INTEGRATED ENERGY PLANNING FOR THE RESIDENTIAL SECTOR: THE CASE STUDY OF CYPRUS

Thesis for the fulfilment of the Master of Science in Environmental Science, Policy and Management
MESPOM

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Supervisors
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"Life can only be understood backwards; but it must be lived forwards."

Søren Aabye Kierkegaard (1813-1855)

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CHAPTER 1: INTRODUCTION

1 INTRODUCTION

Worldwide, 30-40% of all primary energy is used in buildings. In the European Union (EU), buildings account for 40% of the final energy consumption, contributing to significant amounts of carbon dioxide (CO_2) emissions. It offers the largest single potential for energy efficiency.

Motivated by the 70's oil crisis, European Commission has promoted policies for energy savings in the building sector. The EU energy policy has three main targets (Oikonomou and Patel, 2004):

- Liberalization from the monopolistic states of the electricity markets, while in parallel, to secure the supply for the coverage of needs.
- EU's obligation towards the Kyoto Protocol, which requires the reduction of the GHG emissions at a rate of 8% by 2010 compared to the base year 1990.
- Promotion of renewable energy into the energy markets, with a quantitative aim of doubling the EU share of Renewable Energy (RE) supplies in gross inland consumption by 2010.

The aim of improved energy efficiency has been set out in many legal EU instruments. Among the main Community legislation for the building sector are the Boiler Directive (92/42/EEC), the Construction Products Directive (89/106/EEC) and the buildings provisions in the SAVE Directive (93/76/EEC). The **Directive on the energy performance of buildings (EPBD)**, which came into force in January 2003, builds on those measures with the aim to increase the energy performance of public, commercial and private buildings in all Member States (MS). The translation of EPBD in the various national legislation frameworks has provided MS with the opportunity to modify (or, as in case of Cyprus where no building codes existed, to introduce) building performance standards, develop calculation tools, integrate renewable energy sources, design and implement training sessions and to disseminate information (see the EPBD Buildings Platform[1]).

The energy demand in households accounts for 25% of the final energy needs in the EU. The electricity used for domestic appliances shows the sharpest increase of energy consumption in households. Comfort and higher standards of living, multiple purchases of electric appliances and the growing need for air-conditioning are some of the reasons. The response of EU in the growing energy demand in households by domestic appliances is the "EU labelling schemes" and the "Minimum Efficiency Requirements"[2]:

- Energy Labelling of household appliances: increase consumer's awareness on the real energy use of household appliances through a liable and clear labelling in their sales points.

[1] http://www.buildingsplatform.org/cms/

[2] http://ec.europa.eu/energy/demand/legislation/domestic_en.htm

- Minimum Efficiency Requirements: compulsory minimum efficiency requirements will encourage producers of household appliances to improve the product design in view to lower the energy consumption at their use.

The households and tertiary sector in Cyprus account for 29% of the total final energy consumption, with the transport sector consumes 53% and industry sector 19%. Households and tertiary sector has the biggest increase in total final energy consumption, with an annual increase of 11% (comparing with the base year of 1990). The focus of this thesis is on the residential energy consumption.

Prior to the accession in European Union (2004), Cyprus did not have a comprehensive energy efficiency policy, with national legislation, building regulations with energy requirements, targets and other such facets. After the accession in EU, several EU Directives transposed in Cyprus, among them the Energy Performance of Buildings Directive (EPBD). In order to ensure the implementation of EPBD in Cyprus, three legal documents have been approved by the House of Representatives and published in the Government Official Gazette:

- The Law for the Regulation of the Energy Performance of Buildings of 2006, L.142(I)/2006;
- The Amendment of the Law for the Regulation of Roads and Buildings, L.101(I)/2006;
- The Roads and Buildings (Energy Performance of Buildings) Regulations, Κ.Δ.Π.429/2006.

According to estimations by Cyprus Institute of Energy (CIE), the full implementation of the energy performance of buildings directive can cover the adopted energy savings target of 185000 toe by 2016, as well as the intermediate target of 60000 toe by 2010.

The main target of the thesis is to investigate the energy consumption of the building sector in Cyprus and identify policy areas for intervention, in view of the overall EU legislation framework. It consists of five chapters focusing on the presentation of energy consumption trends in the residential sector of Cyprus and on the recommendation of energy efficiency policies and measures. Energy efficiency improvements refer to a reduction in the energy used for a given service (heating, lighting, etc.) or level of activity. The reduction in the energy consumption is usually associated with technological changes but also can result from better organisation and management or improved economic conditions in the sector (“non-technical factors”) (WEC, 2008).

Chapter 2 - BIBLIOGRAPHIC SURVEY aims to provide an overview of how energy is used in buildings, discussing the building stock and the shares of different energy end-use purposes and the distribution of energy consumption in building within the European context and in Cyprus and presenting existing energy policies and measures through a bibliographic survey.

Chapter 3 - METHODOLOGY AND DATA refers to the methodology followed in order to estimate energy consumption trends and the distribution of different end-use purposes in the residential sector of Cyprus. A questionnaire-based energy survey was prepared and distributed into 30 households in Cyprus in order to obtain the necessary data. After the collection of data, a statistical *index system* for the residential energy consumption was constructed. The purpose of the index system is to look into the actuality of residential energy consumption and to provide sufficient data and energy efficient countermeasures for building energy efficiency (Chen et al., 2008).

The results of the collected data are presented in **Chapter 4 - RESULTS**, together with the presentation of some energy efficiency measures and their potential energy savings.

Finally **Chapter 5 - RECOMMENDED POLICIES AND CONCLUSIONS**, presents recommendations on policy measures aiming at improving the residential energy consumption by promoting energy efficiency measures in buildings of Cyprus.

CHAPTER 2: BIBLIOGRAPHIC SURVEY

2 BIBLIOGRAPHIC SURVEY

2.1 EU Building Directive

2.1.1 EPBD – Energy Performance of Building Directive (2002/91/EC)

The Energy **Performance of Buildings Directive (EPBD)** is considered to be a very important legislative component of energy efficiency activities of the European Union designed to help meeting the Kyoto commitments.

The objective of the EPBD is to improve the energy performance of buildings. The Directive lays down requirements as regards (Article 1):

"(a) the general framework for a methodology of calculation of the integrated energy performance of buildings,
(b) the application of minimum requirements on the energy performance of new buildings,
(c) the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation,
(d) energy certification of buildings,
(e) regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old."

Article 3 of the Directive; deal with the Adoption of a methodology. The EPBD provides the general framework for the calculation procedures. Article 3 states that *"Member States shall apply a methodology, at national or regional level, of calculation of the energy performance of buildings on the basis of the general framework set out in the Annex. Parts 1 and 2 of this framework shall be adapted to technical progress in accordance with the procedure referred to in Article 14(2), taking into account standards or norms applied in Member State legislation. This methodology shall be set at national or regional level. The energy performance of a building shall be expressed in a transparent manner and may include a CO_2 emission indicator."*

The application of minimum requirements on the energy performance of new buildings and of large existing buildings that are subject to major renovation is covered in Articles 4, 5 and 6. The minimum requirements may be different for new and existing buildings, and may be different for different categories of building. Article 4 (Paragraph 1) states that *"Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings are set, based on the methodology referred to in Article 3. When setting requirements, Member States may differentiate between new and existing buildings and different categories of buildings. These requirements shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions and the designated function and the age of the building. These requirements shall be reviewed at regular intervals which should not be longer than five years and, if necessary, updated in order to reflect technical progress in the building sector."*

In Article 5 the Commission indicates to Member States that necessary measures should be taken in order to ensure that new buildings meet the requirements of Article 4. Also in this Article, Member States should consider and take into account alternative systems (such as decentralised energy supply systems based on renewable energy, combined heat and power technologies, etc) for new buildings with a total useful floor area over 1000 m^2, prior to construction phase.

Existing buildings are covered by Article 6, where Member States must take necessary measures to ensure that when buildings with a total useful area over 1000 m^2 undergo major renovation; their energy performance is upgraded in order to meet the minimum requirement set previously by Article 4.

Article 7 deals with the setting up of the Energy Performance Certificate for new and existing buildings. Article 7 (Paragraph 2) states that *"The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance. The objective of the certificates shall be limited to the provision of information and any effects of these certificates in terms of legal proceedings or otherwise shall be decided in accordance with national rules."*

The inspection of boilers and air conditioning systems is covered by Articles 8 and 9. These Articles are related to the inspection of hot water boilers used for heating of buildings; and inspection of air conditioning systems used to control air temperature inside buildings, possibly in combination with the control of building ventilation, air humidity and air cleanliness. The Directive (in Article 11) states that *"…the inspection of boilers and air-conditioning systems are carried out in an independent manner by qualified and/or accredited experts, whether operating as sole traders or employed by public or private enterprise bodies."*

2.1.2 History behind EPBD

The idea of European Union was based on the concept of a common and shared supply of energy and other basic economic goods. In the 1950's Europe was an economy of scarcity and energy scarcity was a reality. For that reason the first European Treaties were based on supply side concept and not on the management of demand concept.

In 1951 six countries (Germany, France, Italy, the Netherlands, Belgium and Luxembourg) sign a treaty to run their heavy industries - coal and steel - under a common management. That was the very first European Treaty (European Coal and Steel Treaty) which aimed to increase production of coal and steel and to create a common market for these products. Building on the success of the European Coal and Steel Treaty, the six countries expand cooperation to other economic sectors. They sign the Treaty of Rome, creating the European Economic Community (EEC), or "common market" and the EURATOM (European Atomic Energy Community) Treaty for the promotion of nuclear energy. Later, these 3 Treaties were merged into the Treaty of the European Community and in that process; a Directorate-

General Energy was created. It was decided that decisions on energy matters should require unanimity in the Council of Ministers.

In 1973, Denmark, Ireland and the United Kingdom formally enter the EU. Denmark immediately questioned the concept of increasing energy supply since Denmark had an energy policy with an emphasis on the management of demand. Adding the fact that Ireland was strongly anti-nuclear led to the reality that there was no longer any unanimity on the European energy policy, which in terms meant no possibility for a new direction.

In August 1985, the first positive step towards the EPBD was taken by an internal paper prepared from DG Energy for the European Commission. This document stated that 40% of all energy use in the EU is related to buildings and a number of policy options were outlined. As a result from the discussions for this document, the Commission proposed the SAVE (Specific Actions for Vigorous Energy Efficiency) Directive on May 12th 1989. The Directive required Member States to "develop, implement and report on programmes in the field of energy efficiency in the building sector"[3]. In SAVE Directive, the Commission proposed 13 specific actions, where 10 were directly related to the building sector. After negotiations between Parliament and Council, the finally adopted SAVE Directive was more a kind of declaration of intent rather than binding legislation whereby six measures were introduced (Hubert, 2006):

- Energy certification of buildings
- Separate billing for heating, hot water and air-conditioning based on the actual consumption
- Third party financing for energy savings n the public sector
- The need of thermal insulations of buildings
- Inspection of boilers
- Energy audits in big industrial installations

The SAVE Directive was characterised as an environmental Directive and not an energy Directive.

In the late 1980's, a discussion had started about global warming theory. Environmental non-governmental organizations (NGO's) started to support the global environmental protection idea to prevent further global warming. The press also increased the interest on global warming. In 1997, the EU made a unilateral commitment to reduce CO_2 emissions by 5% by 2010 (compare with base year of 1990). Later at the Kyoto meeting, the EU increased its commitment to 8% (more details about Kyoto protocol in **Paragraph 2.3**). In order to achieve that, the Commission adopted an Action Plan in 2000 to improve energy efficiency. Also, in 2001, proposed to give a legal dimension to the SAVE Directive of 1993. This proposal eventually became the **Energy Performance of Building Directive (2002/91/EC)** on 16th December 2002.

[3] Official Journal L 237, 22.9.1993, p. 28.

In 2006, the European Commission introduce, for the second time, an Energy Efficiency Action Plan (EEAP) which lists 10 priority areas. While buildings were one of the ten, EEAP underlines the necessity of implementation of EPBD fully and properly but also lists envisaged actions for 2009 for even better results. Also in 2006 the Energy Services Directive (ESD) came into force by EU which might be a major driving force for improving energy efficiency in buildings and indeed for the improvement of the EPBD (Hubert, 2006).

2.2 Building Sector and Energy Use

The building and construction sector is a key sector for sustainable development. The construction, use and demolition of buildings generate substantial social and economic benefits to society, but may also have serious negative impacts, in particular on the environment. This sector usually provides 5 to 10% of employment at national level and normally generates 5 to 15% of the GDP (UNEP, 2007). In EU, construction industries amount to 10-12% of GDP or 25% of all manufacturing industry, employing a total of 25-30 million people in 2.7 million companies (ATLAS, 2006).

2.2.1 Energy consumption in buildings

A building is a very complex energy system, especially when allowing a high degree of interactions with its surrounding environment with the aim of improving its energy performances (Casals 2006). Various factors influence energy consumption in buildings. Among them, envelope construction, age distribution of the existing building stock, outdoor weather conditions, number and size of buildings, type, age and efficiency of equipment, fuel split for heating and sanitary hot water production, which are outlined next (Balaras et al, 2007). According to Jones (1998) over building's life cycle, energy is used in five phases: (i) the manufacturing of building products and components; (ii) the transportation of building products and components to the construction site; (iii) the construction itself; (iv) the operational phase; and (v) the final demolition and recycling.

The operational phase is the most energy-intensive phase but it is important to mention that the energy consumption of all phases is significant. Energy during the operation phase is used in buildings to meet a number of end-use demands, such as space and water heating, lighting, catering, air conditioning and refrigeration and equipment such as domestic appliances, computers, lifts and office equipment. Since buildings have a lifetime of 50 to more than 100 years, adding up the energy use during the operational phase is significantly more than that used for manufacturing of building components and construction of building itself (**Figure 2.1**).

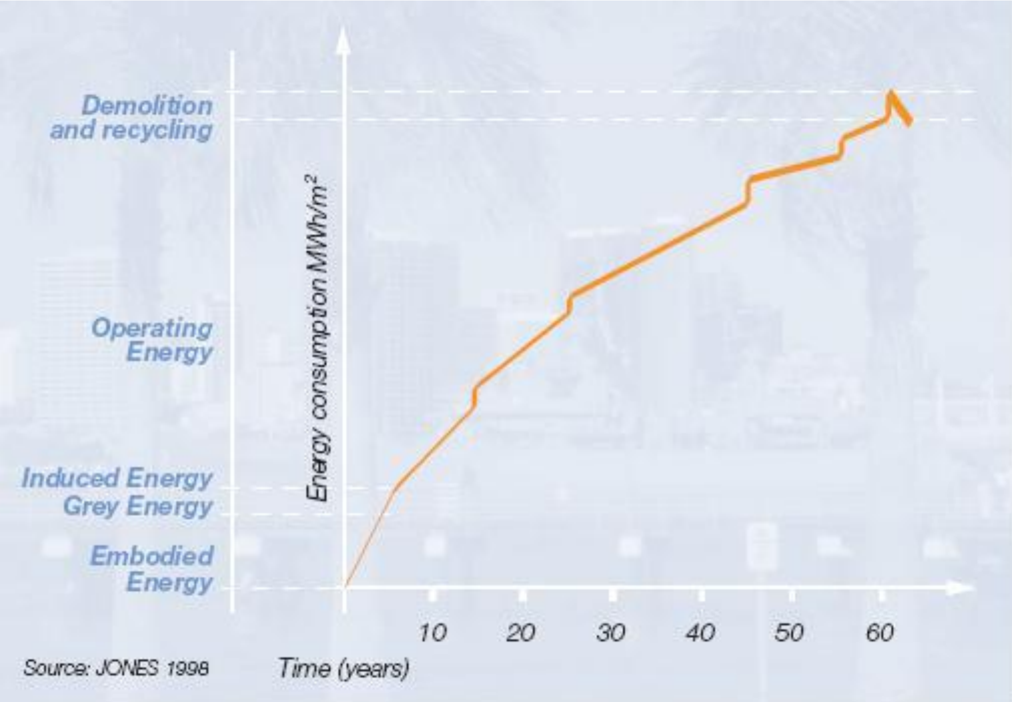

Figure 2.1: Energy consumed in the life of a building, estimated at 60 years

Source: Jones (1998), adapted from Buildings and Climate Change – Status, Challenges and Opportunities (UNEP, 2007).

2.2.2 Building stock of EU

Building sector is divided into a residential and non-residential building type. The non-residential type usually is divided more in a commercial and public services buildings. Statistics on non residential buildings are not so well documented as for the residential sector and it is a common feature throughout the EU.

The number of dwellings in EU-25 is about 196 million, of which about 80% is concentrated in five countries: Germany (18.6%), Italy (13.8%), UK (13.2%), France (12.7%), Spain (10.8%), Poland (6.5%) and The Netherlands (3.5%) (Balaras et al, 2007). **Figure 2.2** examines the availability of the dwellings in EU and demonstrates that the number per 1,000 inhabitants averages at 412.8 dwellings. However, the availability of dwellings varies significantly between the various Member States in EU and more specifically between EU-15 and new MS. In EU-15 the average number of dwelling is 440.6 per 1,000 inhabitants, while in new MS the equivalent figure is 394.7 dwellings. From the 10 new MS only Cyprus and Malta reach the average number of dwellings in EU-15.

In relation to housing tenant, **Figure 2.2** shows that 69% of the housing stock is owner-occupied, while 16.9% is private-rented, 10.1% social-rented and 7.2% others (dwellings provided by employers and religious institutions and dwellings occupied free of rent). However, there are large differences in repartition of dwellings between the various categories in the EU. The status of occupation and ownership is an important factor to be considered because owners/occupiers are much more interested to improve their homes than occupiers in the rented sector.

Country	Year to which data refer	Dwellings		Vacant dwellings % of total dwellings	Dwellings by Tenure			
		No.	Per 1,000 inhabitants		Owner Occupied %	Private Rented %	Social Rented %	Other %
Austria*	2002	3,316,000	412.4	Nav	56.9	40.3	2.8	
Belgium	2001	4,095,008	400	Nav	68	25	7	0
Bulgaria	2002	3,691,787	471	14.4	96.5	0	3.0	0.5
Cyprus	2000	286,500	428	Nav	64.3	35.7	0	0
Czech Republic	2001	4,366,293	427	12.3	47	17	17****	12
Denmark	2003	2,541,000	472	Nav	50.6	17.8	27.2	4.4
Estonia	2000	622,600	434	6.2	85	9	3	0
Finland	1999	2478,000	490	8.6	58	17	17	1
France*	2002	24,525,000	413.3	6.8	56.0	19.7	17.2	7.1
Germany*	2002	35,800,000	434.3	Nav	43	51	6	0
Greece	2001	3,657,000	505	Nav	80.1**	19.9**	0**	0**
Hungary	2000	4,076,800,	406.7	Nav	86.9***	10.4***	0***	
Ireland	2003	1,554,000	391	Nav	77.4$^{\Delta}$	11$^{\Delta}$	6.9$^{\Delta}$	4.7$^{\Delta}$
Italy	2001	26,526,000	471	24	80	16	4	0
Latvia	2000	941,000	398	Nav	60.1	39.6	0.29	0
Lithuania	2002	1,291,700	367	Nav	87.2	8	3	1.8
Luxembourg*	2001	171,953	391.7	2.3	70	27.5	1.5	1
Malta	1995	155,202	420	23	74.1	22.4	3.5	
Netherlands	2002	6,710,800	419.8	Nav	54.2	10.8	35.0	0
Poland	2002	12,523,600	326.6	6.07	55.2	0	22.8	21.5
Portugal*	2001	3,551,000	346	10.8	75.7	21	3.32	0
Romania	2002	8,107,114	361.4	11.6	97.2	0	2.62	1
Slovakia	2001	1,884,846	350	11.6	75.9	0.1	3.7	10.3
Slovenia	2002	777,772	390	14	82.2	2.6	6.5	8.7
Spain	2001	20,800,000	528	13.9	81	9.7	1.6	0
Sweden	2002	4,300,000	482.7	Nav	38	22	24	16
Turkey	2000	Nav	Nav	Nav	63.8	27.2	8.9	
United Kingdom	2001	25,456,000	452.2	Nav	69	9.3	20.8	0
Mean (R)	N/a	N/a	421.8	11.8	69	16.9	10.1	7.2

Note: * data refer to occupied dwellings only; consequently these countries are not included in the calculation of the mean number of dwellings per 1,000 inhabitants. ** - 1994 data ** - 1994 data *** - 1996 data $^{\Delta}$ - 2002 data **** This figure refers to dwellings rented from municipalities, but dwellings of this type may not necessarily be social rented. Depending on the policy of the individual landlord, some are let at commercial rents. The information on the average % of dwellings in each housing tenure is skewed by missing data for some countries. As a result the average values for the four tenure categories exceed 100%.

Figure 2.2: Housing availability in European Countries, various years

Source: Norris and Shiels (2004)

The housing quality in EU is presented in **Figure 2.3**. This figure indicates that in EU the average floor area of dwellings is 76.5 m^2 with an average of 3.6 rooms per dwelling. Again these numbers varies between EU-15 and new MS. For EU-15 the average floor area of dwellings is 84.2 m^2 with an average of 4.4 rooms while for new MS the average floor area is 72.9 m^2 with an average of 3.6 rooms per dwellings. Again from the 10 new MS, only Cyprus and Malta reaches the averages numbers for EU-15.

The annual rate of construction of new dwellings expressed as a percentage of the size of existing stock ranges from 0.3% in Sweden to 3.5% in Ireland with an average of 1.1%, while the estimated annual replacement rate (ratio of the annual demolition rate to the size of existing stock) for dwellings in Europe is actually very low, only 0.07% (Balaras et al, 2007). The residential building stock is not only renewing very slowly, it also consists largely of older constructions. This can be seen also from **Figure 2.3**, where 28.8% of the dwellings where built before 1945, 34.8% between 1945 and 1970, 37.6% between 1970 and 1990 and 8.2% from 1990 to 2004. The year of building construction can provide information regarding the type of envelope construction, in relation with the national building standards in force at that time.

		Date of Construction (DC) (%)				Available Facilities (AF) (%)					
Country	Year to which data refer	Pre-1945	1945-1970	1970-1990	1990-Present	Running Water	Lavatory	Bath/ Shower	Central Heating	Average Number of Rooms (AR)	Floor Area (FA) (in m²)
Austria	2002	26.8	28	28.7	16.4	99.9	98.7	97.5	87.3	4.3	60-90
Belgium	1996	31.8	29.8	34.1	4.2	Nav	Nav	Nav	Nav	Nav	Nav
Bulgaria	2000	24.3	48.2	24.5	1.9	97.6	82.5	Nav	12.7	2.6	65.2
Cyprus*	DC, AR, FA=2000; AF-1999	23*	10.7	38.1	28.2	99.2	97.7	94.8	50	5.8	144.8
Czech Republic	DC=1991; AF, FA=2001; AR= 2000	41.9	24.6	33.5	0**	98.5	95.4	95.5	81.7	2.7	49.3
Denmark	DC, FA=2000; AF=2003	38.9	29.9	25.9	5.3	99.9	99.9	94.3	99.9	Nav	109.3
Estonia****	DC, AF=2002; AR, AF=2000	18.9	22.8	31.5	4.1	82	72	68	59	3.8	68.9
Finland	DC=1996; AF=2002; AR, FA=2000	12	32.9	46.2	7.9	98	96	99	92	3.8	85.7
France*	2002	29.4*	15.1	32.2	5.7	99.9	99.2	99.2	96.3	4	90
Germany*	DC=2002; FA=1996	27.9*	61		11.1	Nav	Nav	Nav	Nav	Nav	88.4
Greece	N/A	Nav	Nav	Nav	Nav	Nav	Nav	Nav	Nav	Nav	Nav
Hungary*	DC, AF=1996; AR, FA=2000	29.5	27.2	38.9	4	84.4	75.6	79.6	48.2	4.1	52
Ireland*	2002	20.5	17.6	36.2	25.7	99.7	Nav	Nav	86.8	5.2	70.2
Italy	DC=1991; AF=1995; FA=1996	29.5	40.7	29.8		99	99	99	79	Nav	88.3
Latvia	2000	25	28	43	4	83.2	77.8	67	64.9	2-3	40-60
Lithuania	DC, AF, AR=2001; FA=2000	27	34	32	7	78.9	76.3	71.8	72	2-3	70.9
Luxembourg	DC, AR=2001; FA=1999	27.3	72.7			100	100	100	100	Nav	81.1
Malta	1995	25.5	22.2	43.1	9.1	99	97.7	96.6	0.7	5	Nav
Netherlands	DC, AF= 2002; AR=2000	20	27	53		100	100	100	90	4.2	Nav
Poland	DC, AF, AR=2002, FA= 1991	23.2	26.9	37	11.6	92.5	80.6	80.8	71.4	3.7	49
Portugal	1991	24.4	31.2	44.2	0	87.2	88.8	82.2	Nav	Nav	Nav
Romania	2002	Nav	Nav	Nav	Nav	53	53	Nav	Nav	2.6	Nav
Slovakia	2001	11.5	35.2	46.6	6.7	94.7	60.2	62.2	76.3	3	40-60
Slovenia	2002	23.4	39.8	28.9	7.8	98.5	93	92	78.6	3	74.6
Spain	2001	22	29.8	34.3	13.8	98.6	96.8	Nav	53.2	5	76-90
Sweden	DC=2002; AF=2000, AR=1990; FA=1996	21	43	28	6	100	100	100	100	4.2	71
Turkey	AR=2000	Nav	Nav	Nav	Nav	94.7	88	94.9	100	Nav	80-100
United Kingdom*	1991	41	22	38	0***	Nav	Nav	Nav	Nav	Nav	Nav
Mean (R)	N/a	28.8	34.8	37.6	8.2	93.3	88.2	88.7	72.7	3.6	76.5

Source: additional information was sourced in the United Nations Economic Commission for Europe (2002).

