responsible entities that will increase the technical and operational expertise for this kind of programs and will lead to improvements on future regulations.

The residential sector (consumers), the government (MEER and utilities?), manufacturers and sellers must work together to have a sustained and successful program. The role of the government is related with the institutional isomorphism that leads to regulatory procedures to manage these programs.

As it is mentioned in chapter five, Latin American programs in the residential sector tend to be similar because they are based on those successful programs such as the Mexican program. The expertise required for technical studies also requires a normative isomorphism through which regional energy efficiency programs could be developed. In summary, institutional isomorphism that involves all the participants of the program must consider international experiences that support the development and implementation of EE practices.

In summary, the government should start the measurements of appliances and consumption to identify the new load characterization curve in order to obtain precise data and information to develop energy efficiency programs.

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APPENDIX A: ENERGY SAVINGS – LIGHTING

Energy saved replacing incadescent lamps: kW/ lamp	0.045	**Days**	365
Hours of usage	4	**Coincidence factor**	0.5

ENERGY SAVINGS WITH THE REPLACEMENT PROGRAM							
YEAR	**No. of lightbulbs replaced**	**Total Power saved (kW)**	**Penetration rate**	**Total Energy saved (kWh)**	**Number of clients (QEU)**	**Total # of lightbulbs**	**Energy saved per client / year (kWh)**
2009 (BASELINE)	1.192.923	26.841	27%	78.375.041	740.073	4.200.000,00	394.2
2010	1.536.452	34.570	33%	100.944.915	766.349	4.311.318,00	394.2
2011	1.900.634	42.764	40%	124.871.685	792.625	4.422.636,00	394.2
2012	2.285.470	51.423	47%	150.155.351	818.901	4.533.954,00	394.2
2013	2.690.958	60.547	53%	176.795.914	845.177	4.645.272,00	394.2
2014	3.117.099	70.135	60%	204.793.373	871.453	4.756.590,00	394.2
2015	3.563.892	80.188	66%	234.147.729	897.729	4.867.908,00	394.2
2016	4.031.339	90.705	73%	264.858.980	924.005	4.979.226,00	394.2
2017	4.519.439	101.687	79%	296.927.129	950.281	5.090.544,00	394.2
2018	5.028.191	113.134	86%	330.352.173	976.557	5.201.862,00	394.2
2019	5.557.597	125.046	92%	365.134.114	1.002.832	5.313.180,00	394.2
2020	6.174.651	138.930	100%	405.674.547	1.029.108	5.424.498,00	394.2

APPENDIX B: ENERGY SAVINGS – REFRIGERATORS

ENERGY SAVINGS WITH THE ENERGY EFFICIENCY PROGRAM

YEAR	ENERGY CONSUMPTION PER STRATUM (kWh/year)							
	0 - 50	51 - 200	201 - 500	501 -1000	1000 - >	TOTAL ENERGY SAVED (kWh/year)	TOTAL POWER SAVED (kW/year)	TOTAL ENERGY SAVED PER CLIENT (kWh/year)
	% OWNERSHIP							
	21%	75%	97%	91%	88%			
	% OF CLIENTS PER STRATUM							
	0.3%	1.3%	13.8%	49.0%	35.7%			
2009	-	-	-	-	-	-	0	0
2010	-	-	-	-	-	-	0	0
2011	44,334	713,131	9,815,015	30,896,718	21,527,409	62,996,607	20,547	1222.7
2012	91,608	1,473,544	20,280,776	67,703,907	47,172,963	136,722,799	44,593	1222.7
2013	141,821	2,281,238	31,397,284	98,835,619	68,864,105	201,520,067	65,727	1222.7
2014	194,974	3,136,214	43,164,540	135,877,801	94,673,391	277,046,920	90,361	1222.7
2015	251,066	4,038,471	55,582,542	185,552,824	129,284,658	374,709,560	122,214	1222.7
2016	310,097	4,988,009	68,651,291	216,107,632	150,573,841	440,630,869	143,715	1222.7
2017	372,068	5,984,829	82,370,786	259,295,280	180,665,004	528,687,967	172,436	1222.7
2018	436,978	7,028,930	96,741,029	304,531,416	212,183,459	620,921,813	202,519	1222.7
2019	504,827	8,120,313	111,762,019	351,816,040	245,129,207	717,332,407	233,964	1222.7
2020	575,616	9,258,977	127,433,755	401,149,153	279,502,247	817,919,749	266,771	1222.7