Figure 2.3: Housing quality in European Countries, various years

Source: Norris and Shiels (2004)

2.2.3 Energy consumption of EU building stock

The EU final energy consumption for 2007 in the households and tertiary sector reaches to 481 Mtoe (with transport sector at 361.6 Mtoe and industry at 327.7 Mtoe), of which 309.9 in households (Directorate-General for Energy and Transport, 2007). Germany, United

Kingdom, France and Italy are the countries with the highest final energy consumption (in absolute terms) in the households and tertiary sector.

Space heating is by far the largest energy consumption end-use in EU-15, and accounts for 68.8% of total domestic consumption; water heating accounts for a further 13.8%; lighting and appliances accounts for 12.8%; and cooking 4.6% (BERR[4], 2006). The share of space heating is declining with slow rate, while on the other hand, electrical appliances and lighting are playing an increasing role. Space heating ranges between 50% and 60% in Sweden and UK and 75% in Germany and The Netherlands. In southern Europe, it is about 50% in Spain and 30% in Portugal (Balaras et al, 2005).

Annual energy consumption in residential buildings averaged 150-230 kWh/m^2 in the 1990s, while in eastern and central Europe was 250-400 kWh/m^2. In northern European countries, well-insulated buildings have an annual consumption of 120–150 kWh/m^2, while the so-called low-energy buildings may even drop down to 60–80 kWh/m^2 (Balaras et al, 2004).

Large electrical appliances (including refrigerators, freezers, washing machines, dishwashers, dryers, and TV sets) account for a decreasing share of the total energy consumption for electrical appliances – from 53% in 1985 to 45% in 2001, while small electrical appliances (radio, video, DVD player, PC, etc) represents an increase weight in this consumption, with 37% in 2001 against 26% in 1985 (BERR, 2006). Despite the reduced share of the total for large electrical appliances, energy consumption for electrical appliances increased by 1.9% per annum as a result of the higher number of appliance ownership and use and standby power consumption (Balaras et al, 2005).

2.3 Buildings and the Kyoto Protocol

2.3.1 Kyoto protocol and targets

The Kyoto Protocol is an international agreement, under the United Nations Framework Convention on Climate Change (UNFCCC) aiming on reduction of greenhouse gas (GHG) emissions. The Kyoto Protocol was adopted at the third Conference of the Parties to the UNFCCC in Kyoto, Japan, on 11th December 1997, after two and a half years of intense negotiations. The Kyoto Protocol established legally binding targets for those industrialized countries that ratify the agreement (Annex B[5] Parties) and the timeframes within which those targets are to be met. The targets are a cut in greenhouse gas emissions of at least 5% (add up to a total cut) against the baseline of 1990. The timeframe which was set up for reaching those targets is between years 2008 and 2012 (five-year timeframe).

The Protocol's major feature is that it has mandatory targets on greenhouse-gas emissions for industrialized countries which have accepted it. Among countries that have withdrawn the support for the Protocol are the United States of America and Australia.

[4] Department for Business, Enterprise & Regulatory Reform, UK.
[5] Annex B refers to the group of developed countries comprising of OECD (as defined in 1990), Russia and the East European Associates.

Commitments under the Protocol vary from nation to nation. The European Union (EU-15 Member States) under the Kyoto Protocol has accepted a quantitative absolute reduction of 8% of its GHG emissions. The Protocol allows the EU to allocate its target among the Member States. The EU-15 target does not apply to the 10 Member States (NMS) that joined the EU on 1 May of 2004. Under the Protocol most of these have their own reduction targets of 8% or 6% compared with a given base year (1990 or earlier). Cyprus and Malta have no targets. The targets for limitation or reduction of GHG emissions set for each EU country under Kyoto Protocol can be seen clearly on **Figure 2.4** that follows.

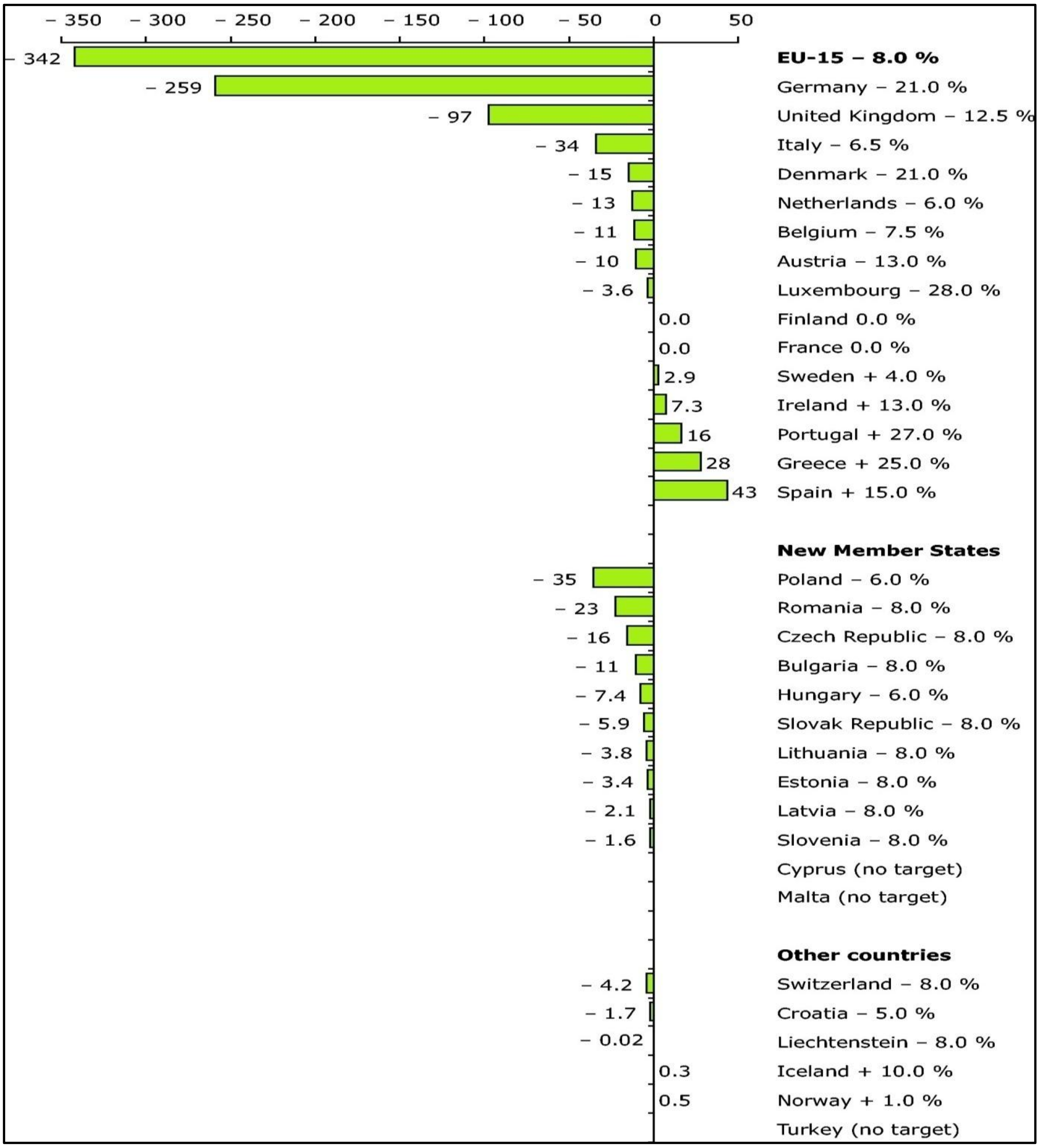

Figure 2.4: Greenhouse gas emission targets (Mt CO2-equivalent) of all EU-27 Member States, EU candidate and other European Economic Area (EEA) member countries for 2008–2012 relative to base-year emissions

Source: European Environment Service (EEA)

The Kyoto Protocol offers flexibility in the way that countries may meet their targets. The three Kyoto flexible mechanisms are: emissions trading between governments with Kyoto targets, the Clean Development Mechanism (CDM) and Joint Implementation (JI). These three market-based mechanisms were designed to allow Annex B Parties to meet their targets cost-effectively by trading emission allowances between themselves and gaining credits for emission-reducing projects abroad.

Emission trading mechanism (so-called “carbon market” because carbon dioxide is the most widely produced greenhouse gas, and because emissions of other greenhouse gases will be recorded and counted in terms of their "carbon dioxide equivalents) allows countries that have emissions units to spare (excess capacity of emissions from countries that are below their Kyoto targets) to sell to countries that are over their targets. The price of “buying” emissions could be steep. The aim of the steep price is to put more pressure to countries to use energy more efficiently and to research, develop and promote alternative sources of energy that have low or now emissions.

The CDM and the JI mechanisms allow Annex B Parties to achieve part of their emission reduction targets by conducting emission-reduction projects abroad but the reductions achievement of those projects would be counted towards their own commitments. The difference between those two mechanisms is that the JI allows for projects in other Annex B Parties with Kyoto targets, while CDM projects are carried out in countries without targets (i.e. developing countries). The aims of those two mechanisms, beside the emission reduction, are to lower compliance costs, transfer advanced technologies and knowledge to developing countries and promote co-operation between countries with Kyoto targets[6].

2.3.2 Greenhouse gas emissions in EU

In 2004, EU was responsible for 23% of the total GHG emissions[7] for all Annex 1 countries (industrialised countries and countries that are undergoing the process of transition to market economies). The 23% is translated to 5.093 millions tonnes of CO_2-equivalent[8] (excluding LULUCF[9]) of 17.981 millions tonnes. As a comparison the shares of total GHG emissions from other industrialised countries (excluding LULUCF), were about 40 % for USA, about 8 % for Japan and about 4 % each for Australia and Canada (UNFCCC).

In the EU-27[10], total GHG emissions (excluding LULUCF) decreased by 7.9% between 1990 (base year) and 2005. Between years 2004 and 2005, GHG emissions decreased by 0.7% bringing emissions 7.9 % below the 1990 level (**Figure 2.5**).

[6] Buildings and Climate Change – Status, Challenges and Opportunities. United Nations Environment Programme (UNEP), 2007.
[7] European Environment Agency (EEA) – Europe’s Environment, The Fourth Assessment, 2007.
[8] Different greenhouse gases have different climate change effects. To simplify presentations, all gases are expressed as the corresponding effect of CO2 (CO2-equivalents).
[9] Land Use, Land-Use Change and Forestry.
[10] EU-15 plus New Member States.

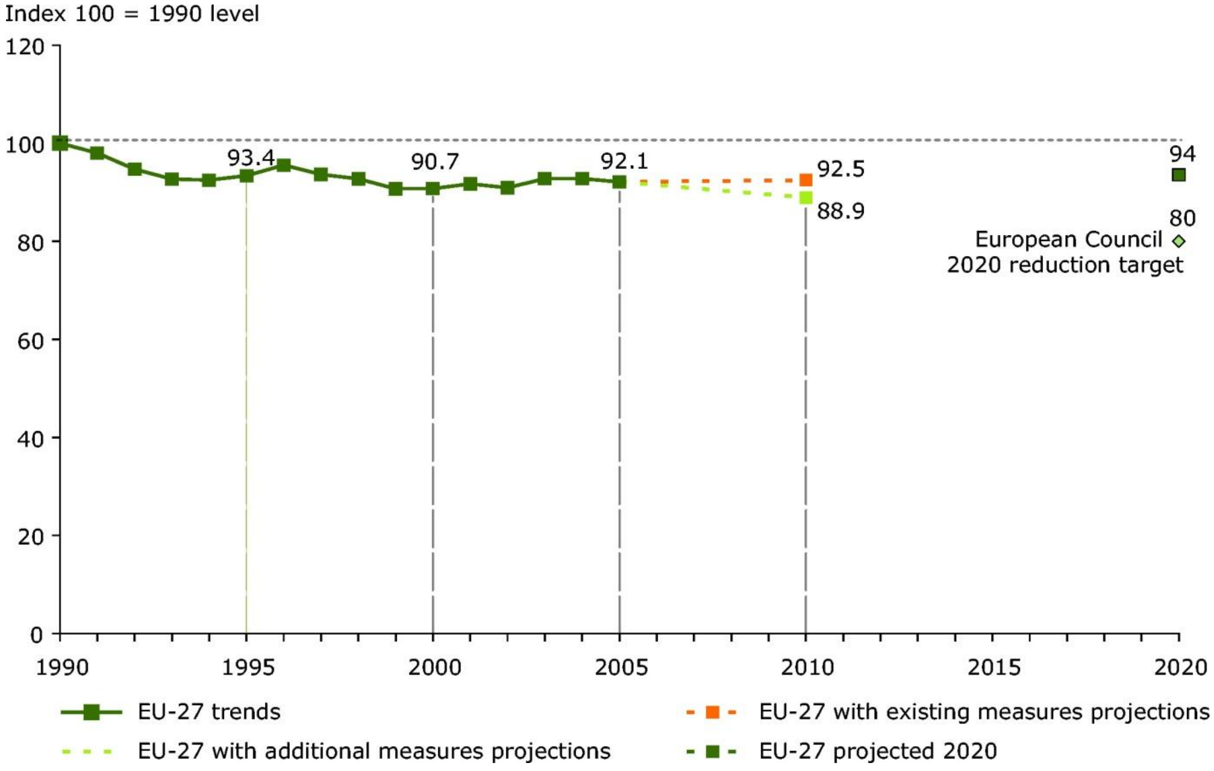

Figure 2.5: EU-27 greenhouse gas emission trends and projections to 2020

Source: European Environment Service (EEA)

As it can be seen from the above figure, during years 2002 – 2004 there was an upward trend, which makes the decrease of 0.7% between 2004 and 2005 a positive step, although emissions are still higher than the levels existing between 1999 and 2002 (in 2000, GHG emissions were 9.3% below base year). In the above figure we can also observe GHG emissions projected to 2010, with existing and with additional domestic policies and measures. It is important to notice that projected GHG emissions in 2010, with the existing measures, would estimate to be 7.5% below 1990 and 0.4% above 2005. With additional measures the projected GHG emissions would be 11.1% below 1990 and also 3.2% below 2005. GHG emissions and projections in European countries can be seen in **Figure 2.6** that follows.

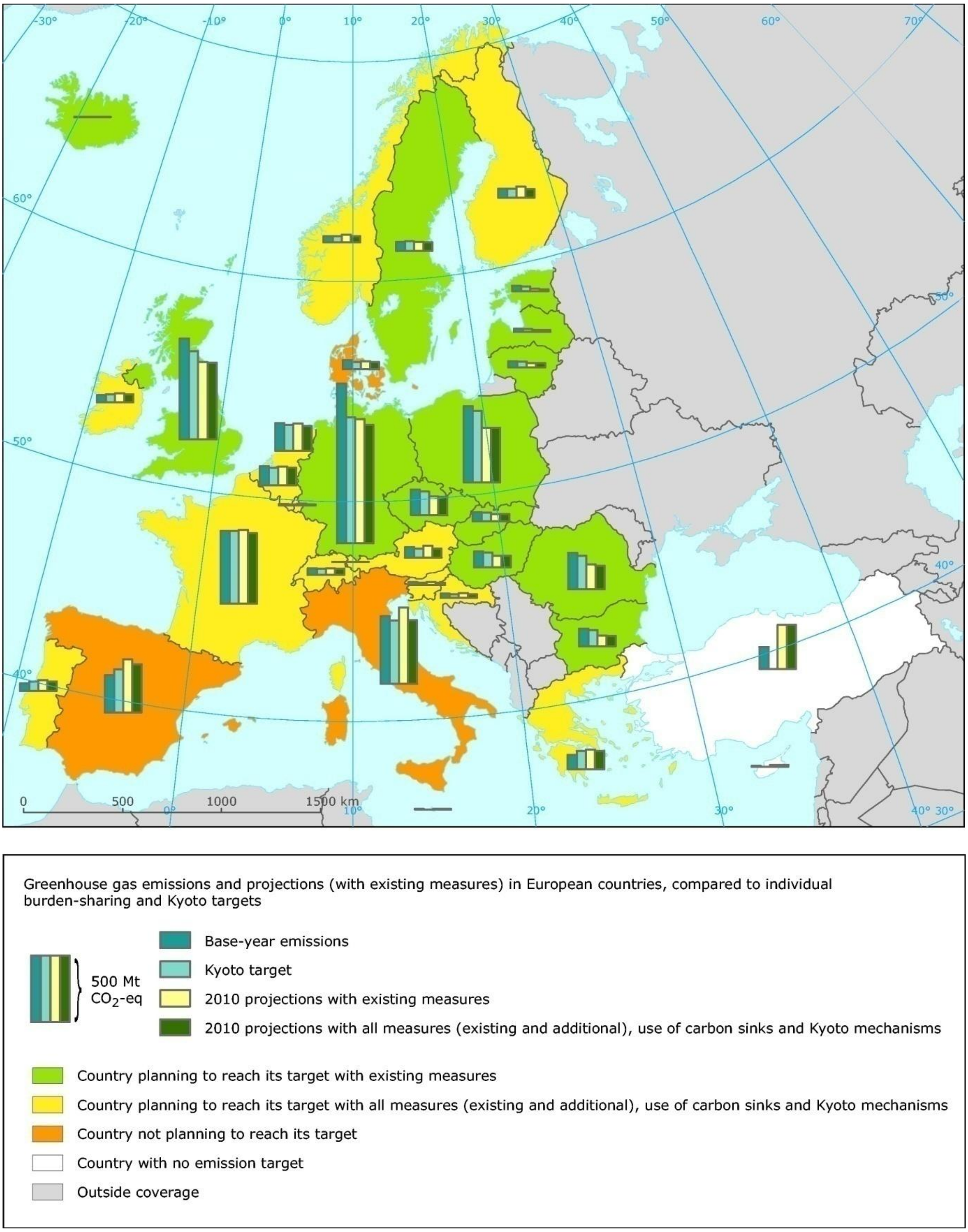

Figure 2.6: Projections of greenhouse gas emissions in Europe for 2010

Source: European Environment Service (EEA)

In EU-15, GHG emissions decreased by 0.8% (or 35.2 Mt CO_2-equivalent) between years 2004 and 2005 mainly due to a decrease in CO_2 emissions by 0.7 % (26 Mt)[11]. Despite this

[11] EEA - Greenhouse gas emission trends and projections in Europe 2007.

reduction, 2005 emissions are still higher than in 2000 (see **Figure 2.7**). The decrease in GHG emissions in 2004 – 2005 was mainly due to reductions in sectors such as public electricity and heat production, households and services, and road transport.

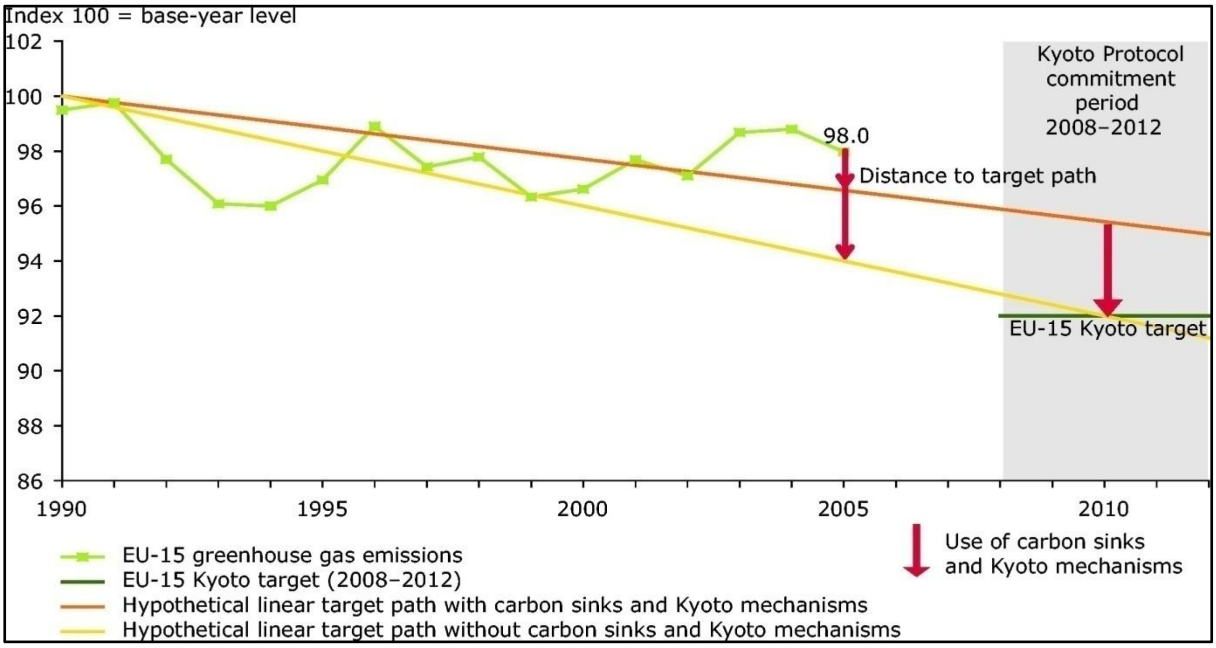

Figure 2.7: Comparison of 2005 EU-15 emissions with hypothetical target paths towards the EU-15 Kyoto target

Source: European Environment Service (EEA)

The reduction achieved in 2005 (2.0% below base year) represents one quarter of the 8% needed to reach Kyoto EU-15 target. The figure above shows that despite the reduction (comparing to the base year) of GHG emissions, those emissions are still above their target path[12] even when the further expected reductions due to the use of carbon sinks and Kyoto mechanisms are taken into account. This means that the EU-15 is not considered to be on track for Kyoto targets based on past trends. Countries that are on track for Kyoto targets (even without the use of carbon sink and Kyoto mechanisms) are: Sweden, the United Kingdom, Germany, Finland, France and Belgium. Seven countries are not in the track for Kyoto targets: Spain, Austria, Italy, Ireland, Portugal, Greece and Denmark.

2.3.3 Greenhouse gas emissions in EU from building sector

Emissions of CO_2 from energy use in households accounted for 10% of total EU‑15 greenhouse gas emissions in 2005. From 1990 to 2005, household emissions fluctuated mainly in line with outdoor temperature in the winter season, with an overall slightly increasing trend (**Figure 2.8**) (EEA, 2007a).

[12] Hypothetical line between base-year emissions in 1990 and the emission target for 2010.

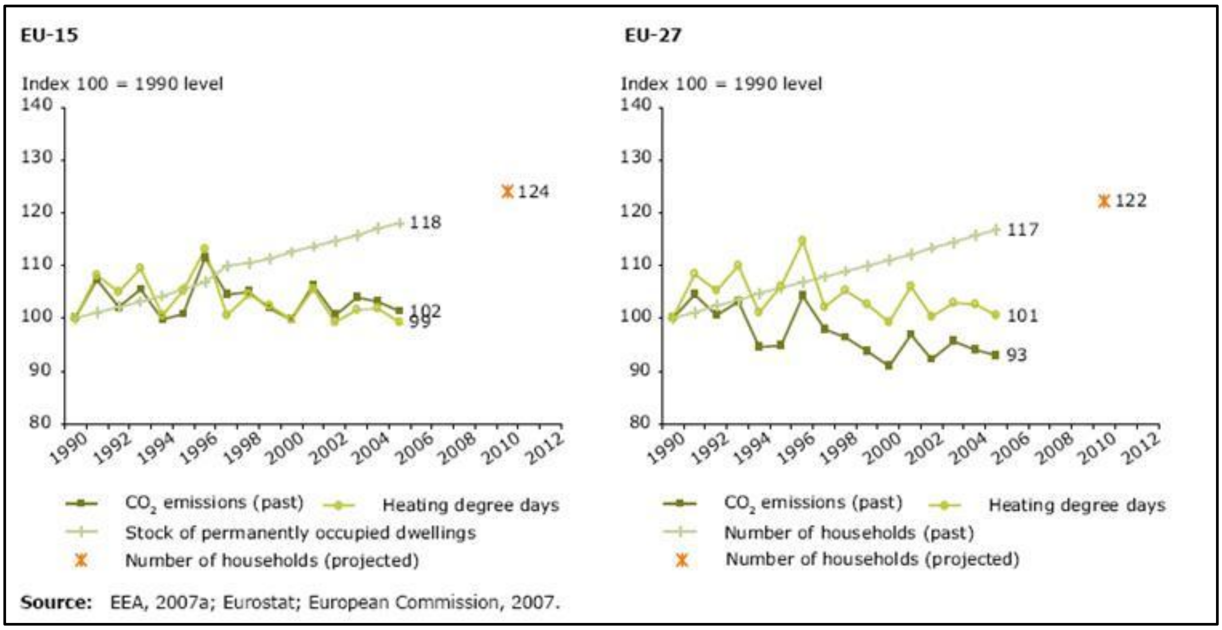

Figure 2.8: EU‑15 and EU‑27 CO2 emissions from households, compared with the number of permanently-occupied dwellings, heating degree days

Source: European Environment Service (EEA)

Between 1990 and 2005, CO_2 emissions from households increased by 2 % in the EU-15. Main factors influencing CO_2 emissions from households are: the outdoor temperature; number and size of households; building codes; age distribution of the existing building stock and fuel split for heating and warm water. Germany had the largest decrease in absolute terms of CO_2 emissions from households (16 million tonnes), while Spain and France had the largest emission increases in absolute terms (EEA 2007b).

2.4 Energy Profile of Cyprus

Cyprus being an island has a small and isolated energy system without any interconnections. The rapid economic development during the last years, mainly due to tourist sector and the rise in the standard of living cause an increase in the total annual energy consumption of about 65% comparing to 1990. Households and tertiary sector has the biggest increase of almost 175% comparing to 1990 consuming the 30% of total final energy consumption. Thus, the potential for energy savings in buildings is significant. For this reason it is important firstly to examine the Cyprus building stock.

2.4.1 Cyprus building stock

Cyprus building stock consists of residential and non-residential buildings (or tertiary or commercial).

Residential buildings are the most common and numerous types of buildings, mainly divided into two main categories: houses and apartments. In Cyprus, residential buildings count for the 82% of the building stock. In the residential stock, 72% are houses and 28% apartments (**Figure 2.9**).

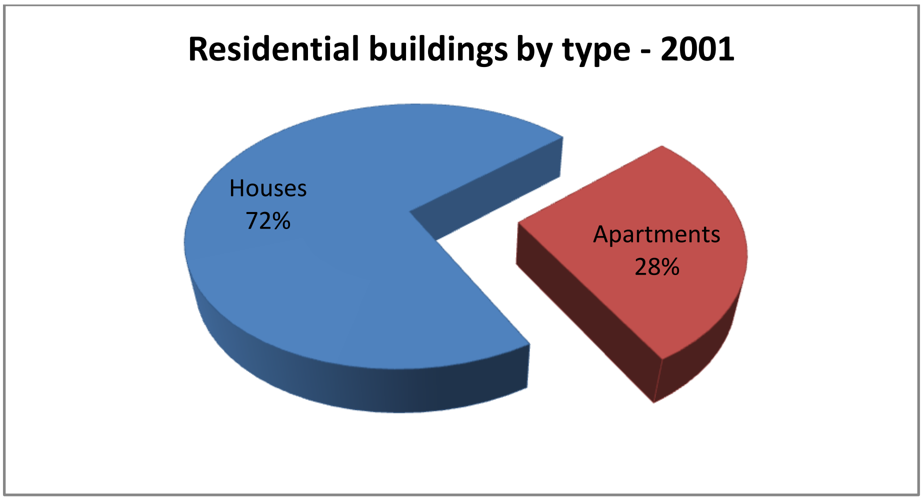

Figure 2.9: Breakdown of residential building stock by type

Information and detailed data for the non-residential building stock in Cyprus is extremely limited. A recent investigation has revealed the lack of available data in many other countries in EU, format inconsistencies of available data and the overall difficulty in collecting necessary information for the non-residential building stock in the EU-25 (Gaglia et al., 2007). The number of non-residential buildings reaches the number of 76498 in 2005. An overview of the building stock according to the different building use can be seen in **Table 2.1** that follows.

Table 2.1: Overview of building stock according to different building use

Building stock	Number of buildings
Total Residential	**341333**
Houses	245770
Apartments	95573
Total Non-Residential	**76498**
Education	2113
Health and Social Work	2593
Hotels	937
Restaurant	2858
Wholesale & Commission trade	20300
Construction	6728
Manufacturing	6135

Source: Statistical Service of Cyprus

The total number of residential buildings enumerated in 2006 was 341333, of which 268166 (78.5%) was occupied as usual place of residence and 83167 or 21.5% were vacant or of temporary residence. Comparing with the year of 1990 there was an increase of 63.5% in the residential building stock, which means an increase of 3.75% per annum.

Based on the results of the Census in Construction and Buildings of 2006 (Statistical Service of Cyprus), 16461 residential buildings were completed compared to 16416 in the previous year and 11013 in 2004. Out of 16461 new residences, 7723 were houses with an average total housing area of 192.7 m^2 and 8738 apartments with an average apartment area of 111 m^2. Another important housing indicator is that out of the 16461 new residences, 3082 or 19% were reported to be used for own residence and 12071 or 73% were intended for rental or sale. The total residential building area of 2006 reached 2.5 km^2, while the total residential building area for the period 1984-2006 reached 30 km^2.

With regard to heating facilities the majority of residential buildings reported the use of gas stove with 33.2% (Census of Population, 2001). The second preferred type of heating was central heating (27.2%), followed by split units with hot air (9.4%), kerosene stoves (8.6%), electric stoves (8.4%), storage heaters (5.5%) and fireplaces (4.8%). A percentage of 1.9% of the dwellings reported no heating facilities of any type. **Figure 2.10** shows the different of heating facilities in percentage between years of 1992 and 2001. Until 1992 the dominant heating facilities was again the gas stove but with more than double percentage (68%) comparing to 2001. Another important factor is that the increase in using central heating, split units for hot air and storage heaters from 1992 to 2001 reaches 125%, 400% and 150% respectively.

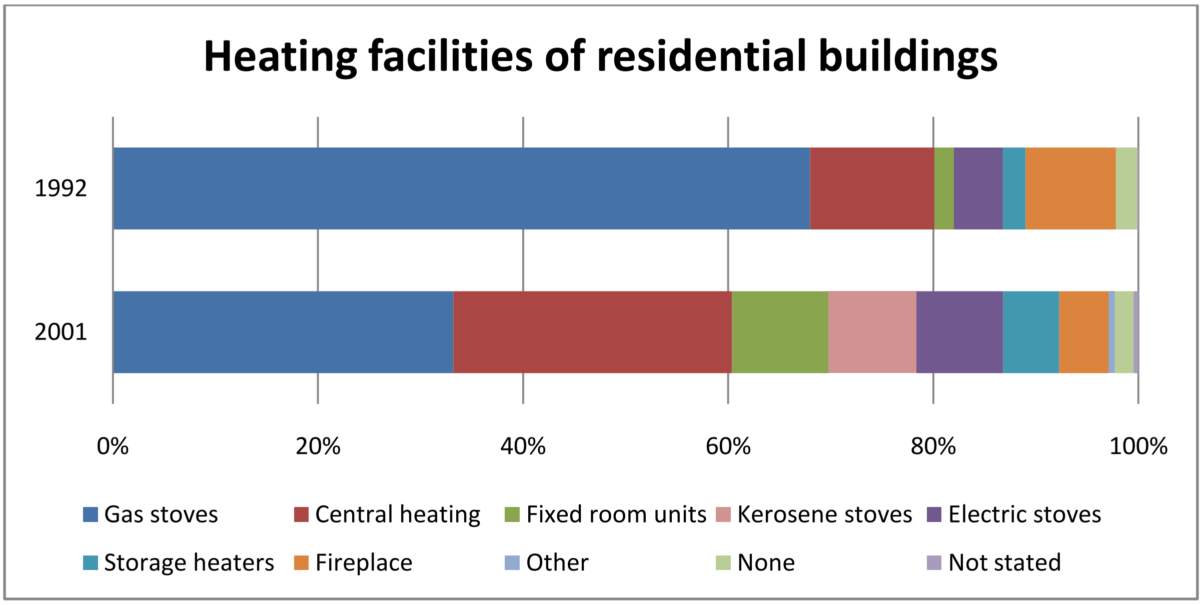

Figure 2.10: Heating facilities of residential buildings between years of 1992 and 2001

The breakdown of Cyprus building stock for different periods of construction is illustrated in **Figure 2.11**. The buildings constructed before 1960 correspond to 14% of the total building stock, between years 1960-1990 accounts to 49% and after 1990 to 37%.

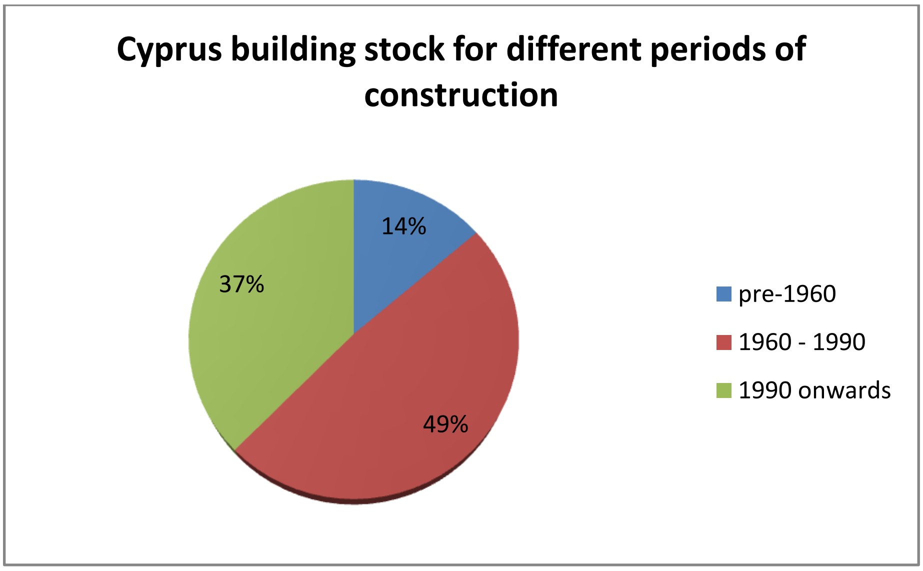

Figure 2.11: Breakdown of Cyprus building stock for different periods of construction

It is important from energy point of view to investigate the building envelope and materials were used during the construction of houses in Cyprus over years. Florides et al (2001) described the evolution of domestic dwelling in Cyprus during the last century according to the period of construction with respect to their heating and cooling requirements. They stated that the houses in Cyprus changed radically in three faces during the last century. Before 1960, houses (named as traditional houses) were constructed from easily obtainable local materials. Between 1960 and 1985 the construction of houses changed to more readily available materials, resulting in a very cheap construction and gradually from 1985 onwards to a more insulated and expensive construction.

Traditional houses were constructed from walls of about 0.5m in thickness, made from mud and straw blocks. The roof was also well insulated with high ceilings (in the middle the high of the roof reached 5-6m while in the corners about 4m). High ceilings allow thermal stratification and decrease the transfer of heat gains through them. The doors were rather high and the window openings tall with small width in order to increase the night ventilation rate to keep the building as cool as possible during the summer. In a way the traditional houses were well adapted to climate conditions and offered an acceptable living environment (Florides et al. 2000, 2001).

After the independence of Cyprus in 1960, the lifestyle of the inhabitants changed. The sudden tourist development and the overall change of the general attitude had an influence and great impact also to the building sector. In addition, the high rate of urbanization and the military events of 1974 changed completely the character of houses. During that period there was an enormous increase in apartments and multi-storey buildings (from 2097 apartment blocks of pro-1960 period to 54448 of 1960-1990 periods) with the absence of town planning and regulations. The residential buildings during this period were constructed from hollow bricks with walls of 0.25m and 0.15m of flat concrete roof with no insulation.

The present construction method is continuation of the previous period, with a typical house being built with walls from hollow bricks made of fired clay of 0.20m thickness and 0.025m layer of plaster in both sides of the wall. Some exceptions (in recent years) are houses with walls constructed with two bricks (usually hollow bricks made of fired clay) with a layer of insulation of about 0.05m with a total thickness of about 0.3m. The floors are made of concrete slabs while flat roofs consist of slab of 0.15m thickness and an additional of 0.03m layer of plaster on the underside.

2.4.2 Cyprus energy system

2.4.2.1 Energy consumption trends

Cyprus is a small island situated in the north-eastern Mediterranean with a population of approximately 750000 people. It has an area of 9251 km^2, of which forests cover approximately 18%. During the last 30 years, Cyprus has enjoyed continuous economic growth due mainly to growth in the tourism and financial services' sector. Cyprus GDP per capita income is currently estimated at €17000 (2004), which is classified as the highest income country of all new entering EU countries equivalent to 85% of EU-25 GDP per capita[13]. The economic growth, population growth together with the change in lifestyle of the people resulted a steadily increase of energy demand while the electricity demand has been increasing at a rate faster than economic growth. **Figure 2.12** is showing the growth of GDP per capita, accompanied by an analogous growth in final energy consumption.

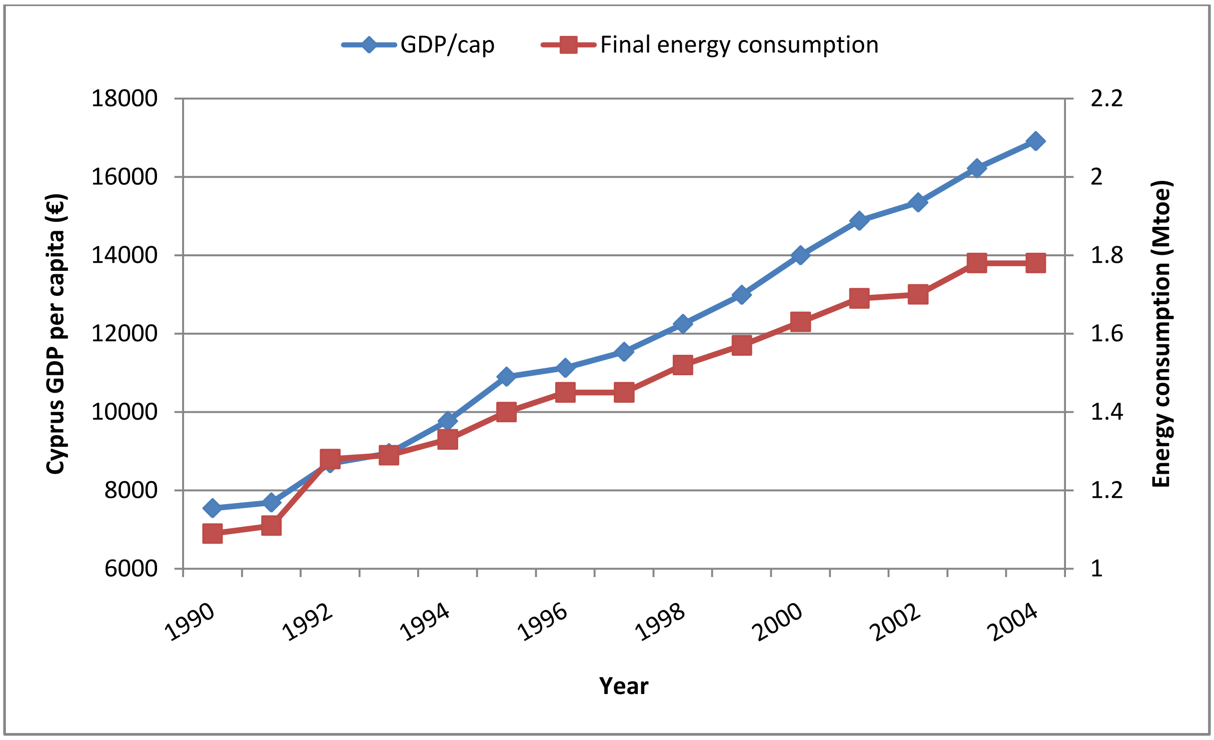

Figure 2.12: Cyprus GDP per capita and final energy consumption profile 1990-2004

[13] Eurostat. Measuring progress towards a more sustainable Europe – Sustainable development indicators for the EU. Data 1990-2005.

Cyprus has a small and isolated energy system without any interconnections. There are no indigenous energy sources and is totally dependent to energy imports except a small contribution of solar energy, which is used extensively for domestic water heating. Cyprus depends on imported fossil fuels for 95.5% of its energy needs, where the rest 4.5% consists of solar used in buildings and some biomass (almost negligible) used in industry (**Figure 2.13**). A remarkable of 62% of the country's export earnings is used to pay for the country's oil import (Koroneos et al., 2003).

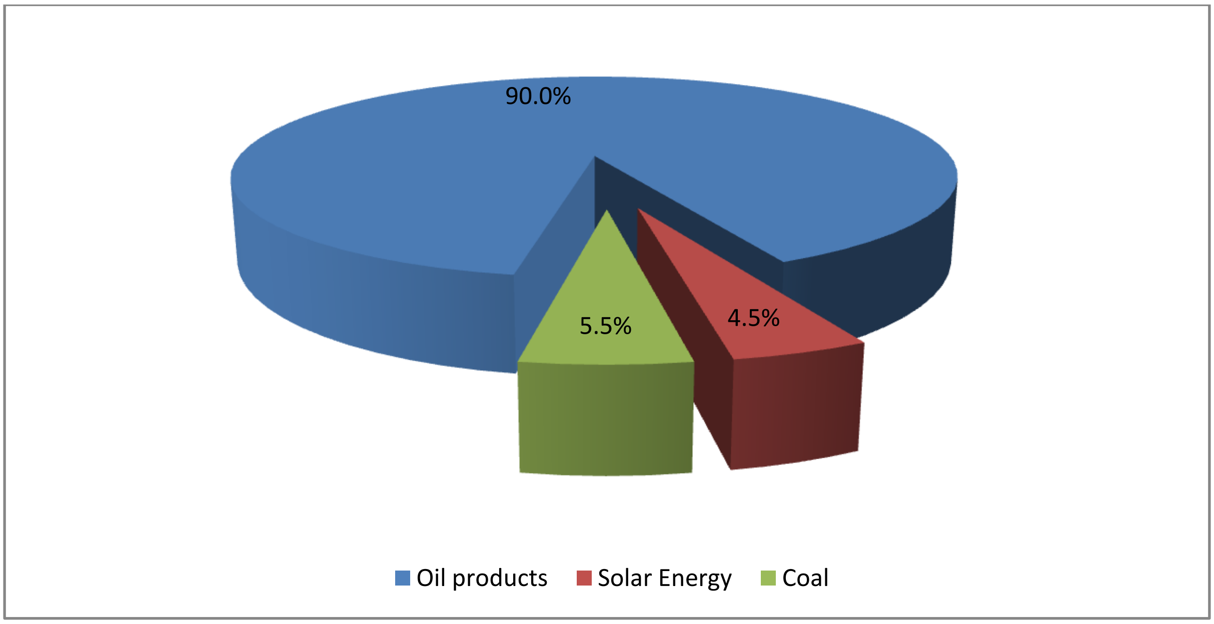

Figure 2.13: Primary energy sources in Cyprus

The imported fuel of different oil products of Cyprus for the period 1990-2006 is shown in **Figure 2.14**. The rapid increase of imported Heavy Fuel Oil (HFO) during the last years is mainly due to the rapid increase of electricity generation which has as a principal fuel the HFO. All the imported gasoline and kerosene is consumed by transport sector. Diesel is used for all sectors but the major consumer (50%) is again the transport sector. Liquefied Petroleum Gases (LPG) is used in the domestic and services sectors, where coal and fuel oil are used only by industry. Small quantities of coal are also imported for cement production. Finally, no gas is used for energy production in Cyprus[14].

[14] Papastavros C. Mediterranean and National Strategies for Sustainable Development. Energy efficiency and renewable energy – National study. 2007.

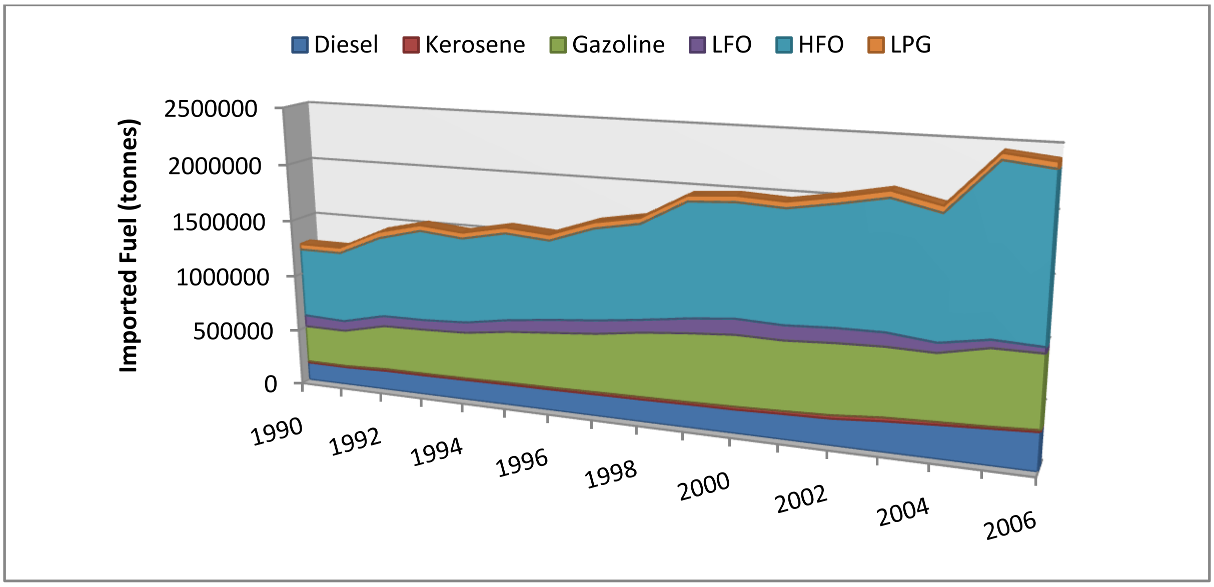

Figure 2.14: Imported fuels in tonnes for the period 1990-2006

The rapid economic growth in combination with the lack of policies for energy conservation, total final energy consumption (TFEC) rose by about 4.2% per year between 1990 and 2005. The TFEC in 2005 was 1.81 Mtoe, where in 1990 was 1.09 Mtoe. The sector which has the biggest increase in TFEC is the households and tertiary sector with an annual increase of about 11%, followed by transport with 3.4% and industry sector by 1.2% (**Figure 2.15**). In 2005, transport sector consumed approximately 53% of the total energy consumption, while households and tertiary consumed 29% and industry 18% (**Figure 2.16**).