		REFRIGERATORS COINCIDENCE FACTOR	POWER (kW)	ENERGY SAVINGS (kWh / year)
EFFICIENT REFRIGERATORS:				
13 cubic feet refrigerator	380 kWh/year	0.35	0.12	1,420
25 cubic feet refrigerator	461 kWh/year	0.35	0.15	1,339
INEFFICIENT REFRIGERATORS:	1800kWh/year	0.25	0.82	0

APPENDIX C: ENERGY SAVINGS – WATER HEATERS

Energy consumption for electric domestic water heaters (kWh/year) per suscriber	3460
% of savings after installing timers	12,0%
Energy savings from installing timer (kWh/year) per suscriber	415
Coincidence factor	0,4

YEAR	% OWNERSHIP		Total Energy saved (kWh)	Total Power saved (kW)	Energy saved per client / year (kWh)
	91%	90%			
	% OF CLIENTS PER STRATUM				
	49,0%	35,7%			
	STRATUM				
	501 -1000	1000 - >			
2009	-	-	-	-	-
2010	-	-	-	-	-
2011	9,580,520.7	6,865,987.3	16,446,508	93.9	319,2
2012	19,796,241.1	14,187,197.5	33,983,439	194.0	319,2
2013	30,647,161.2	21,963,630.7	52,610,792	300.3	319,2
2014	42,133,280.9	30,195,286.8	72,328,568	412.8	319,2
2015	54,254,600.3	38,882,165.9	93,136,766	531.6	319,2
2016	67,011,119.3	48,024,267.9	115,035,387	656.6	319,2
2017	80,402,838.0	57,621,592.8	138,024,431	787.8	319,2
2018	94,429,756.4	67,674,140.7	162,103,897	925.3	319,2
2019	109,091,874.5	78,181,911.6	187,273,786	1.068.9	319,2
2020	124,389,192.2	89,144,905.3	213,534,097	1.218.8	319,2

APPENDIX D: ECONOMIC SAVINGS FOR DISTRIBUTORS (QUITO'S ELECTRICITY UTILITY)

YEAR	Total Power saved (kW) from the EE program				
	LIGHTING	REFRIGERATORS	WATER HEATERS	TOTAL SAVINGS	COST SAVINGS FOR QUITO´S E. U. ($USD)
2009 (BASELINE)	26,841	-	-	26,841	18,359
2010	33,906	-	-	33,906	23,192
2011	41,299	20,547	94	61,940	42,367
2012	49,021	44,593	194	93,808	64,165
2013	57,070	65,727	300	123,098	84,199
2014	65,448	90,361	413	156,222	106,856
2015	74,154	122,214	532	196,900	134,679
2016	83,188	143,715	657	227,559	155,651
2017	92,549	172,436	788	265,773	181,789
2018	102,240	202,519	925	305,683	209,087
2019	112,258	233,964	1,069	347,290	237,547
2020	122,051	266,771	1,219	390,041	266,788

YEAR	Total Energy saved (kWh) from the EE program (DISTRIBUTION)				
	LIGHTING	REFRIGERATORS	WATER HEATERS	TOTAL SAVINGS	USD$ SAVED IN ELECTRICITY FOR DISTRIBUTORS
2009 (BASELINE)	78,375,173	0	0	78,375,173	4,702,510
2010	99,005,561	0	0	99,005,561	5,940,334
2011	120,594,030	62,996,607	16,446,508	200,037,145	12,002,229
2012	143,140,579	136,722,799	33,983,439	313,846,817	18,830,809
2013	166,645,209	201,520,067	52,610,792	420,776,069	25,246,564
2014	191,107,920	277,046,920	72,328,568	540,483,408	32,429,004
2015	216,528,712	374,709,560	93,136,766	684,375,038	41,062,502
2016	242,907,584	440,630,869	115,035,387	798,573,840	47,914,430
2017	270,244,536	528,687,967	138,024,431	936,956,934	56,217,416
2018	298,539,570	620,921,813	162,103,897	1,081,565,279	64,893,917
2019	327,792,684	717,332,407	187,273,786	1,232,398,876	73,943,933
2020	356,389,519	817,919,749	213,534,097	1,387,843,365	83,270,602