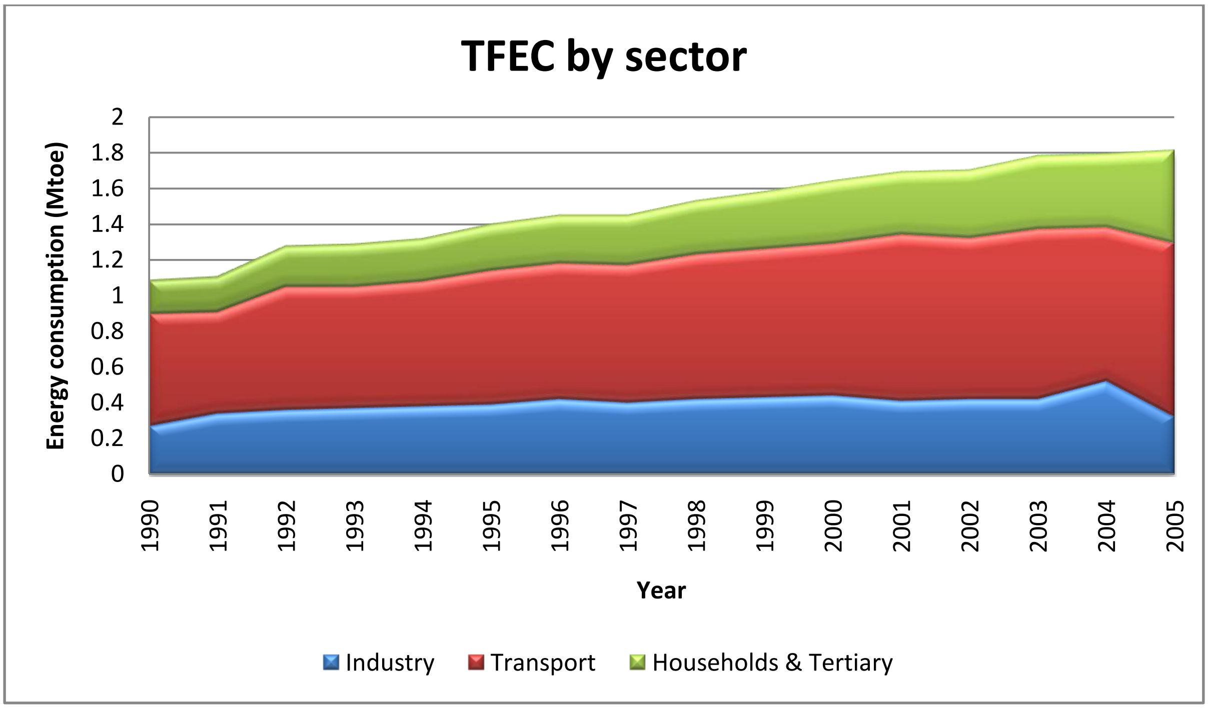

Figure 2.15: Total final energy consumption by sector

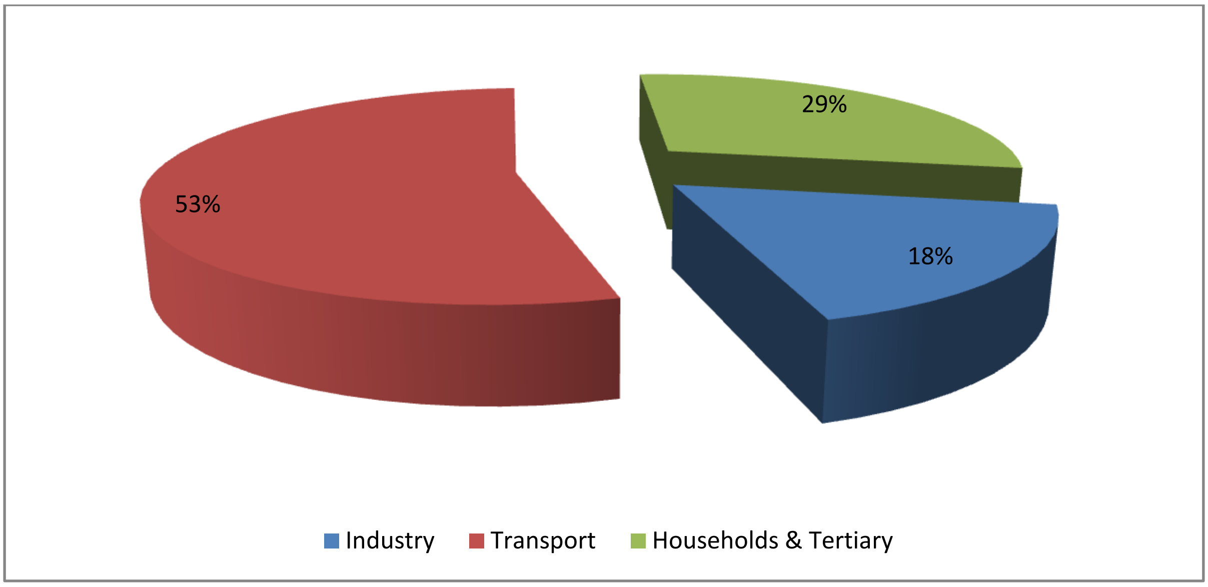

Figure 2.16: Share of each sector to the total final energy consumption in 2005

Oil products contribute the most to the total final energy consumption by fuel/product (approximately 76%) with electricity, renewables and solid fuels providing 19%, 3% and 2% respectively (**Figure 2.17**). Electricity consumption has the largest increase with a 7.9% per annum in the period 1990-2005 followed by oil products with 3.8% per annum. The total energy consumption per fuel/product can be seen in **Figure 2.18**.

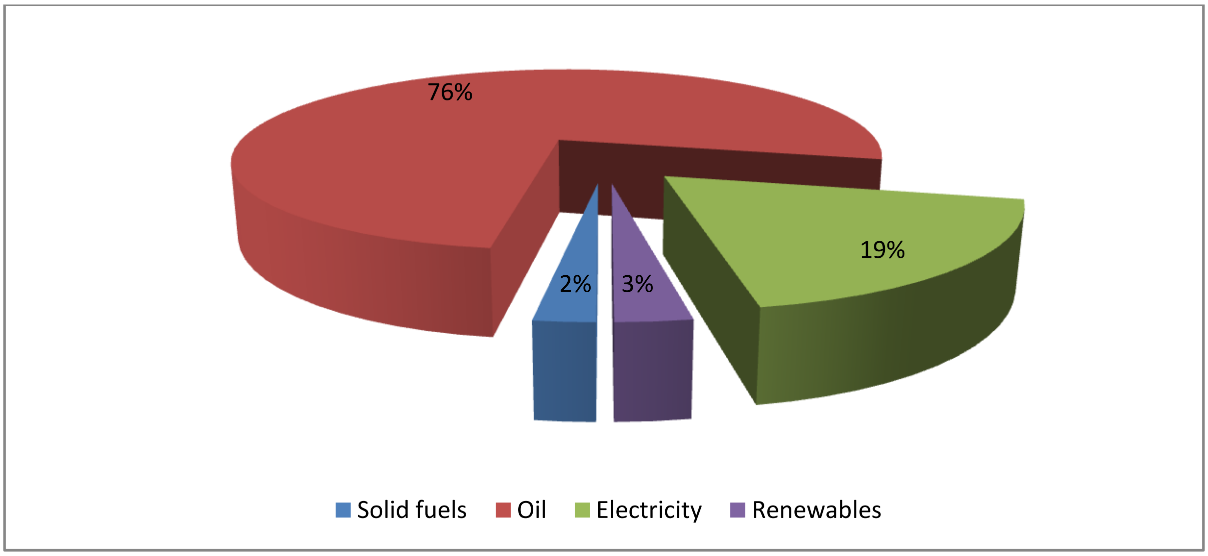

Figure 2.17: Share of each fuel/product to the final energy consumption

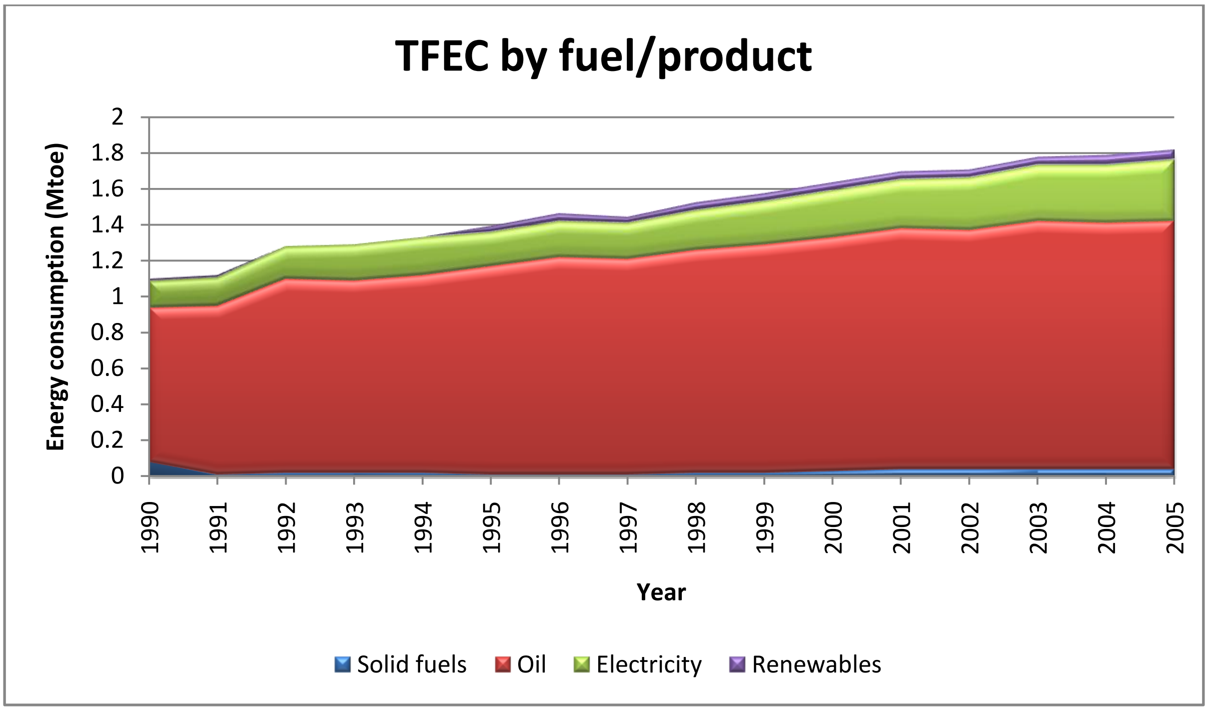

Figure 2.18: Total final energy consumption by fuel/product

2.4.2.2 Energy efficiency trends

The overall energy efficiency trends can be described by two macro indicators: the primary energy intensity (the ratio of primary energy consumption over GDP), and the final energy intensity (the ratio of final consumption over GDP). The primary intensity is an indicator of the energy productivity of the whole economy. The final intensity characterises the energy productivity of final consumers only. Energy intensity is an important ratio because it can be used to gauge energy economy and efficiency of energy. **Figure 2.19** shows the primary and final energy intensity for the period 1990-2004.

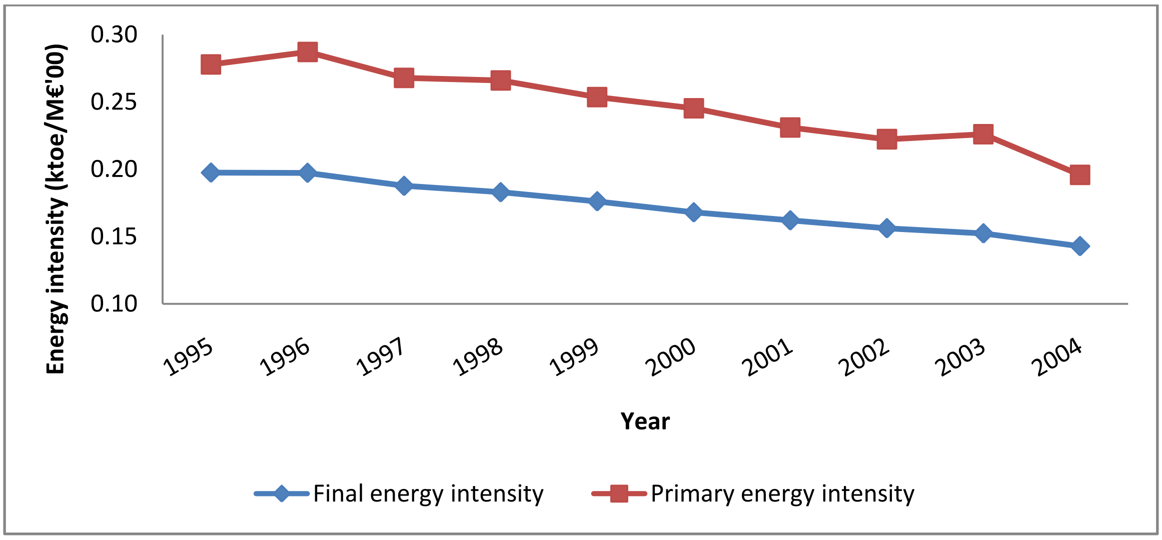

Figure 2.19: Primary and final energy intensity

The above graph shows that during the period 1995-2004 primary energy intensity has decreased by 2.95% per annum. In the same period final energy intensity has decreased by

2.75% per annum. The values of primary and final energy intensities in the year 2004 are 0.196 ktoe/M€'00 and 0.143 ktoe/M€'00 respectively.

The decreasing energy intensity over years shows an improvement on energy efficiency during this period. It is important to mention that energy intensity is not strictly a measure of energy efficiency as it can be affected by structural and behavioural changes, such as a shift away from energy-intensive industries, or a change in household heating patterns. The goal is not just to improve energy efficiency or reduce energy intensity but to achieve energy savings, thus reducing energy consumption in absolute terms. The following graph (**Figure 2.20**) shows the trends of GDP, final energy consumption and final energy intensity over the period of 1995-2004.

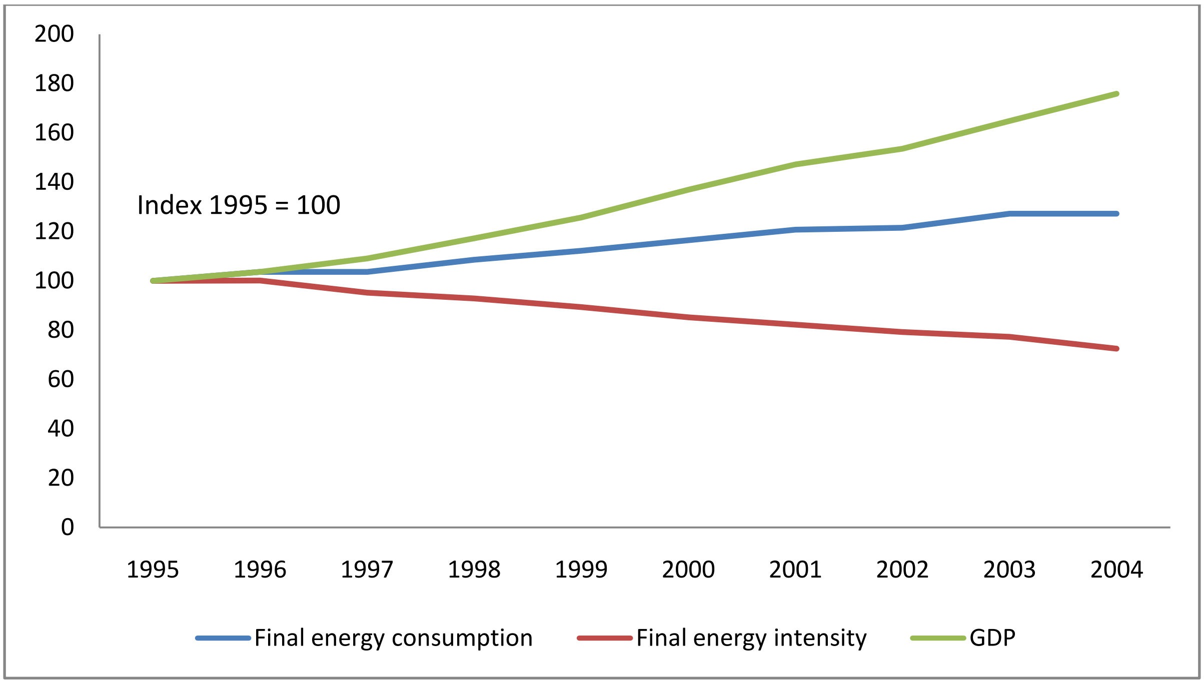

Figure 2.20: Final energy intensity, FEC, GDP between 1995 and 2004, 1995 = 100

Total energy consumption in Cyprus grew at an annual rate of 2.1% over the period from 1995 to 2004, while GDP grew at an estimated average annual rate of 4.3%. As a result, total energy intensity fell at an average rate of 2.75% per year. This means that the total energy intensity in 2004 was in real terms almost 27.5% less than in 1995, indicating that each unit of growth of GDP now requires around 27.5% less energy.

2.4.2.3 Electricity sector

The power system of Cyprus operates in isolation and at present consists of three thermal power stations with a total installed capacity of 988 MW (Maxoulis and Kalogirou, 2007). The installed capacity of the power station can be seen in **Table 2.2**.

Table 2.2: Cyprus power station installed capacity.

Power station	Turbines	Installed capacity (MW)	Total capacity (MW)
Vasilikos power station	Oil/steam	2x130	260
Vasilikos power station	Gas	1x38	28
Dhekelia power station	Oil/steam	6x60	360
Moni power station	Oil/steam	6x30	180
Moni power station	Gas	4x37.5	150
		Total installed capacity	**988**

The demand of electricity in Cyprus continues to rise. The evolution of the energy production and demand since 1971 are presented in **Figure 2.21**, while **Figure 2.22** shows the prediction of gross electricity demand of each year until 2015.

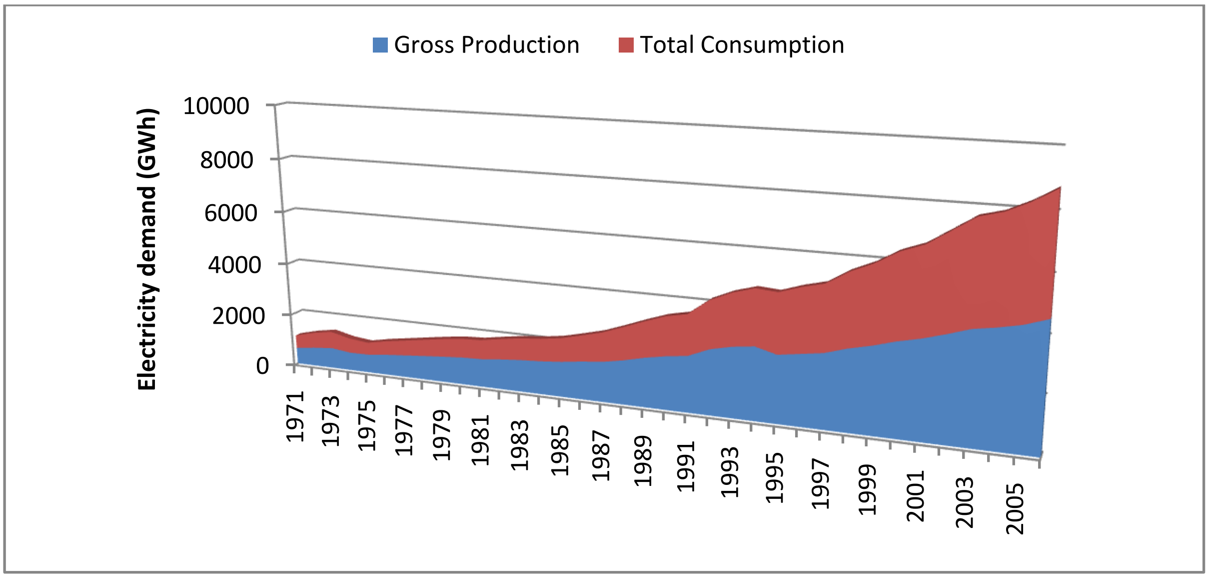

Figure 2.21: Total electricity production and consumption (1971-2006)

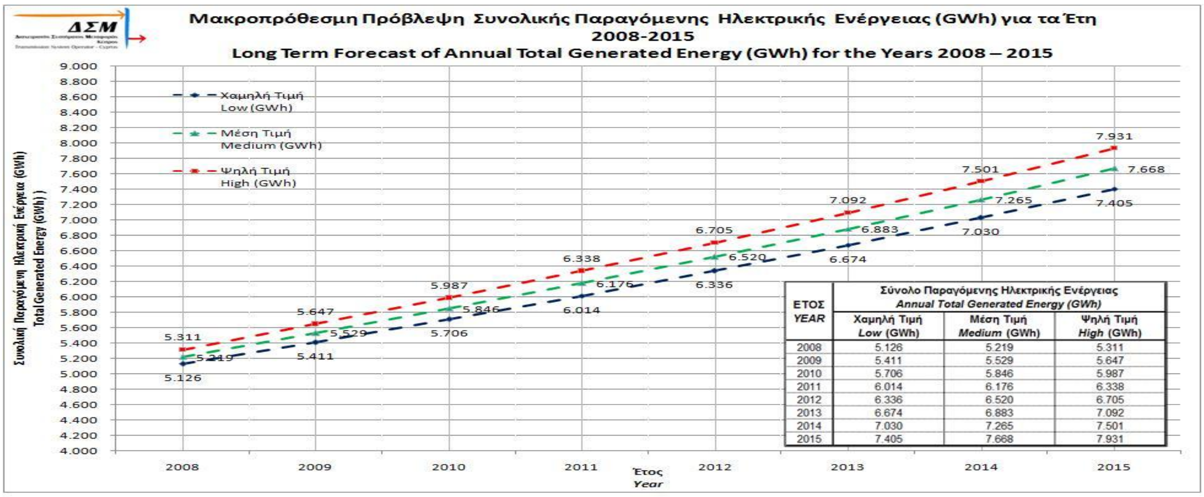

Figure 2.22: Prediction of electricity demand until 2015

Source: Transmission System Operator (TSO) – Cyprus

Due to the increase of electricity demand, new power plants will be gradually added to the system (total of 710MW). This additional load will be mainly provided by three efficient combined cycle gas turbine units (CCGTs). The CCGTs will initially burn diesel but the plan is to switch to natural gas in 2011 (Maxoulis and Kalogirou, 2007).

The electricity market share for 2006 is presented in **Figure 2.23**. The commercial is the largest consumption sector with 41%, while the households (domestic) sector represents the 36% and the industrial sector the 18% of the total electricity consumption.

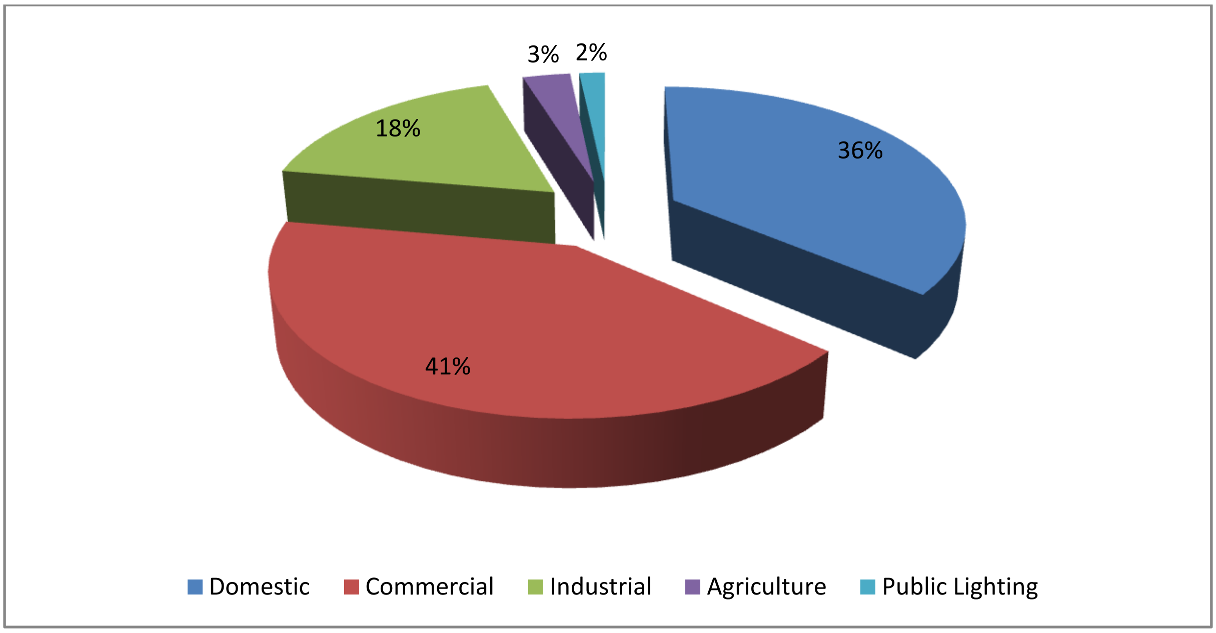

Figure 2.23: Electricity consumption by sector (2006)

Focusing to the main consumers of electricity (commercial, domestic and industrial sector), we can observe that the increase in electricity consumption for domestic and commercial sector has been remarkable during last years (**Figure 2.24**). The explanation lies in the increase use of electricity for space heating, water heating, cooking and air-conditioning. Thus, by introducing proper building regulation, disqualify electrical heaters for cooking, water heating and space heating; the electricity demand could be decreased significantly, diminishing the need for new power capacity (Koroneos et al., 2003).

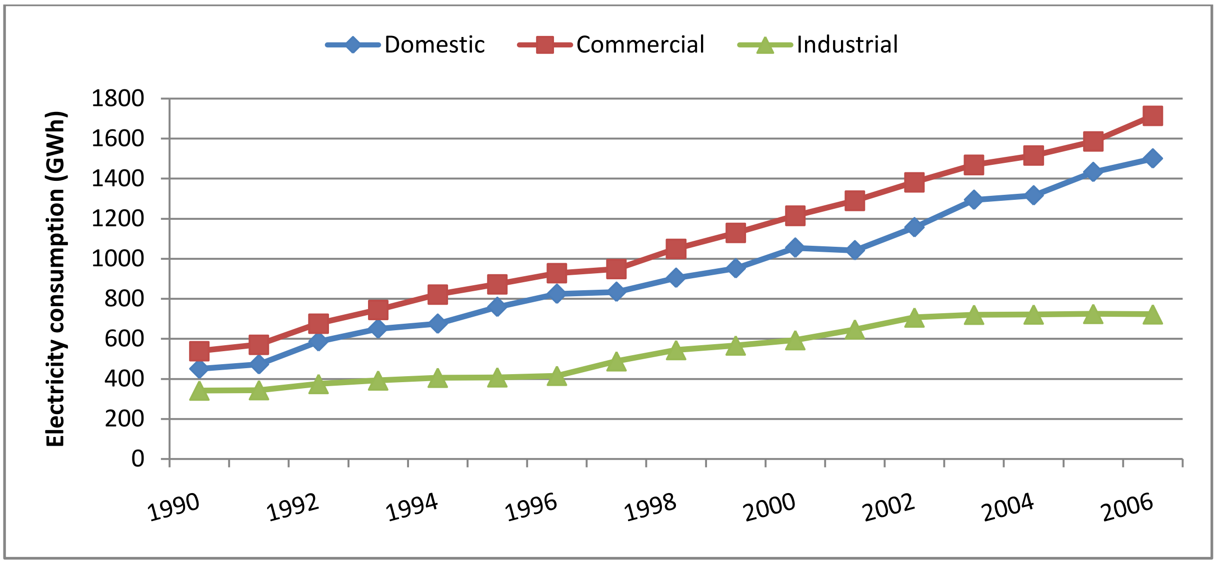

Figure 2.24: Electricity consumption trend of main sectors (1990-2006)

2.4.2.4 Renewable energy

The main renewable energy form in Cyprus is solar thermal, mainly used for hot water heating. As it mentioned above, the share of solar energy to the total energy demand of Cyprus is in the range of 4.5%. This 4.5% of the solar thermal contribution arises from a respectful 29% contribution in the residential sector and a modest 5% in the tourism sector, i.e. the use of solar thermal energy by hotels (Maxoulis et al., 2007). Today, 93% of all houses in Cyprus have a solar water heating system installed and operating, where the installed collector area is about 0.9 m^2 per capita (**Figure 2.25**), which is the highest figure worldwide (Maxoulis and Kalogirou, 2007). With the favourable climate (Cyprus is called the "Sun Island" because sun shines for about 300 days per year), the potential solar applications are significant.

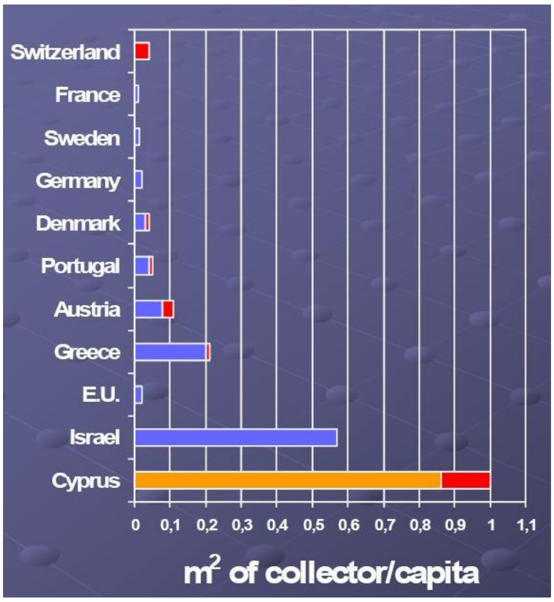

Figure 2.25: Solar collectors per capita

Source: Cyprus Institute of Energy (CIE)

Despite the fact that Cyprus is one of the leading countries in the world (2006 WREC trophy[15] award) when it comes to utilizing solar water heaters, renewable energy systems (RES) still make an unacceptable modest contribution to the Cyprus energy balance, as compare with the available technical potential (Koroneos et al., 2003). The energy policies for RES and the potential of renewable energy in Cyprus are discussed in **Paragraphs 2.5 and 2.6**.

2.4.2.5 Natural gas

The energy system of Cyprus does not include natural gas. In the near future, the Government of Cyprus is planning the import and use of natural gas. According to the Ministry of Commerce, Industry and Tourism, a study which was performed by a consultancy company (in 2002) showed that the most economic and safe manner for the supply and transport of natural gas to Cyprus is in the form of Liquefied Natural Gas (LNG) and using vessels.

In the framework of introducing natural gas in the energy system of Cyprus, the Government has set the following main objectives:

1. The establishment of an *Energy Centre* for import and storage of natural gas in LNG form.
2. The effective implementation of the relative legislation, which is in line with the requirements Directive 98/30/EC, regarding the control and monitoring of the natural gas market.

The *Energy Centre* will satisfy the present and future demand of Cyprus in natural gas and oil products. The natural gas will mainly be used for electricity generation by EAC. The determination of natural gas quantities will be based on the forecasting demands of EAC for national electricity consumption. Natural gas will be mainly used for electricity generation using CCGT (combined cycle gas turbine) technology and thus contributing to diversify the energy supplies to the island. The energy centre will include an LNG terminal and a tank farm for the storage and handling of oil products (strategic and operational stocks).

2.5 RES Potential in Cyprus

As mentioned earlier, Cyprus is almost completely dependent on imported fossil fuels for its energy supply. Since there are no indigenous energy sources, the use of renewable energy sources is highly recommended and needed in the energy profile of Cyprus for several reasons. Among those are:

- To reduce of dependency on energy imports and increase security of supply.
- To lower the high and often unpredicted amounts used by the Cyprus Government to pay for oil imports (Koroneos et al., 2003).
- To ameliorate environmental effects of burning fossil fuels (Koroneos et al., 2003):
    - Total increase of 0.5^{o}C in temperature during the last century
    - Decrease of 12% in rainfall

[15] World Renewable Energy Trophy.

  - Electricity production is responsible for 44% of CO_2 total emission
- Harmonization with the EU standards in promoting RES and improving energy efficiency.

For those reasons Cyprus Government has developed an Action Plan[16] for the promotion of RES and Energy Saving. The targets of this plan is to increase the share of energy from renewable sources in the provision of total energy produced from 4% in 1995, to 9% in 2010 and the increase of electricity generated from renewable sources to 6% by 2010 from present zero level (**Figure 2.26**). For this purpose the provision of £42 million CY Pounds (about €72 million Euros) by 2010 on grants and subsidies as a financing mechanism will be given for the implementation of programmes of the plan.

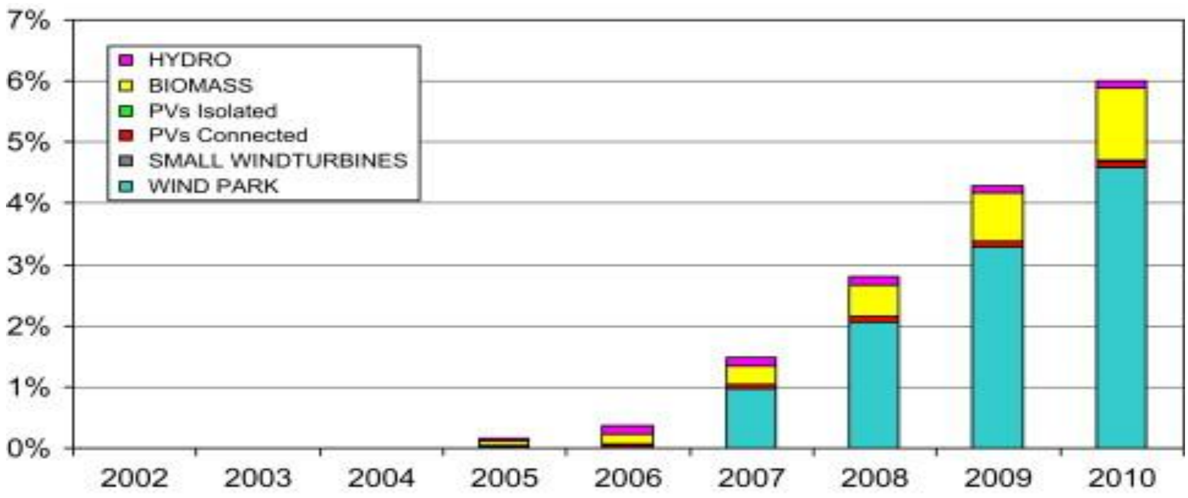

Figure 2.26: Projection of electrical energy generated by RES

As a general remark, we can say that the contribution of RES to the Cyprus energy balance is unacceptably modest, as compare with the availability of sources and technical potential. Before we analyse the potential of RES in Cyprus, it is essential to refer to weather conditions and climate of Cyprus.

2.5.1 Weather of Cyprus

Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked in respect of temperature, rainfall and weather generally. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-March are separated by short autumn and spring seasons of rapid change in weather conditions.

Cyprus has a hot summer and mild winter but this generalization must be modified by consideration of altitude and of marine influences which give cooler summers and warmer winters near most of the coastline and especially on the west coast. The seasonal difference between mid-summer and mid-winter temperatures is quite large, at 18°C inland and about 14°C on the coasts. Differences between day maximum and night minimum temperatures are also quite large especially inland in summer. These differences are: 8 to 10°C in winter on

[16] NTUA, EREC, Cyprus Institute of Energy - "Towards a White Paper for RES and RUE Strategy and Action Plan for the Republic of Cyprus".

the lowlands and 5 to 6°C on the mountains increasing in summer to 16°C on the central plain and 9 to 12°C elsewhere.

The climatic conditions of Cyprus are predominantly very sunny with daily average solar radiation of about 5.4 kWh/m^2 on a horizontal surface. The solar energy input is particularly high at areas where the dry summer is well pronounced, lasting from April to October. In the lowlands, the daily sunshine duration varies from 5.5 h in winter to about 12.5 h in summer. Mean daily global solar radiation varies from about 2.3 kWh/m^2 in the cloudiest months of the year, December and January, to about 7.2 kWh/m2 in July (Maxoulis and Kalogirou, 2007).

Pashardes and Christofides (1995) performed a comprehensive analysis of the wind speed. The results showed that, although Cyprus is not characterized by high wind potential, several areas were identified as having annual mean wind speeds greater than 5 m/s at 10 m height. These locations are situated in the southern coastal zone of the island and in some exposed locations in the mountains. These areas seem to be very promising for wind turbines installation.

The average annual total precipitation increases up the south-western windward slopes from 450 millimetres (mm) to nearly 1,100 mm at the top of the central massif. On the leeward slopes amounts decrease steadily northwards and eastwards to between 300 and 350 mm in the central plain and the flat south-eastern parts of the island. Rainfall in the warmer months contributes little or nothing to water resources, while autumn and winter rainfall is variable. The average rainfall for the year as a whole is about 480 mm but it was as low as 182 mm in 1972/73 and as high as 759 mm in 1968/69. As it mentioned above a statistical analysis of rainfall in Cyprus reveals a decreasing trend of rainfall amounts in the last 30 year.

2.5.2 Wind potential

As it mentioned above, there are areas in Cyprus that seem to be very promising for wind turbines installation. Cyprus Energy Regulatory Authority (CERA) has already granted 22 licences for wind parks with total installed capacity of 425.40MW with the potential of raising the installed capacity for another 411.85MW[17]. EAC has also announced the development of a wind park of installed capacity of 6MW.

The utilization of wind energy in Cyprus, is quite similar with the situation in Greece (at least in the early stages) which is described as a story of high expectations, intense initial entrepreneurial interest, delays in the start-up phase of projects and disappointments during the implementation procedure (Maxoulis and Kalogirou, 2007, Papadopoulos et al., 2008).

2.5.3 Solar potential

As it mentioned previously, Cyprus enjoys a very mild climate with a lot of sunny days which makes solar energy being highly potential source for the island. Solar energy is highly penetrated into Cyprus energy market in the form of solar water heaters (more than 190000 installed units, which corresponds to approximately 0.9m^2 per inhabitant). Besides the use of

[17] CERA Annual Report 2006

solar energy for domestic hot water needs, there is still no commercial application of industrial process heat and as far as photovoltaics are concerned, solar electricity is barely met on island (Koroneos et al. 2003).

The application of photovoltaics is very limited due to their high cost. Currently, the biggest photovoltaic application in Cyprus is an 80kW shading system installed in the new head office of EAC (see **Photo 1**). The penetration of photovoltaics in Cyprus is expected to rise as the technology becomes more mature and more economically viable (Maxoulis and Kalogirou, 2007).

Photo 1: PV in new head office of EAC

2.5.4 Biomass potential

Biomass resources in Cyprus include a wide range of biomass residues, agriculture and forest, municipal solid waste, sewage water sludge and a considerable potential of energy crops (Papastavros, 2007). At the present stage, Cyprus is making use of agriculture residues for the production of electricity. This is achieved through the utilization of biogas. Cyprus Energy Regulatory Authority (CERA) has granted 2 licences for electricity production from biomass with total installed capacity of 1.75MW. Taking into consideration the number of animal farms in the island, this method has high potential especially if associations among farms are created.

Regarding the electricity production from municipal wastes, studies shown that the three major municipalities of Cyprus (Nicosia, Lemesos and Larnaka) can feed three big waste disposal plants with the potential of producing 3.3MW (Maxoulis and Kalogirou, 2007).

Even though there are limited studies about the potential of energy crops in Cyprus, this method is considered to be limited due to the water shortage problem and the small size of the island.

2.6 National legislations and existing policies

2.6.1 Energy institutions in Cyprus

The main institutions and authorities in Cyprus regarding energy administrative organization, production and distribution, market structure and decision making process are presented in **Figure 2.27.**

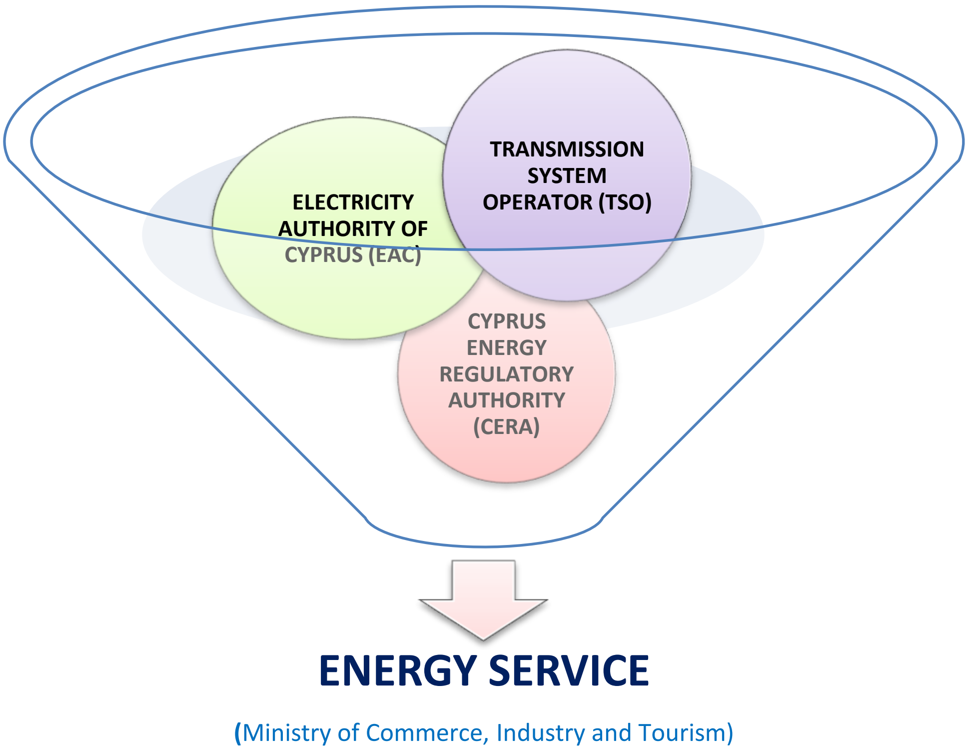

Figure 2.27: Main energy institutions and authorities in Cyprus

Energy Service

The Energy Service of the Ministry of Commerce, Industry and Tourism has the overall responsibility of Energy in Cyprus and specifically for:

- Monitoring and coordinating the supply and availability of sufficient energy capacity for domestic needs.
- Monitoring and participating in the formation of the European Policy for energy issues.

- Suggesting ways for the implementation of the European Acquis, assists in the preparation of Laws, Regulations, Rules etc and implements programmes for their promotion.
- Preparing and implementing programmes for energy conservation, the promotion of renewable energy sources (RES) and the developing of technologies for the utilization of RES.
- Assisting the Government in the formation of the national energy policy for Cyprus in coordination with all other bodies involved.

Electricity Authority of Cyprus (EAC)

The Electricity Authority of Cyprus is an independent, semi government corporation established under the Electricity Development Law Cap.171 of 1952 in order to exercise and perform functions relating to the generation and supply of electric energy in Cyprus[18].

Although the law concerning electricity generation has recently been modified and the market has been liberalized (May 1st 2004, entry of Cyprus in EU), EAC is still the only energy provider in Cyprus.

Cyprus Energy Regulatory Authority (CERA)

The Cyprus Energy Regulatory Authority is an independent authority of Cyprus and has executive powers and competences in the energy field. The main objectives of CERA are[19]:

- To encourage, promote and safeguard the healthy and substantial competition in the Electricity and Natural Gas Markets.
- To protect Consumers' interests.
- To promote the development of economically viable and efficient Electricity and Natural Gas Markets.
- To ensure the Security, Continuation, Quality and Reliability of Electricity Supply.
- To take into consideration the Protection of the Environment.
- To encourage the efficient generation and use of Electricity.
- To promote the use of Renewable Energy Sources (RES).

Transmission System Operator

The Transmission System Operator (TSO) was established under the decision of the Government of the Republic of Cyprus for harmonization with Directive 96/92/EC of the European Parliament and of the Council of the 19th December 1996, concerning the common rules for the internal electricity market.

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[18] EAC Annual Report 2006.

[19] CERA, Report to the European Commission in line with the Electricity and Gas Directives for the period July 2004 to July 2005.

The main functions and responsibilities of the TSO are[20]:

- Secure the operation of the Electricity Transmission System and to manage the electricity market on an objective, non-discriminatory basis in a competitive environment.
- Support and promote electricity generation from renewable energy sources.
- Ensures access to the Transmission System of all producers and suppliers of electricity.
- Coordinates the actions taken for the repair and clearing of faults occurring in the Generation or Transmission Systems, in order for them to operate in an efficient co-ordinated, secure, reliable, and economical way, ensuring unhindered and uninterrupted supply of electricity to all consumers.

2.6.2 National legislations and existing policies for energy efficiency in buildings

It is extremely important to mention that prior to accession in EU in 2004, Cyprus government did not had a comprehensive energy efficiency policy and no energy performance building regulations existed. The majority of the new buildings were constructed without any minimum energy efficiency requirements (thermal insulation, efficiency of equipment, lighting, RES, bioclimatic design, etc.).

After the accession in EU, several EU Directives transposed in Cyprus, among them the Energy Performance of Buildings Directive (EPBD). In order to ensure the implementation of EPBD in Cyprus, three legal documents have been approved by the House of Representatives and published in the Government Official Gazette:

- The Law for the Regulation of the Energy Performance of Buildings of 2006, L.142(I)/2006;
- The Amendment of the Law for the Regulation of Roads and Buildings, L.101(I)/2006;
- The Roads and Buildings (Energy Performance of Buildings) Regulations, Κ.Δ.Π.429/2006.

A partial force of those laws started from 21st of December 2007, where all new buildings and buildings with a total useful floor area over 1000 m^2 which undergo major renovation should fulfil the demands for thermal insulation of building envelope in order to satisfy the maximum overall thermal transmittance values (U-value) setting by the law. For this reason, an excel-based program for calculation of U-value was prepared by the appropriate authority (**Figure 2.28**). More details for this subject are given on **Chapter 4 - RESULTS**.

[20] http://www.dsm.org.cy/nqcontent.cfm?a_id=827&tt=graphic&lang=l2

THERMAL TRANSMITTANCE (U-VALUE) CALCULATOR SHEET					
Description					
A/A	Material	Material Thickness **d** (m)	Thermal Conductivity λ (W/mK)	Thermal Resistance R (m^2K/W)	Typical Construction Detail
1			1.000	0.000	
2			1.000	0.000	
3			1.000	0.000	
4			1.000	0.000	
5			1.000	0.000	
6			1.000	0.000	
7			1.000	0.000	
8			1.000	0.000	
9			1.000	0.000	
10			1.000	0.000	
Heat flow		Οριζόντια		**Thermal transmittance U (W/m^2K)**	
Rsi (m^2K/W)		0.130			
Rse (m^2K/W)		0.040		**5.882**	
Notes					

Figure 2.28: U-value calculator

Other main provisions of the EPBD (such as minimum efficiency requirements, certification, inspection of boilers and air-conditioning systems) have not been applied yet and Cyprus has requested for a 3 year extension period.

According to estimations by Cyprus Institute of Energy (CIE), the full implementation of the energy performance of buildings directive can cover the adopted energy savings target of 185000 toe by 2016, as well as the intermediate target of 60000 toe by 2010.

The Cyprus Government operates a financial support scheme providing grants and subsidies for energy savings and RES investments in the building sector. The schemes cover all technologies which can achieve a 10% primary energy savings after the investment. **Table 2.3** that follows give more details about these schemes.

Table 2.3: Energy efficiency improvement measures.

EEI No 1	**Title of the energy efficiency improvement measure**	Grants scheme for energy savings and to encourage the use of RES (end use) in the residential sector (existing dwellings).
	Investment	Energy conservation, with new investments in materials for thermal insulation, in private residences in non-mountainous areas[21].
	Subsidy / Eligibility	For private residences only. Subsidization of 30% of the eligible costs under the restriction of the maximum eligible costs. Maximum amount of financial support £1000 (€1700)
EEI No2	**Investment**	Energy conservation, with new investments in materials for thermal insulation, in private residences in mountainous areas[22]
	Subsidy / Eligibility	100% for the first £800 (€1370) of the eligible cost and 30% on the rest of the eligible costs under the restriction of the maximum eligible costs. Maximum amount of financial support £1500 (€2565).
EEI No 3	**Investment**	Heat pump with ground heat exchanger for space heating/cooling.
	Subsidy / Eligibility	45% of the eligible cost under the restriction of the maximum eligible costs. Maximum amount of financial support £9000 (€15400).
	Effectiveness	4000 applications annually.
	Expected annual energy savings by 2010	4000 toe.
EEI No 4	**Title of the energy efficiency improvement measure**	Grants scheme to encourage the use of RES (end use) in the residential sector.
	Investment	Central active solar water heating systems (new installation and/or replacement).
	Subsidy / Eligibility	The subsidization will be 45% of the eligible costs under the restriction of the maximum eligible costs. Maximum amount of financial support £15000 (€25650).
EEI No 5	**Investment**	Solar systems for space heating and cooling (new installation and/or replacement).
	Subsidy / Eligibility	The subsidization will be 55% of the eligible costs under the restriction of the maximum eligible costs. Maximum amount of financial support £68750 (€117500).
	Investment	Domestic solar systems (new

[21] For the purposes of the present scheme, non-mountainous areas are the areas with an altitude lower than 600 meters from the sea level.

[22] For the purposes of the present scheme, mountainous areas are the areas with an altitude higher than 600 meters from the sea level

		installation/replacement).
	Subsidy / Eligibility	£100 (€170) per thermosyphonic solar systems (passive) without circulator and cold water pump and £200 (€340) per solar system (passive or active) with circulator and/or with a cold water pump.
EEI No 7	**Investment**	Solar water heating systems for swimming pools (new installation and/or replacement).
	Subsidy / Eligibility	The subsidization will be 45% of the eligible costs under the restriction of the maximum eligible costs. Maximum amount of financial sup-port £15000 (€25650).
EEI No 8	**Investment**	Stand-alone (not connected to the network) PV systems, with generating capacity of up to 20kW, combined or not with other energy producing systems from RES.
	Subsidy / Eligibility	The subsidization will be 55% of the eligible costs under the restriction of the maximum eligible costs. Maxi-mum amount of financial support £38000 (€65000).
	Effectiveness	529 applications in 2004. 1600 applications in 2005. 2620 applications in 2006.
	Expected annual energy savings in 2010 and 2016	9930 toe by 2010. 13220 toe by 2016.
EEI No 9	**Title of the energy efficiency improvement measure**	Free fluorescent lamps. Information campaign.
	Investment	More than 1500000 lamps (six per household) will be distributed by 2011.
	Subsidy / Eligibility	Free.
	Expected annual energy savings	32400 toe.