APPENDIX E: NPV FOR REFRIGERATORS

EFFICIENT REFRIGERATORS

YEARS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Purchase price	$ (1.140)																	
Cost for running per year		$(62)	$ (62)	$(62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)	$ (62)
Savings per year (USD $)		104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104	104
Cost for running – savings per year (USD $)	$ (1.140)	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42	$ 42
<u>NET PRESENT VALUE (COST FOR CONSUMERS)</u>	($ 757.07)																	

INEFFICIENT REFRIGERATORS

YEARS	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Purchase price	$ (1.040,18)																	
Cost for running per year		$(168)	$(168)	$(168)	$ (168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$(168)	$ (168)
<u>NET PRESENT VALUE (COST FOR CONSUMERS)</u>	($ 2.572,61)																	

APPENDIX F: EMISSION REDUCTIONS IMPLEMENTING THE EE PROGRAM (MTON)

YEAR	LIGHTING	Mton of CO_2 per kWh	REFRIGERATORS	Mton of CO_2 per kWh	WATER HEATERS	Mton of CO_2 per kWh	TOTAL SAVINGS	TOTAL Mton of CO_2 per kWh
2009	391,87,586	0.018	0	0.000	0	0	39,187,586	0.040
2010	49,502,780	0.022	0	0.000	0	0	49,502,780	0.051
2011	60,297,015	0.027	62,996,607	0.029	16,446,508	0.07	139,740,130	0.145
2012	71,570,290	0.032	136,722,799	0.062	33,983,439	0.015	242,276,527	0.253
2013	83,322,605	0.038	201,520,067	0.091	52,610,792	0.024	337,453,464	0.352
2014	95,553,960	0.043	277,046,920	0.126	72,328,568	0.033	444,929,447	0.464
2015	108,264,356	0.049	374,709,560	0.170	93,136,766	0.042	576,110,682	0.601
2016	121,453,792	0.055	440,630,869	0.200	115,035,387	0.052	677,120,048	0.706
2017	135,122,268	0.061	528,687,967	0.240	138,024,431	0.063	801,834,666	0.836
2018	149,269,785	0.068	620,921,813	0.282	162,103,897	0.074	932,295,495	0.973
2019	163,896,342	0.074	717,332,407	0.325	187,273,786	0.085	1,068,502,534	1.115
2020	178,194,759	0.081	817,919,749	0.371	213,534,097	0.097	1,209,648,606	1.262

APPENDIX G: INSTITUTIONAL CHARACTERISTICS FOR EE PROGRAMS IN THE RESIDENTIAL SECTOR

COUNTRY	PROGRAM TYPE	INSTITUTION RESPONSIBLE / ACTORS	TYPE OF ISOMORPHISM	CHARACTERISTICS	NORMS / PROCEDURES
Ecuador[13]	Substitution of saving light bulbs	Ministry of Electricity and Renewable Energy (MEER), Electricity Distribution Companies, Energy Efficiency Commission, Buyers of Carbon credits, population	Mimetic (Similar to the Mexican model)	The program has bought the light bulbs through the MERE, and has distributed them through the Electricity Distribution Companies. It is missing the approval of carbon credits trade. The State waits for financial help through a Clean Development Mechanisms as carbon credits trade. Reduced price of saving light bulbs for consumers	The strategy of implementation has the following steps: 1) Do the terms of reference for contracting the company that is going to provide the efficient light bulbs. 2) Establish the contract for selling carbon credits. 3) Development of the distribution program for saving light bulbs. 4) Launch the program in the whole country. 5) Monitoring of the program according to the United Nations approved methodology including a National monitoring for 10 years period. 6) Implementation of the Social Incentives Plan.