CHAPTER 3: METHODOLOGY AND DATA

3 METHODOLOGY AND DATA

3.1 The methodology

Energy in the residential sector is used for heating and cooling, lighting, hot water and for electric appliances. There are several key factors in determining the energy consumption in residences. Among them is the physical size of the residence, the climate zone, the design characteristics of the building, the income level of the household and the available energy infrastructure (Santamouris et al., 2007). In order to design policies for energy saving measures in the residential sector, the key element is the knowledge of the energy and social characteristics of the households.

Since there have not been any previous energy performance regulations (building codes, minimum efficiency standards for equipment, etc.) in Cyprus, data concerning the above key elements are very limited. For this reason an energy analysis of households in Cyprus is performed using a bottom-up analysis.

Bottom-up analysis starts at a micro-level which in this case is the energy consumption by end-use at equipment and appliances level of an individual household and building up to the aggregate energy consumption of the residential sector. Energy consumption estimates by end-use are generally not available from utility load data. Bottom-up data that can be used for end-use breakdowns are questionnaire-based surveys, billing data analysis, energy audits and measurements.

A questionnaire-based energy survey has been used in this thesis for obtaining the necessary data. The questionnaire was prepared in a way to give us estimation of energy end-use breakdown of a household and also to provide us behavioural information and other socioeconomic variables that have a significant effect on the residential energy use. The energy questionnaire used in this thesis is presented in **Appendix A**. Except that, energy bills were analysed and also an interview was performed with an expert in engineering knowledge regarding technical and constructional features of houses in Cyprus. Also some assumptions were made, data from studies that were performed in other countries were used and finally another data source that was used is my personal experience, living in Cyprus for more than 25 years. The measurement method was not used due to limited time and high costs of this method. Metering data are available for end-uses in some countries, but practically no country in the world have metering data giving sufficient information to decompose total electricity consumption on different end-uses (Larsen and Nesbakken, 2004).

For the collection of data from all the sources, a statistical index system for the residential energy consumption was constructed based on a statistical system developed by Chen et al. (2008) in order to investigate the national energy consumption in the residential building sector of China. The system was adapted according to our available data and the conditions in Cyprus. The purpose of the index system is to look into the actuality of residential energy consumption and to provide sufficient data and energy efficient countermeasures for building energy efficiency (Chen et al., 2008).

3.1.1 The structure of the statistical index system

The index system for the residential energy consumption consists of six categories of indices (**Figure 3.1**). The first category of indices refers to household characteristics such as the population and the age of each household, household annual income, the highest educational level in the household and the status of residence (**Figure 3.2**).

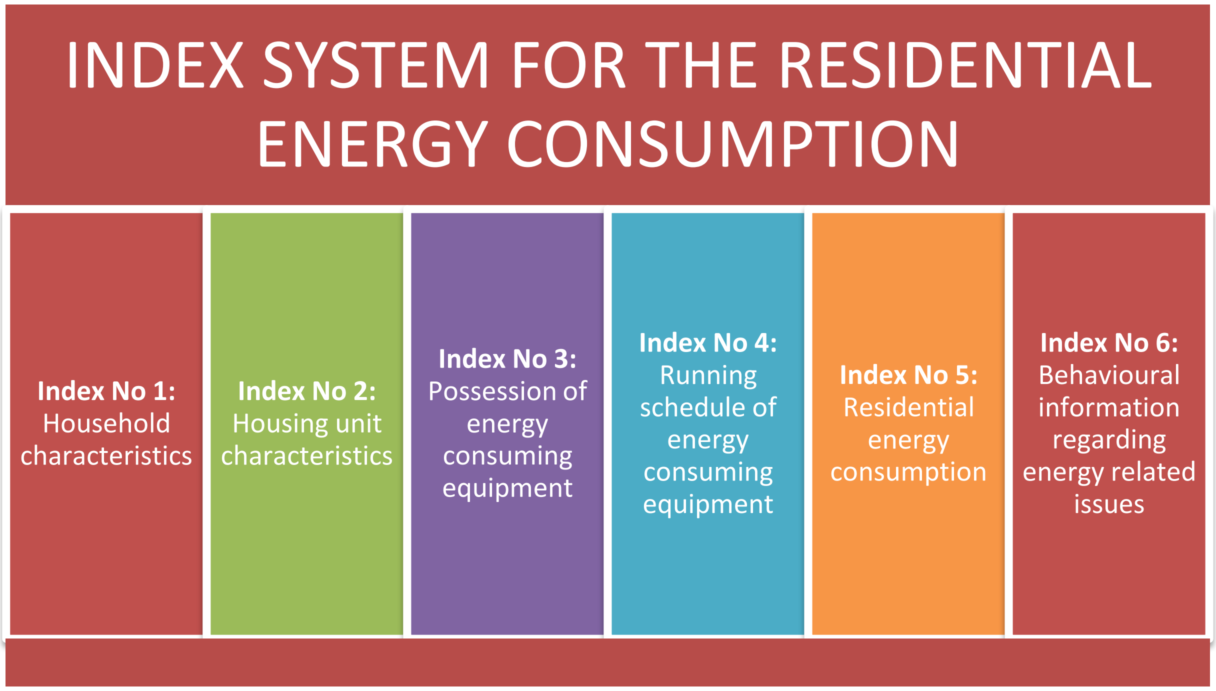


Figure 3.1: Index system for the residential energy consumption

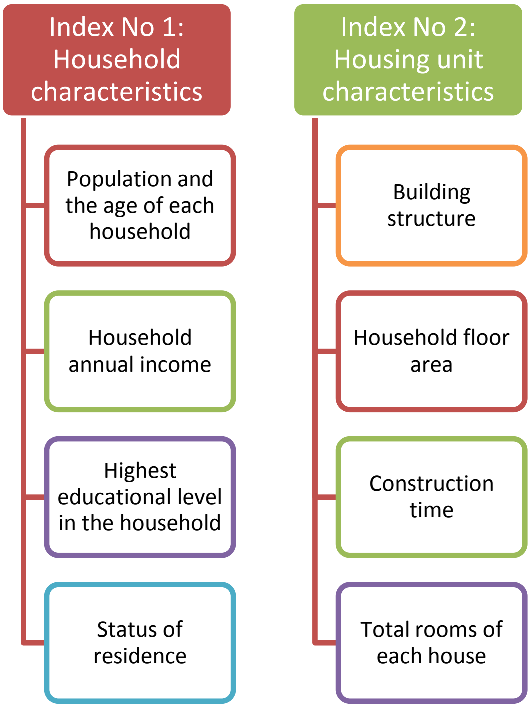


Figure 3.2: Statistical indices of household and housing unit characteristics

The second category of indices refers to the housing unit characteristics, i.e. building structure, household floor area, construction time and total rooms of each house (**Figure 3.2**). The housing unit characteristic index is important because the thermodynamic properties of an enclosed building, directly affects the consumption of space heating and air conditioning. The third category is the indices which reflect the possession of energy consuming equipments in households. **Figure 3.3** shows the division of the third category of indices into different end-use categories. The fourth category of indices, which refers to the running schedule of every energy consuming equipment, is impossible to accurately record the actual running condition of each equipment in each household, so average running hours were used. The fifth category of indices which reflects daily, monthly and annual energy consumption of various energy sources consumed by different kinds of equipment is actually the results obtained from the previous indices. Finally the sixth category of indices refers to behavioural information regarding energy consumption and potential savings such as importance criteria ranking of new purchased domestic equipment, necessity reasons for saving electricity, knowledge and usage of renewable energy systems (**Figure 3.3**).

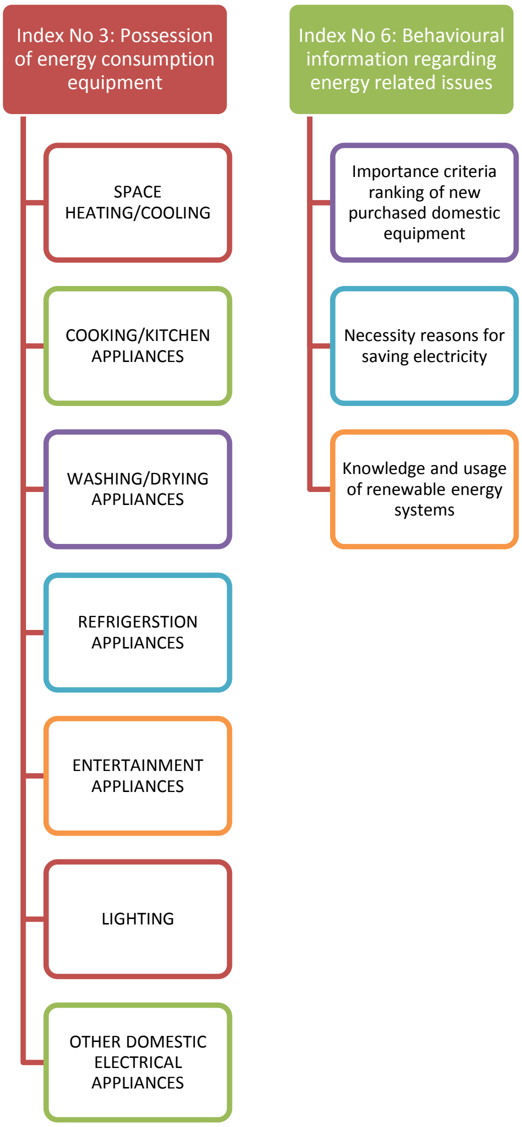


Figure 3.3: Statistical indices of possession of energy consumption equipment and behavioural information

Table 3.1 shows the calculation equations and relevant assumptions for the construction of Index No 5 (residential energy consumption) as used for each one of the subcategories of Index No 3 (possession of energy consumption equipment).

Table 3.1: Equations used for residential energy consumption calculations

Space heating/cooling:

$$EC = EC_{cooling-RAC} + EC_{heating-RAC} + EC_{electric\ heater}$$

$$EC_{cooling-RAC} = EC_{heating-RAC} = EC_{electric\ heater} = PI * ATU * SCN$$

Where:

EC	Electricity Consumption	(kWh/day) or (kWh/month) or (kWh/year)
PI	Power Input of Room Air Condition-RAC	(kW)
ATU	Average Time of Use	(hours/day)
WCN	Weighted Condition Number	the particular conditions prevailing in the house, regarding the number of occupants, mode of operation, etc.

Assumptions:

WCN = 1	number of persons in the household < 2
	RAC < 2
WCN = 2	2 < RAC < 4
WCN = 3	RAC > 4
ATU = 1.45 for cooling	total floor area <120 m^2
ATU = 1.00 for heating	
ATU = 2.90 for cooling	120 < total floor area < 200 m^2
ATU = 2.00 for heating	
ATU = 4.80 for cooling	total floor area > 200 m^2
ATU = 4.00 for heating	

Cooking/kitchen appliances:

$$EC = EC_{ck} = EC_{cooker} + EC_{toaster} + EC_{mixer} + EC_{microwave} + EC_{coffeemaker}$$

$$EC_{cooker} = EC_{toaster} = EC_{mixer} = PI * ATU$$

$$EC_{microwave} = PI * ATU + EC_{standby}$$

$$EC_{coffeemaker} = PC_h * NOH$$

Where:

EC	Electricity Consumption	(kWh/day) or (kWh/month) or (kWh/year)
EC_{ck}	Electricity Consumption of each	(kWh/day) or (kWh/month) or (kWh/year)

	cooking/kitchen appliance	
$EC_{standby}$	Electricity Consumption due to standby mode	(kWh/day) or (kWh/month) or (kWh/year)
PI	Power Input of cooking appliance	(kW)
ATU	Average Time of Use	(hours/day)
PC_h	Power Consumption per 10 minutes	(kWh/10min.)
NOH	Number Of usage	(hours)

Washing/drying appliances:

$$EC = EC_{washing\ m/c} + EC_{drying\ m/c} + EC_{dishwasher}$$

$$EC_{washing\ m/c} = EC_{drying\ m/c} = EC_{dishwasher} = PC_u * NOU$$

Where:

PC_u	Power Consumption per usage	(kWh/usage)
NOU	Number Of Usages	

Refrigeration appliances:

$$EC = EC_{fridge} + EC_{freezer}$$

$$EC_{fridge} = EC_{freezer} = PI * ATU$$

Entertainment appliances:

$$\mathrm{EC} = \mathrm{EC_{TV}} + \mathrm{EC_{homecinema}} + \mathrm{EC_{DVD}} + \mathrm{EC_{hifi}} + \mathrm{EC_{videogame}} + \mathrm{EC_{satellitebox}} + \mathrm{EC_{PC}} + \mathrm{EC_{laptop}}$$

$$\mathrm{EC_{TV}} = \mathrm{EC_{homecinema}} = \mathrm{EC_{DVD}} = \mathrm{EC_{hifi}} = \mathrm{EC_{videogame}} = \mathrm{EC_{satellitebox}} = \mathrm{EC_{PC}} = \mathrm{EC_{laptop}} = PI * ATU + EC_{standby}$$

Lighting:

$$EC = EC_{incandescent} + EC_{halogen-low} + EC_{halogen-high} + EC_{CFL}$$

$$EC_{incandescent} = EC_{halogen-low} = EC_{halogen-high} = EC_{CFL} = PI * ATU$$

Assumptions:

Typical power per lamp (W)	
Incandescent	60
Low wattage halogen	35
High wattage halogen	120
Compact fluorescent (CFL)	18

The next step after constructing and manipulate the data from the residential energy consumption index system is to estimate energy savings which can be achieved in the residential sector by promote energy efficiency and conservation measures such as thermal insulation, double glazing, new boilers, maintenance, HVAC, solar collectors, energy efficient appliances and lamps, etc., and to propose supporting policies for the above measures which may include laws, regulations, administrative provisions and financing in order to achieve the goal of reducing energy consumption in a building by minimize the financial impact and maximize the social welfare.

3.2 The data

The data set used in constructing the statistical index system was obtained from a number of sources. The main source is the household energy survey in the form of a questionnaire that was performed in 30 households (Spring 2008). The **Table 3.2** that follows shows the different data sources that were used for each Index.

Table 3.2: Data sources used for statistical index system

Index No 1: 1. Household energy survey
Index No 2: 1. Household energy survey 2. Personal interview of Christoforou Tryfonas[23], an engineering expert regarding technical and constructional features of houses in Cyprus 3. Florides et al. (2000) 4. Florides et al. (2001)
Index No 3: 1. Household energy survey 2. Statistical Service of Cyprus
Index No 4: 1. Household energy survey 2. Methodology Study Eco-design of Energy-using Products (MEEUP) - Study for the Directorate-General for Energy (EU) 3. Energy Efficiency of Room Air-Conditioners (EERAC) - Study for the Directorate-General for Energy (EU) 4. Almeida and Fonseca (2006) 5. Atanasiu and Bertoldi (2007) 6. Helsingin Energia - Energy company in Finland 7. Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe (REMODECE project) - http://www.isr.uc.pt/~remodece/ 8. ENERGY STAR - www.energystar.gov 9. Personal experience
Index No 5: Data sources of Indices 3 and 4.
Index No 6: 1. Household energy survey 2. Eurobarometer 3. Personal experience

[23] Katsambas, Christoforou & Associates. Mechanical – Electrical Consultans.

CHAPTER 4: RESULTS

4 RESULTS

The residential sector in Cyprus consumes energy from three main sources; electricity, oil products (gas oil and liquefied petroleum gases) and renewables (mainly solar energy). **Figure 4.1** shows a schematic diagram of the residential final energy consumption in 2004.

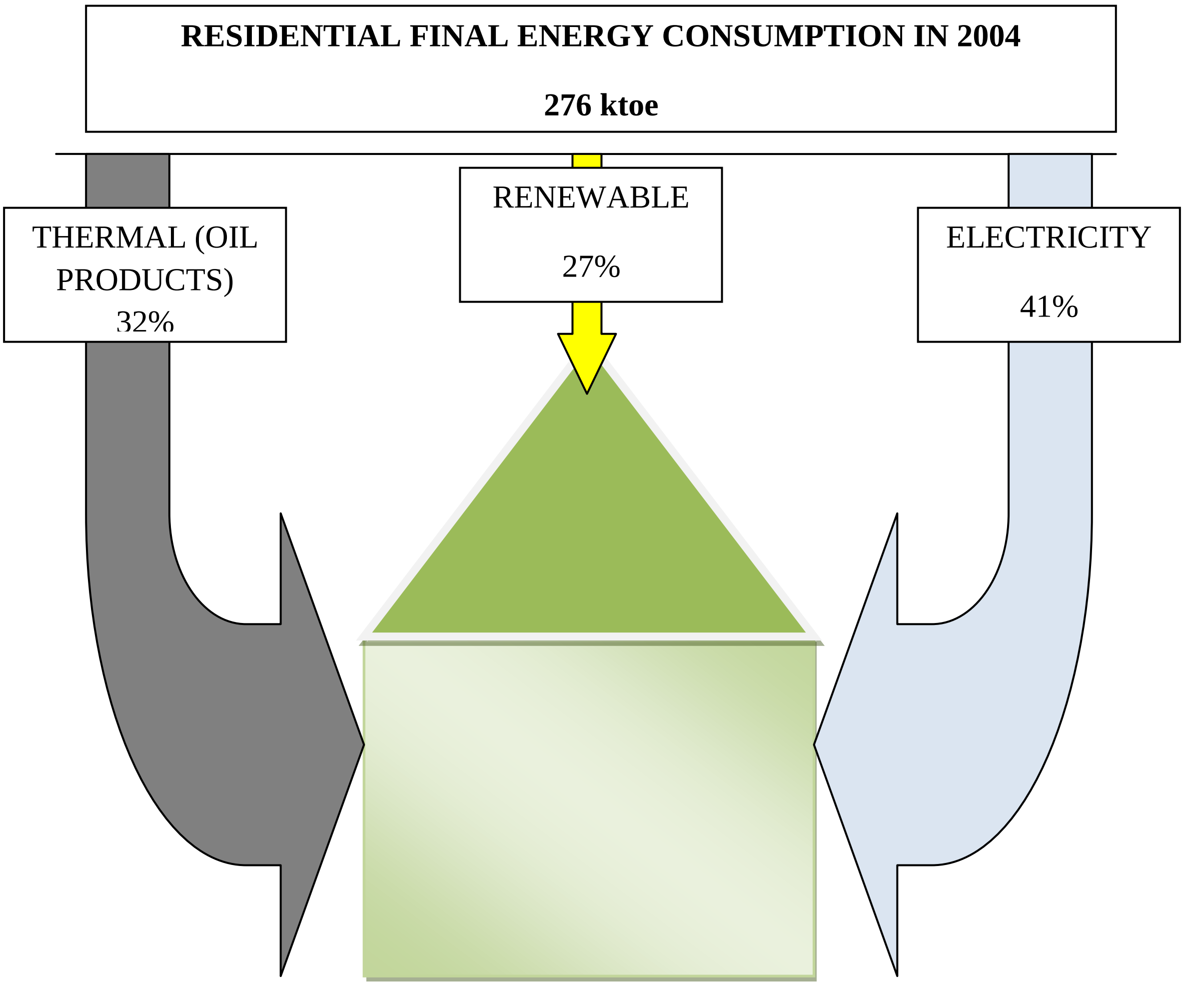


Figure 4.1: Residential energy consumption in 2004

The increase of electricity consumption in the residential sector during the last years has been remarkable with an average annual increase of 9-10% (Koroneos et al., 2003). One of the main drivers that increase the electricity consumption is the fast penetration of small residential air-conditioners (RAC) and their extensive use during the summer months. There are also other factors, including (Bertoldi and Atanasiu, 2007):

- More penetration of "traditional" appliances (e.g. dishwashers, tumble driers, personal computers, which are all still far away from saturation levels); introduction of new appliances and devices, mainly consumer electronics and information and communication technology (ICT) equipment (Set Top boxes, DVD players, etc.) many with standby losses.
- Increased use of "traditional" equipment: more hours of TV watching, more hours of use of personal computer, more washing and use of hot water.

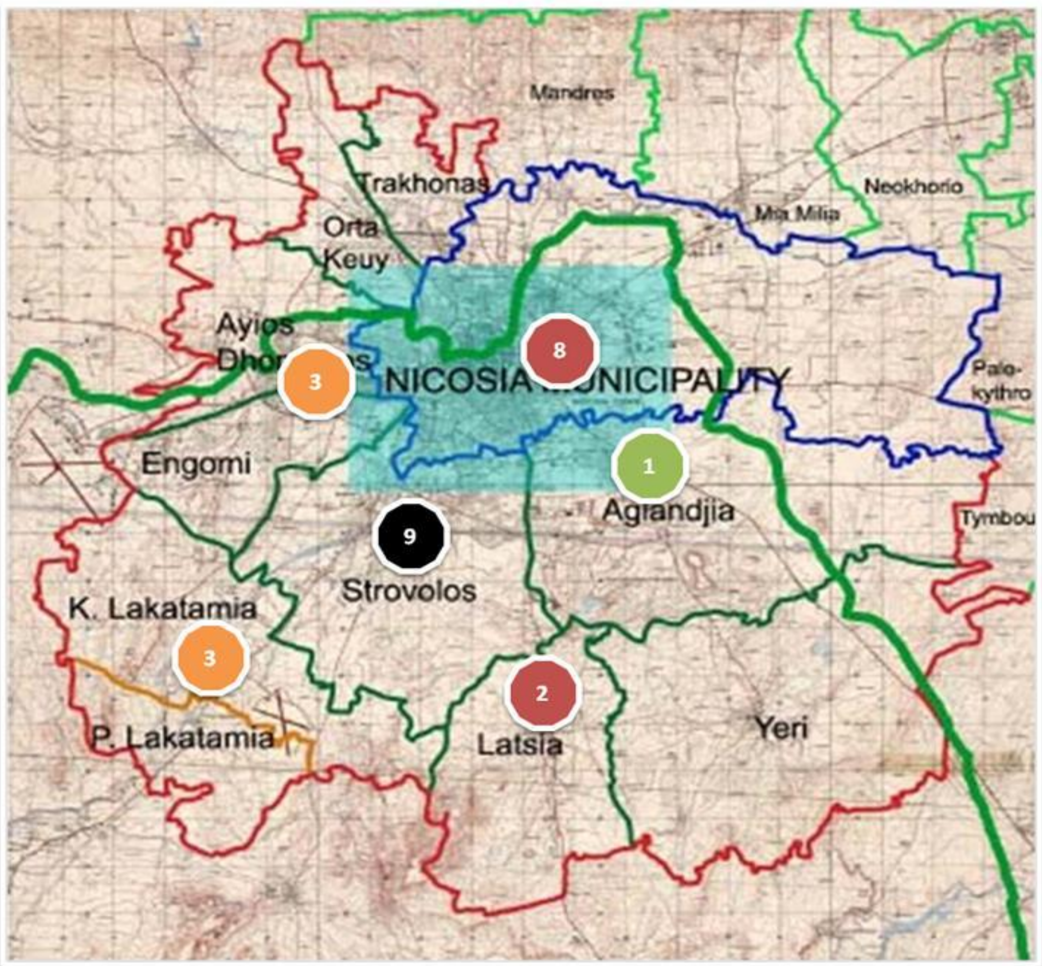
- Increased number of double or triple appliances, mainly TVs and refrigerators/freezers.
- More single family houses, each with some basic appliances, and larger houses and apartments. This results in more lighting and especially more heating and cooling.

The above driving factors of increasing electricity consumption can be also concluded from the results obtained from the household energy survey carried out for this thesis, results which are presented in this chapter.

4.1 Cyprus residential energy consumption results

4.1.1 General remarks

A detailed household energy survey was performed in 30 homes in order to obtain an understanding of appliance use and energy-related behaviour and to estimate the annual electricity consumption of a household. The 30 houses studied were located mainly in Nicosia (93%), the capital and biggest town of Cyprus, where the rest (7%) were located in Larnaca. The mapping and the number of studied houses in each area can be seen in the following map (**Map 1**). In addition to those houses in the map, another two houses were located in the sub-urban area of Nicosia and as it mentioned above, two houses were located in Larnaca.



Map 1: Location of studied houses

4.1.2 Index No 1: Household characteristics

The relationship between the variables of Index 1 in regard to energy use is given in **Figure 4.2**.

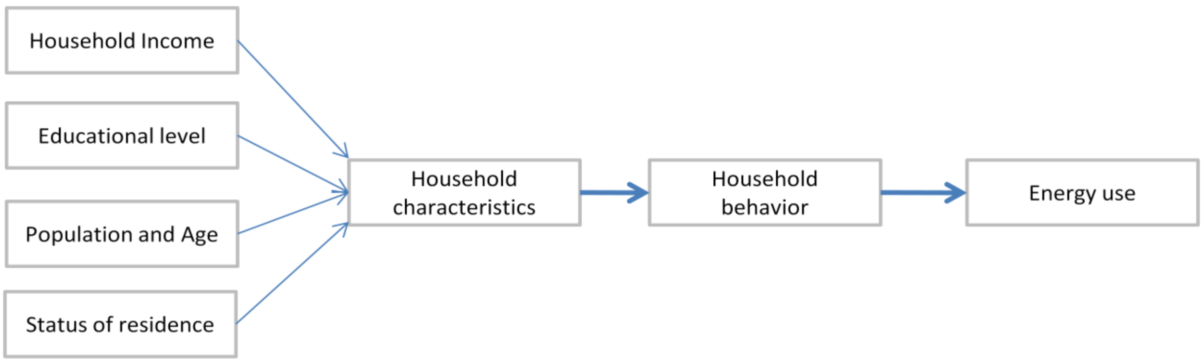


Figure 4.2: Relationship among variables of Index No 1

The majority of the sample families (60%) live in single family house, where the rest 40% in apartments. Household income (householders' combined total income) varies from 13% earning less than 20000 Euros per annum, 47% earning between €20000 and €30000, 17% earning between €30000 and €40000 to 23% of household total income exceeding €40000 (**Figure 4.3**). The vast majority (90%) of the sample families own the house they live, where only 10% rent it.

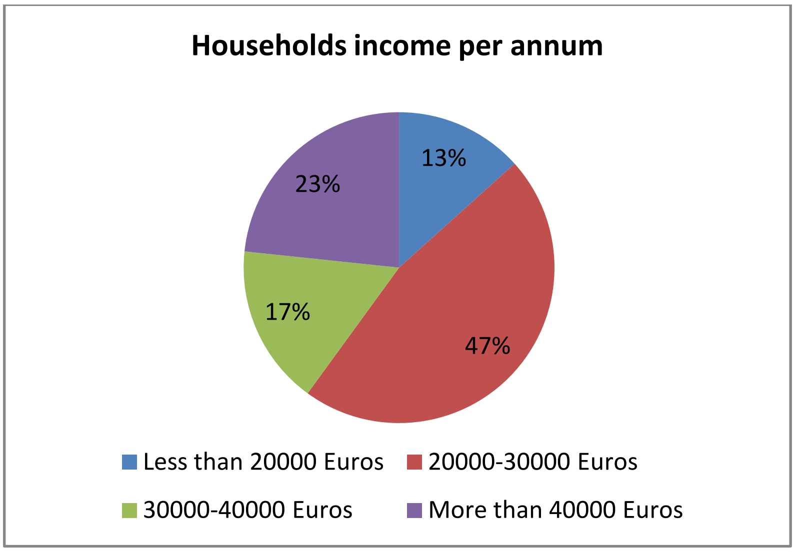


Figure 4.3: Households income per annum

The average number of people living in each household is 2.9. Eight percent of occupants were younger than 12 years old, 9% between 13 and 18 years old, the majority (77%) between 19 and 69 and 6% of all occupants were older than 69 years old. The number of occupants and their age influences energy consumption, for example, households where there are no children consumes less energy than a household with children or older people (Yohanis et al., 2008, Verhallen and Raaij, 1981). Unfortunately this observation can not be concluded from the results of this survey since the proportion of households with children or older people is extremely small comparing with the households of no children or older people, which gives a high probability of large statistical error. Lastly, the education level in the households is considered to be high, since the plurality of those who answered have a degree from college or higher.

4.1.3 Index No 2: Housing unit characteristics

Even though it is not a subject of this thesis, a definition of three important engineering terms is given below in order to understand better the significance and the magnitude of an insulated house related to energy performance and savings compared with a house with no or limited insulation. The definitions are:

- **Thermal conductivity (λ)** is a measure of the rate at which heat is conducted through a particular material under specified conditions [W/mK].
- **Thermal transmittance (U-value)** is a measure of the overall rate of heat transfer, by all mechanisms under standard conditions, through a particular section of construction [W/m^{2}K].
- **Thermal resistance (R)** is a measure of the opposition to heat transfer offered by a particular component in a building element [m^{2}K/W].

The main purpose of insulate the building shell of a house is to keep the house warm in winter and cool in summer (**Figure 4.4**). This is achieved by keeping heat inside a building for as long as possible by restrict the rate at which heat energy is exchanged with the surroundings (for winter) and reduce the flow of heat into a building when the outside temperature is higher than the inside temperature (for summer). Heat loss in a building occurs by a number of mechanisms. This is illustrated in **Figure 4.5** which shows the approximate percentages of heat loss from a poorly-insulated building. The U-value of a construction is therefore a commonly used measure of insulation.

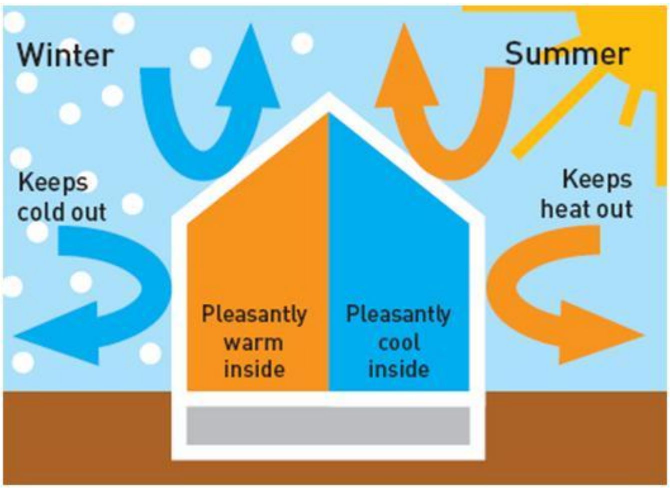


Figure 4.4: The main purpose of an insulated house

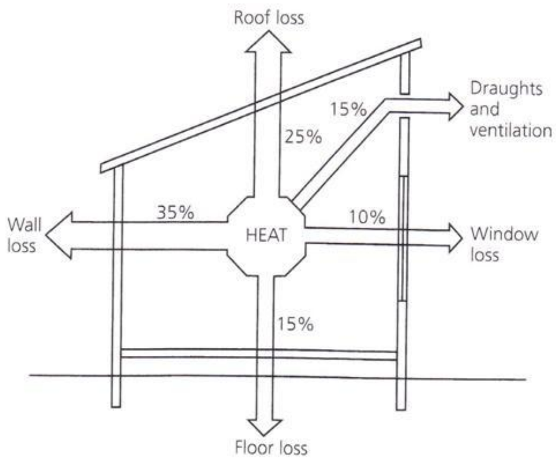


Figure 4.5: Heat losses in a building

As it mentioned before, prior to Cyprus accession in EU in 2004 no energy performance building regulations existed. The majority of the new buildings (more than 80%) were constructed without any minimum energy efficiency requirements. A typical house in Cyprus is usually built with hollow bricks made of fired clay.

As from 21st of December 2007, maximum U-values must be satisfied for every new building by the introduction of the new law for energy performance in buildings. The law is obligatory for buildings where the constructor deposit the appropriate papers for the construction licence after that date. Buildings that are in the construction process and got their licence before that date, are not obligate to fulfil the maximum U-value standards. Typical U-values of a common house in Cyprus before the introduction of the law and the new standards provided by the law and other design conditions (heating and cooling temperatures) are given in **Table 4.1**.

Table 4.1: Design conditions of a building in Cyprus

Building element	Typical U-value before the introduction of the law [W/m^2K]	Maximum U-value after the introduction of the law [W/m^2K]
Walls	1.40	0.85
Roof	1.50	0.75
Floor	1.50	0.75
	Design conditions	
Heating temperature		22°C
Cooling temperature		24 °C

Window U-values are particularly important as they can be naturally significantly higher than any wall, roof and floor with reasonable insulation. For many years now the building constructors in Cyprus shift from single glazed to double glazed windows. In Cyprus, an air filled double glazing window with 12mm cavity is normally used by constructors, which has a U-value equals to 2.8 [W/m^{2}K]. This value is already lower than the maximum U-value giving by the new law, which is equal to 3.8 [W/m^{2}K].

The average floor area of the households represented in the survey is 152.6 m^2. For single family houses the average floor area is 187.2 m^2, while for apartments is 100.7 m^2. This is very close to the figure given by Statistical Service of Cyprus[24]. The average number of rooms in each household is 6.2. From the surveyed houses, 10% were constructed before 1960, 27% between years of 1960 and 1990 and the majority (53%) after 1990 (**Figure 4.6**).

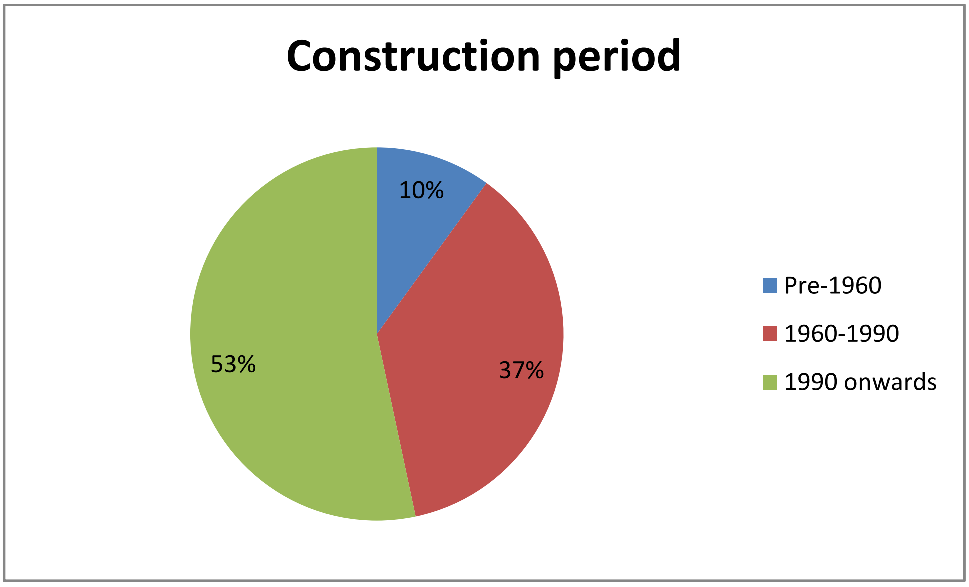


Figure 4.6: Construction period of the investigated houses

4.1.4 Index No 3: Possession of energy consuming equipment

Cyprus registers a higher level of main appliances penetration than the average for NMS, and is very close to EU-15 average (Atanasiu and Bertoldi, 2008). In Cyprus, equipments necessary for living live, such as TV sets and refrigerators is in a large possession, while the number of equipments that are not necessities in a house is relatively smaller. **Figure 4.7** shows the penetration of major appliances in households of Cyprus, as results from the household energy survey. From the penetration rate and the existing number of households we can the estimate the number of installed appliances. **Table 4.2** compares the household penetration of four major appliances from three different sources with the average number of penetration in NMS and EU-15.

[24] Census of Construction and Buildings, 2006.

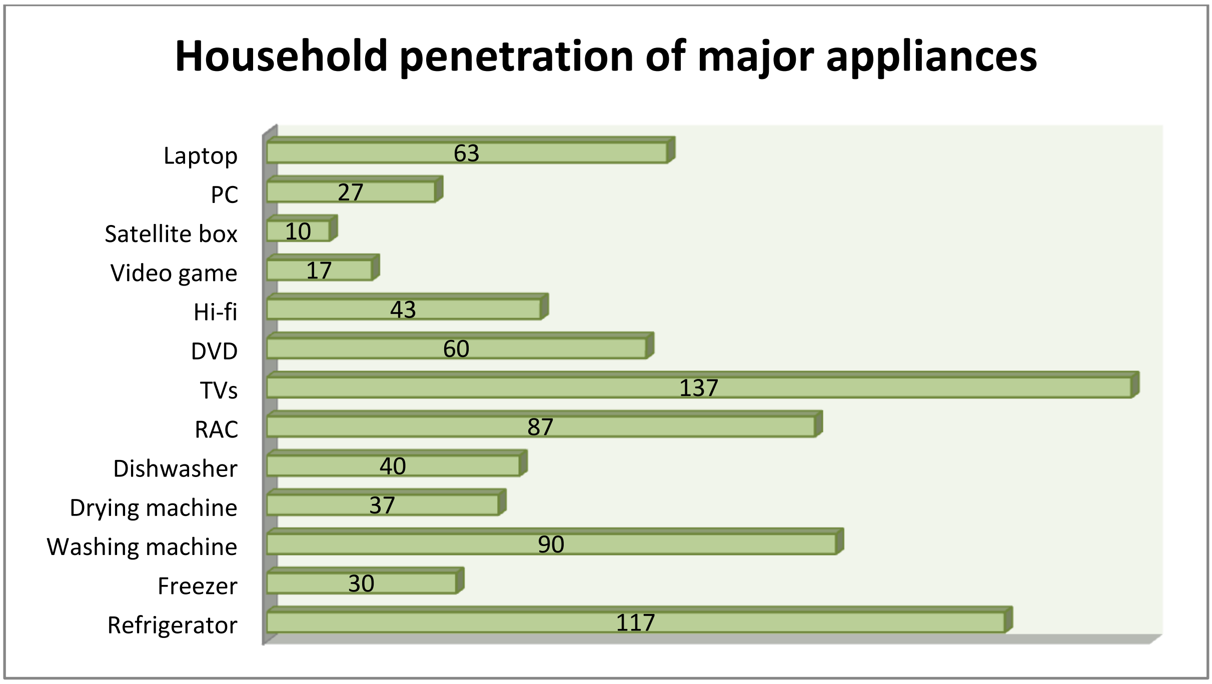


Figure 4.7: Household penetration of major appliances in Cyprus

Table 4.2: Cyprus household penetration of major appliances comparing with NMS and EU-15

	Cyprus household penetration					
	Household energy survey (%)	JRC[25] survey (%)	Statistical Service of Cyprus (%)		NMS	EU-15
Refrigerator	117	100	99.7		89.55	106
Freezer	30	19	---		41.47	52
Washing mashing	90	95	94.7		68.12	100
Dishwasher	40	37	36.9		4.64	40

The largest proportion of the refrigeration appliances (43%) are of age less than 5 years, while 40% are between 5 and 10 and 17% more than 10 years old. The numbers for washing machines are: less than 5 year old are 56%, between 5 and 10 years are 33% and more than 10 years old are 11% (see **Figure 4.8**). The majority of the surveyed occupants were not familiar with the energy class of their appliances. For the refrigeration appliances, only 25% of the surveyed occupants knew the energy class of their appliances with the majority (75%) being of energy class “A”, 12.5% of class “A+” and 12.5% of class “C”. For the washing machines the numbers are: approximately 30% knew the energy class with the vast majority (87.5%) being of energy class “A” and 12.5% of class “B”.

[25] European Commission Joint Research Centre (JRC).

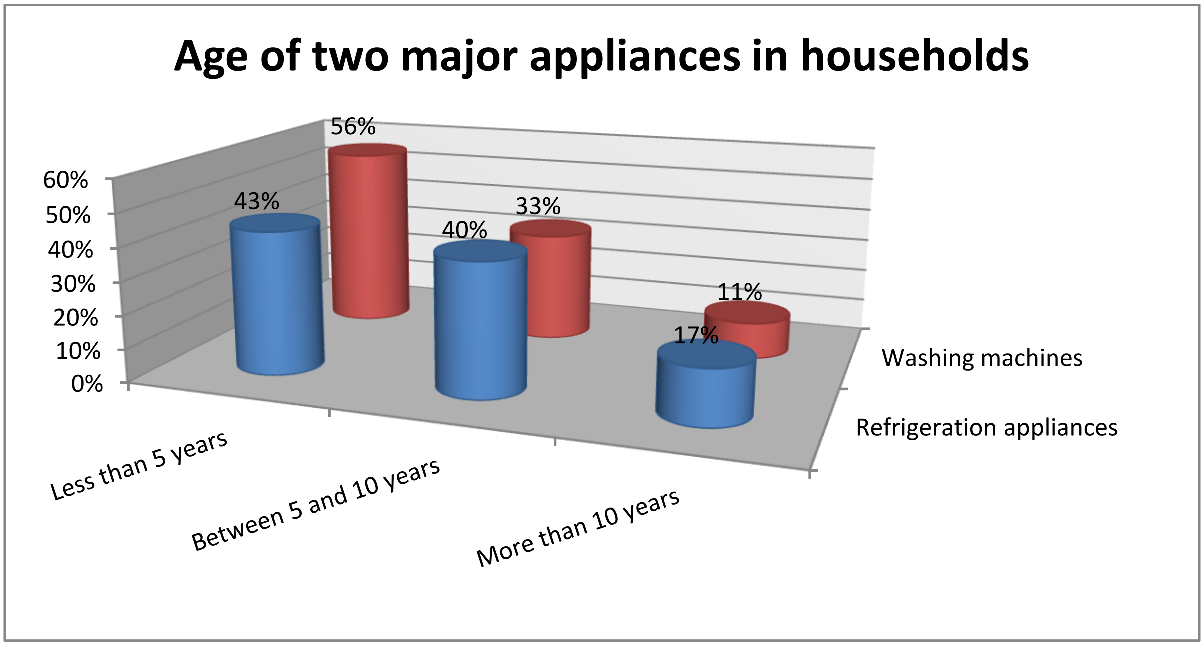


Figure 4.8: Age of refrigeration and washing machine appliances in Cyprus households

In the surveyed houses, approximately 29% are using central heating for heating the space followed by split units with hot air (27%), kerosene stoves (14.5%), electric heaters (12.5%), gas stoves (8%), fireplace (6%) and storage heaters (2%). Comparing with the numbers from the Statistical Service of Cyprus (Census of population, 2001) we can see approximately the same numbers in almost all heating facilities except of the case of split units with hot air and gas stoves. According to the Statistical Service, in 2001 33% were using gas stoves and 9.4% split units with hot air (**Figure 4.9**). For cooling the space, room air-conditioners (RAC) are used in 26 out of 30 (87%) surveyed houses where the number is 2.65 air-conditioners per household. These numbers show the high penetration of RAC during the last years.

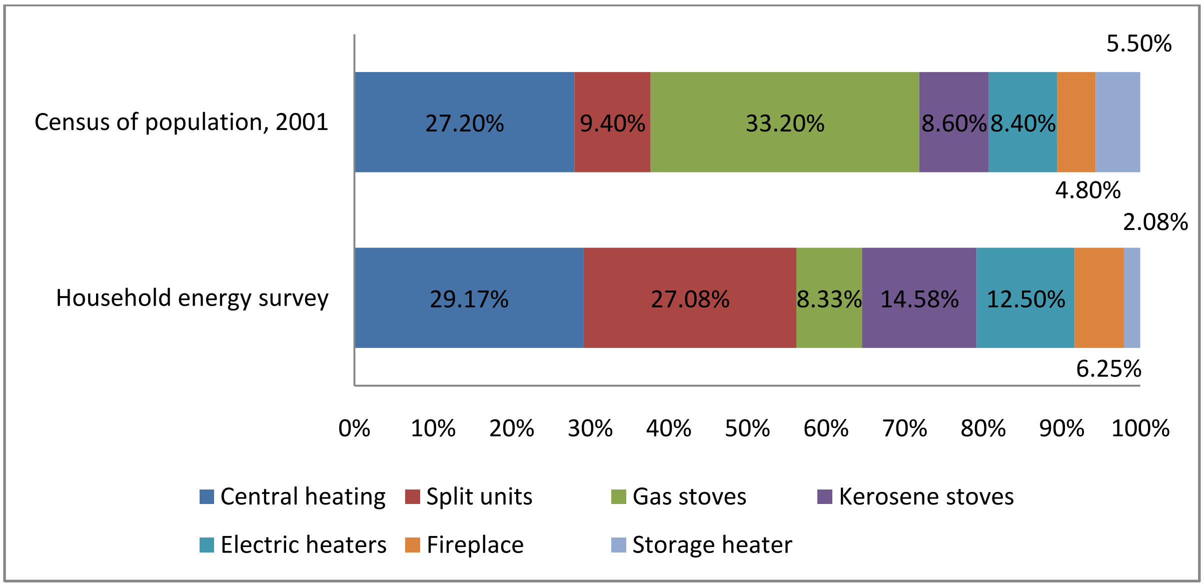


Figure 4.9: Comparison of heating facilities in households of Cyprus

In the surveyed houses the average number of light points per household is 17 with the incandescent bulb type be the preferred one with 9 bulbs per household, followed by low wattage halogen bulb type with 4, the compact fluorescent lamp (CFL) with 3 and the high wattage halogen bulb type with 1 bulb per household. These numbers are very close with the estimation numbers given by Energy Service of Cyprus.

4.1.5 Index No 4: Running schedule of energy consuming equipments

In terms of running schedule, the necessities of life are widely used, such as TV sets, while the high-power equipment such as electrical cooker, microwave ovens and washing machines, is relatively rarely used (Chen et al. 2008). In order to estimate the running schedule of each equipment, data from the household energy survey, similar studies from other countries and personal experience were used (see **Chapter 3 – METHODOLOGY AND DATA).**

4.1.6 Index No 5: Residential energy consumption

The results of this index are the outcome from the data collected in indices 3 and 4. The mean electricity consumption of the surveyed houses is 7680 kWh/year (or 0.66 toe/year). The electricity consumption is approximately the same for both summer and winter period (3711 and 3969 kWh/y respectively). **Figure 4.10** shows the correlation of electricity consumption for the surveyed houses as a function of floor area. The figure clearly shows the dependence of electricity consumption on floor area; this can be represented in the correlation in the following Equation:

$$\boxed{\boldsymbol{E = 16A + 5192}}$$

Where, E is the average annual electricity consumption (kWh) and A is the floor area (m^2).

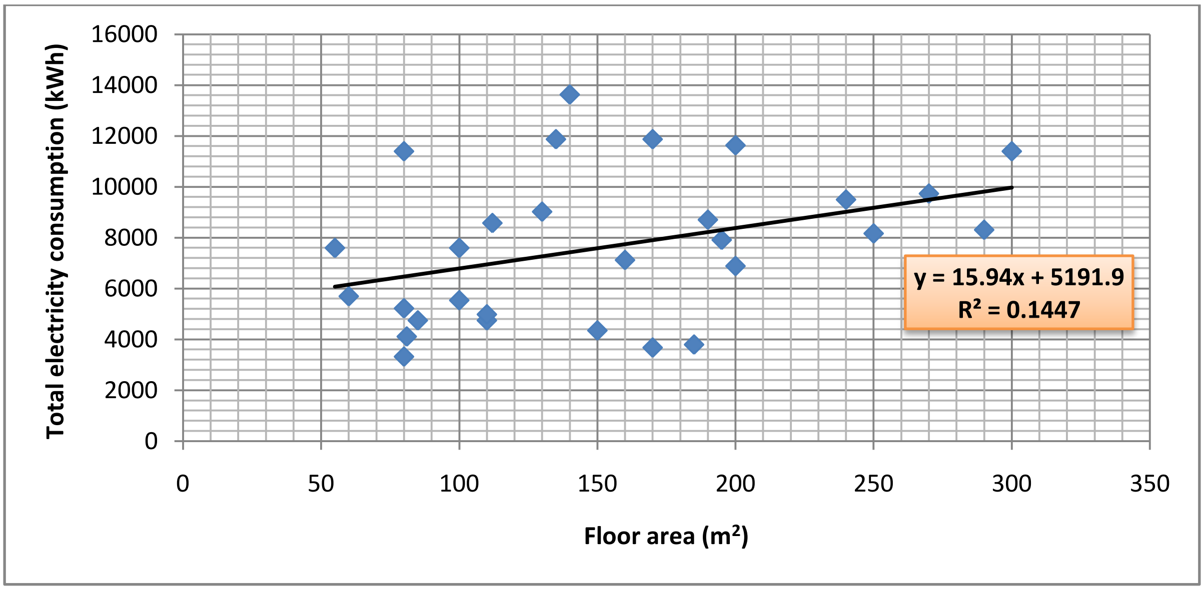


Figure 4.10: Total electricity consumption as a function of floor area

The annual electricity consumption per floor area range from 21 to 142 kWh/m^2, where the mean value is 58 kWh/m^2. The average value for single family houses is 42 kWh/m^2, while for apartments the number is 73 kWh/m^2.