[13] (Ministerio de Electricidad y Energia Renovable, 2008)

Mexico [14]	ILUMEX Project (Substitution of saving light bulbs)	Fideicomiso para el Ahorro de Energia Electrica- FIDE (Fund for energy savings), Federal Commission for energy savings (CONAE)	Coercive (Standardization)	Includes pilot programs, incentives and funds. The government of Norway is financing the program	DUEE-IEE: Formulation of technical basis for energy saving norms in domestic and industrial appliances. Distrito Federal, Mexico 1993 * (Source: normalizacion y Eficiencia Energetica) Norms of energy efficiency for domestic refrigerators NOM-074-SCFI-1994 * The FIDE buys the saving light bulbs and sell them to the public (maximum 10 light bulbs, the payment can be done in 8 months), while the CONAE given financial help to the FIDE to continue the program
Chile [15]	Standards & Labeling	Manufacturer, Organism of Certification (OC) , Marketer, Fuels and Electricity Superintendence (SEC)	Normative	Aims to incorporate International Standards for lighting to the national system	1) The manufacturers ask for certification of their products to the OC, 2) The OC does tests the appliances and approves or rejects them, 3) The marketer sells certified products, and 4) The SEC approves operations of the OC, it does the protocols for standards, and monitors

[14] (Dufour, 2006)
[15] (Jaime González F., 2006)

					the standards.
Colombia[16]	Standards & Labeling	Manufacturer, Organism of Certification (OC - In this case is ICONTEC) , Marketer, Commerce and Industry Superintendence (SCI) and Colombia National University	Coercive and Normative	Law: Rational Use of Energy (URE). Aims to build an Andean program to improve capacities to eliminate development and implementation barriers for Energy Efficiency Standards and labels.	1) The manufacturers ask for certification of their products to the OC, they test the appliances in the laboratory of the Colombian national University, and the OC approves or rejects them, 3) The marketer sells certified products, and 4) The SCI approves operations of the OC, it does the protocols for standards, and monitors the standards.

[16] (FABIO GONZALEZ B., 2006)

APPENDIX H: INTERNATIONAL EXPERIENCE FOR DOMESTIC LIGHTING

COUNTRY	MECHANISM USED	AVERAGE PRICE OF MARKETED LIGHT BULBS ($USD)	PARTICIPANTS	PROGRAM'S DURATION	OBSERVATIONS
BRAZIL	CESP (Sao Paulo Electric Company): Included discount coupons in the electricity bill.	11	76889	1993 (40 days)	LFC of 9W electromagnetic ballast were marketed without limiting the number of light bulbs bought.
	CPFL energy Distribution Company): Included discount coupons in the electricity bill.	4.82 – 29.04	153775	1994 (1 month)	They marketed 13 models of compact and circular lamps with electronic and magnetic ballast without limiting the number of lamps bought.
	CPFL energy Distribution Company): Hire purchase through the electricity bill during one year	10.4 – 25.2	43101	1995 - 1996 (6 months)	They marketed 7 models of compact and circular lamps with electronic and magnetic ballast without limiting the number of lamps bought.
	CEMIG (Electric Company of Minas Gerais)	Any cost	52000	1995-1996 (1 year)	Company's personnel installed the LFC's in low-consumption homes (less to 50 kWh/month)
	COLEC: Offered discounts of USD $4 and $8 to users with low incomes combined with a 10 payment financing without interests during a year	12- 18	4173	1997 – 1998 (4 months)	Limited to buy 3 compact and circular lamps

COSTA RICA	One year payment in the electricity bill. Consumers acquired CFL's in the recovery agencies of the electricity companies	11.60	375000 units sold	1996 - 1999	Special CFL's due to the high potency factor and low harmonic distortion.
PERU	The purchase of CFL's with recovery in the electricity bill was failed and the other alternative was to do a communication campaign to purchase CFL's a the commercial channels	17 - 20	49000 sold through the electricity bill. While 1.7 million where sold through commercial channels	1995 - 1999	The product marketed was not especial production with medium technical specifications.

SOURCE: (Dufour, 2006)