In order to calculate the total energy consumption of surveyed houses, the percentages given in **Figure 4.1** were used. After introducing those numbers in our data the average annual energy consumption of households is 18740 kWh/y (or 1.61 toe/y). This number breakdowns in 7680 kWh/y for electricity consumption, 5991 kWh/y for thermal consumption (from oil products) and 5069 kWh/y from renewable sources (mainly from solar water heating, SWH). The total annual energy consumption per floor area is then found to range from 50 to 337 kWh/m^2, where the mean value for households is 142 kWh/m^2. The number of average total energy consumption for single family houses is 103 kWh/m^2, while for apartments the number is 178 kWh/m^2.

Previous studies show that electricity consumption (and generally energy consumption) is strongly related to the family income (Santamouris et al., 2007). This can also be concluded from the results obtained from this household energy survey (see **Figure 4.11** that follows).

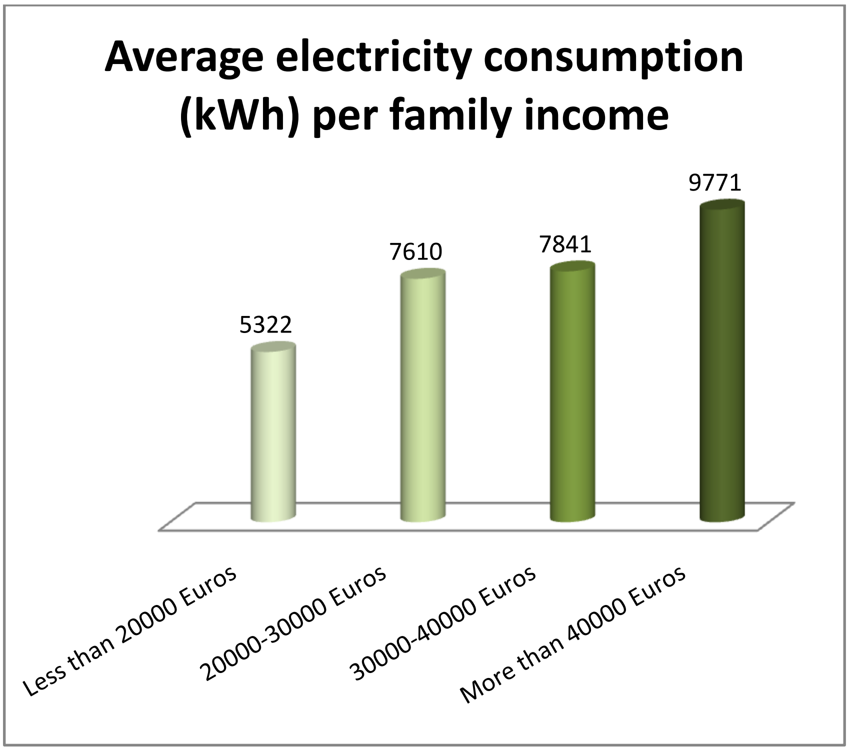


Figure 4.11: Average electricity consumption per household income

The residential energy use per capita of the surveyed houses is approximately 6500 kWh/cap annually. According to the European Commission, D.G. for Energy and Transport, the residential energy use per capita varies widely among European countries, for example, from 1500-5000 kWh/cap in Southern Europe, 6000-8000 kWh/cap in most northwest Europe countries, to over 8000 kWh/cap in Scandinavian countries. Even though the levels in most EU countries are fairly steady, in some southern European countries, residential energy use increase steadily during the last decade (Balaras et al., 2005). The average consumption of electricity per capita of the surveyed houses is approximately 2650 kWh/cap annually. In EU, also the number of average consumption of electricity per capita is quite diverse, ranging from 1000 kWh/cap in some countries (mainly southern Europe countries) up to 4500 kWh/cap in others (mainly Scandinavian countries).

Table 4.3 that follows summarize all the important results for electricity and total energy consumption obtained from the surveyed houses.

Table 4.3: Results from surveyed houses on residential energy consumption

TOTAL ANNUAL ENERGY CONSUMPTION IN HOUSEHOLDS							
Electricity		Thermal		Renewable		Total	
kWh	TOE	kWh	TOE	kWh	TOE	kWh	TOE
7680	0.66	5991	0.52	5069	0.44	18739	1.61

TOTAL ANNUAL ENERGY CONSUMPTION PER FLOOR AREA			
	Average (kWh/m^2)	Maximum (kWh/m^2)	Minimum (kWh/m^2)
Apartments	178	337	101
Single family houses	103	215	50
Total	142	---	---

TOTAL ANNUAL ELECTRICITY CONSUMPTION IN HOUSEHOLDS			
	Average (kWh/m^2)	Maximum (kWh/m^2)	Minimum (kWh/m^2)
Apartments	7358	13628	3323
Single family houses	7895	11872	3680
Total	7680	---	---

TOTAL ANNUAL ELECTRICITY CONSUMPTION PER FLOOR AREA			
	Average (kWh/m^2)	Maximum (kWh/m^2)	Minimum (kWh/m^2)
Apartments	73	142	42
Single family houses	42	88	21
Total	58	---	---

	kWh/cap	TOE/cap
Residential energy use per capita	6500	0.56
Residential electricity use per capita	2650	0.23

Household energy consumption in this thesis is divided into 7 so-called energy functions (or end-use): space heating/cooling, cooking/kitchen appliances, entertainment appliances, lighting, washing/drying appliances, refrigeration appliances and other domestic electrical appliances. The demand of each energy function is congregated by one or more energy consuming systems or appliances (**Table 4.4**). The equations used for the calculation of the energy demand of each function are presented in **Chapter 3 - METHODOLOGY AND DATA**.

Table 4.4: Energy functions and their systems or appliances

Energy functions	Energy consuming system or appliance
SPACE HEATING/COOLING	• System(s) used for heating or cooling each household (e.g. central heating, room air-conditioner, etc.)
COOKING/KITCHEN APPLIANCES	• Cooker • Microwave • Toaster • Mixer • Coffee maker
ENTERTAINMENT APPLIANCES	• TV sets • Home cinema • DVD recorder/player • Hi-fi • Video game • Satellite box • PC • Laptop
LIGHTING	• Incandescent • Low wattage halogen • High wattage halogen • Compact fluorescent
WASHING/DRYING APPLIANCES	• Washing Machine • Drying machine • Dishwasher
REFRIGERATION APPLIANCES	• Fridge-freezers • Freezers
OTHER DOMESTIC ELECTRICAL APPLIANCES	• Electrical domestic water heater • Other electricity consuming appliances

From this thesis' survey it was found that space heating/cooling is the main energy consumer for the residential sector. It accounts for 46% of the total, while other domestic electrical appliances accounts for 16%, lighting 12%, entertainment appliances, washing/drying appliances and refrigeration appliances accounts for 7% each and cooking/kitchen appliances 5% (see **Figure 4.12** that follows).

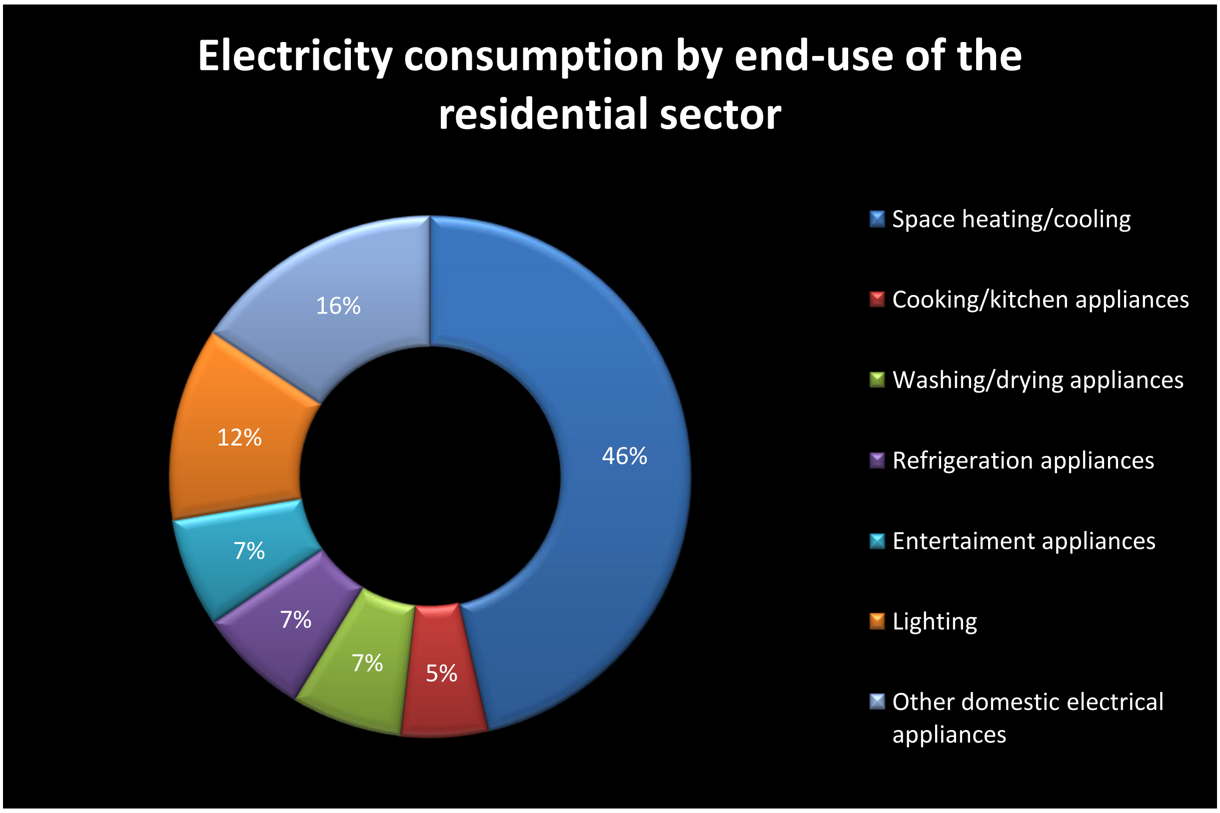


Figure 4.12: Electricity consumption by each function in the residential sector

4.1.7 Index No 6: Behavioural information regarding energy related issues

Previous studies demonstrate that total energy consumption can be reduced by 10-30% by changing occupants' behaviour alone (Palmborg, 1986 and Mullaly, 1998). During the household energy survey, questions were asked regarding present and future occupants' behaviour in energy consumption and savings for the residential sector, the possibility of using renewable systems and in general the knowledge of the people in energy related issues.

Some important aspects of behavioural information regarding usage of major appliances and activities can be seen in **Table 4.5**.

Table 4.5: Behavioural information of surveyed occupants

Washing machines	Average time of usage per week	4
Drying machine	Average time of usage per week	3
Dishwasher	Average time of usage per week	4
TV	Average time of use per day (hours)	7
PC	Average time of use per day (hours)	0.9
Laptop	Average time of use per day (hours)	1.85
Shower	Number of showers per person per day	1

Figure 4.13 shows how the occupants ranked six different criteria (ease of use, price, electricity consumption, etc) according to importance in the case were new appliance is purchased. As it can be seen from the figure below, price and ease of use are the most

important criteria when someone purchase a new domestic appliance, with the electricity consumption of the appliance and design/style are following. External dimensions and capacity are coming last as importance criteria.

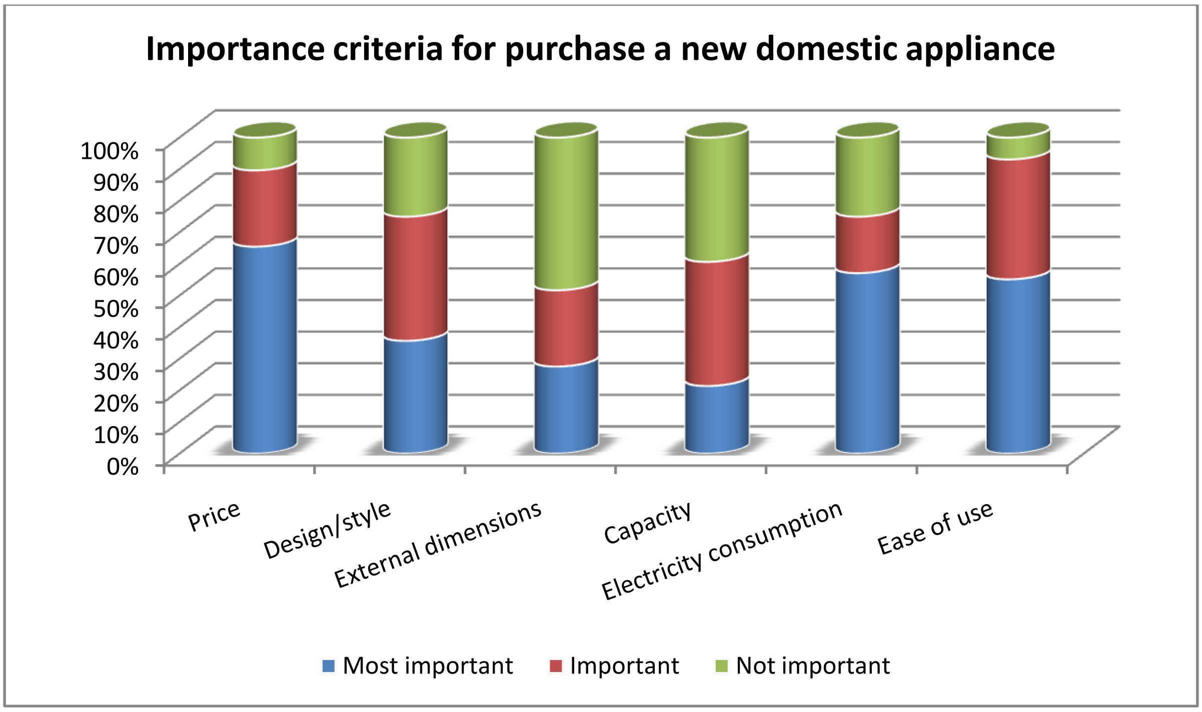


Figure 4.13: Importance criteria for purchase a new domestic appliance

The necessity to save electricity according to surveyed occupants is shown in **Figure 4.14**. It is clear that financial savings is the most important necessity to save electricity, while the depletion of energy supplies and greenhouse effect (global warming) are following. No one believes that there is a risk of war due to electricity crisis in the future.

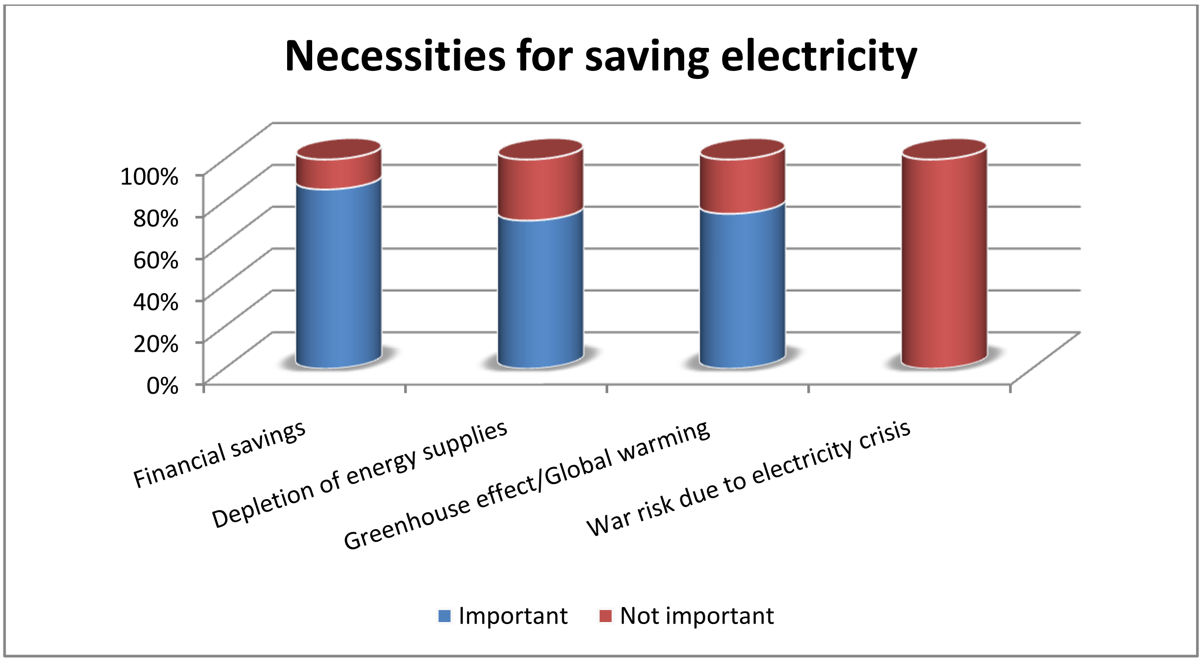


Figure 4.14: Necessities to save electricity

The most important source of information for electricity savings is the TV, as 90% of the surveyed occupants learned from the TV programmes about electricity savings followed by magazines/newspapers with 82%. Internet is the third important source of information with 53%, while the influence from schools accounted only for an approximate 40% of the surveyed occupants.

The percentage of the surveyed occupants that have considered saving energy is approximately 75% while the rest 25% never considered saving energy. The prevailing way to save energy is the changing of inefficient lamps (incandescent) with more efficient ones (CFLs). Other ways that surveyed occupants used to save energy are by using energy saving and environmental friendly products, by switching off appliances to minimise standby consumption, using thermal insulation and double glazing windows and changing lifestyle.

An important conclusion of the survey is that 86% of the surveyed occupants are willing to use photovoltaics (or other renewable energy system) as long as it is economically feasible. Seven percent (7%) are not interested in using renewable energy systems, while another 7% gave *don't know* as a reply.

Another important conclusion that came out from personal conversation with the occupants is that there are two major reasons why the proposed from the government energy efficiency improvement measures are not satisfactory:

1. Procedures are time consuming due to bureaucracy.
2. The level of subsidies is low.

4.2 Energy efficiency measures and potential savings

"Energy efficiency measures" refers to methods and means for reducing the energy consumed in the provision of a given good or service, especially compared to conventional or standard approaches[26]. Energy technologies for the residential sector that fall into the energy efficiency category includes improved insulation, high performance building envelopes and windows, efficient equipment and appliances technologies, efficient lighting system and other existing and emerging technologies.

These energy technologies can offer environmental, economic and social benefits and for those reasons energy technologies are receiving increasing attention from governments, industry and consumers in all over the world during last decades.

In the following paragraphs, some energy technologies for the residential sector and their potential benefits for Cyprus residential sector are introduced.

4.2.1 Quality of the building envelope

The aim is to investigate common measures and techniques which can be adopted by building companies either in the designing phase or in the maintenance phase of a residential building,

[26] RETScreen International - RETScreen® Engineering & Cases Textbook.

for decreasing energy consumption. The building envelope is constituted by walls, roofs, windows and doors and it can have an important impact on residential energy consumption.

The quality of the building envelope of households is determined by many parameters, where the most important ones are the insulation of the opaque elements and the type of installed glazing (Santamouris et al., 2007).

4.2.1.1 Opaque building envelope

Thermal insulation of the opaque building envelope can save energy in the heating period, but also can reduce the energy demand for space cooling, a common problem for the southern European countries (like Cyprus) with warm climate. Especially, insulation of external walls and roof can provide robust and considerable savings.

Table 4.6 shows a comparison of typical U-values of the building envelopes components. The U-values in the table are not required by the respective national regulations but normally applied to meet the energy performance requirement.

Table 4.6: Countries specific component U-values

	U-VALUE (W/m²K)																					
	Roof							**External Wall**								**Ground floor**						
Country	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**	**0.85**	**0.15**	**0.25**	**0.35**	**0.45**	**0.55**	**0.65**	**0.75**
Sweden	■							■								■						
Norway	■								■							■						
Finland	■								■								■					
Denmark	■								■							■						
Lithuania	■								■								■					
Ireland	■								■								■					
Russian Federation	■	■	■					■								■	■	■				
UK	■									■							■					
Netherlands		■	■						■	■							■					
Austria		■								■									■			
Germany		■										■							■			
Switzerland			■							■											■	
France		■									■							■				
Belgium				■								■									■	
Italy			■								■								■			
Portugal						■							■								■	
Spain						■							■								■	
CYPRUS							■								■							■

Source: TEBUC – Towards an European Building Code

The above table shows that Northern European countries have much stricter requirements than Southern European countries. The main reason is the colder climate of the Northern countries which has a significant impact on the applied U-value of components. Cyprus is using the biggest U-values from all countries in all 3 components (roof, external walls and ground floor). This can be explained by the fact that this is the first time that such standards are introduced in Cyprus, while other countries have use them for several years now and already revised them more than once (**Table 4.7**).

Table 4.7: U-values for new buildings for different climate zones (Estimated average values)

Structural components	Cool northern climatic zone		Moderate central climatic zone		Warm southern climatic zone		CYPRUS
	U-values (W/m^2K)						
	1975-1990	Since 1991	1975-1990	Since 1991	1975-1990	Since 1991	Since 2007
External walls	0.3	0.20	1.0	0.5	1.2	0.6	**0.85**
Roof	0.2	0.15	0.5	0.4	0.8	0.5	**0.75**
Floor	0.2	0.15	0.8	0.5	0.8	0.5	**0.75**

Source: Ecofys report - The Contribution of Mineral Wool and other Thermal Insulation Materials to Energy Saving and Climate Protection in Europe. – EURIMA, 2002.

It was mentioned earlier that building sector is considered as a key issue for the Kyoto Protocol. Worldwide, 30-40% of all primary energy is consumed in buildings. The energy consumption of the building sector contributes significantly to global greenhouse gas emissions and finally to global warming. A study conducted by Ecofys on behalf of European Association of Insulation Manufacturers (EURIMA) proposed target U-values in order to reach a certain level of CO_2-emissions savings. **Table 4.8** presents these results for warm southern climate zone.

Table 4.8: Measures to reach Post-Kyoto targets

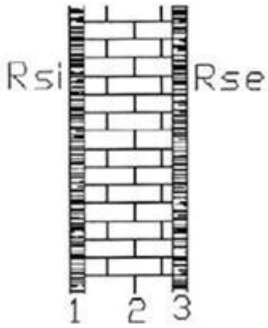
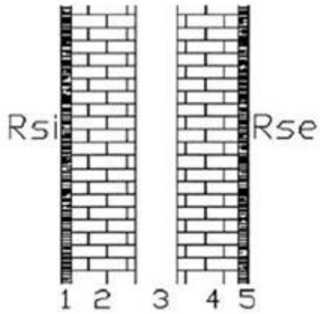
Measures to reach CO_2-emission savings	Warm southern climate zone			CYPRUS
	80% CO_2-emission savings	85% CO_2-emission savings	90% CO_2-emission savings	
U-value wall	0.65	0.50	0.40	**0.85**
U-value roof	0.50	0.35	0.30	**0.75**
U-value floor	1.00	0.80	0.60	**0.75**
U-value window	1.60	1.60	1.20	**3.80**

Source: Ecofys report - U-values for Better Energy Performance of Buildings. – EURIMA

As already mentioned the law for mandatory insulation in Cyprus came into force recently. Typical U-values of a common house in Cyprus before the introduction of the law and the new standards provided by the new law can be seen in **Table 4.1**.

Florides et al (2001) simulated a common type of building construction (with no insulation) and an insulated one, using the TRNSYS simulation program, with respect to the cooling and heating load. The building characteristics of the two type of building constructions and the results of the simulation are presented in **Table 4.9**.

Table 4.9: Cooling/heating load and characteristics of two different building constructions

<table>
<tr><th></th><th>No insulation house</th><th>Insulated house</th></tr>
<tr><td colspan="3">WALL CHARACTERISTICS</td></tr>
<tr><td>Wall details</td><td>
1. Plaster (slush grout) of 0.025m thickness
2. Brick of 0.2m thickness
3. Plaster (slush grout) of 0.025m thickness</td><td>
1. Plaster (slush grout) of 0.025m thickness
2. Brick of 0.1m thickness
3. Insulation - Expanded polystyrene of 0.03m thickness
4. Brick of 0.1m thickness
5. Plaster (slush grout) of 0.025m thickness</td></tr>
<tr><td>U-value of the wall</td><td>1.416</td><td>0.586</td></tr>
<tr><td colspan="3">LOAD (kWh)</td></tr>
<tr><td>Cooling at 25°C</td><td>42300</td><td>23790</td></tr>
<tr><td>Heating at 21°C</td><td>16012</td><td>4660</td></tr>
</table>

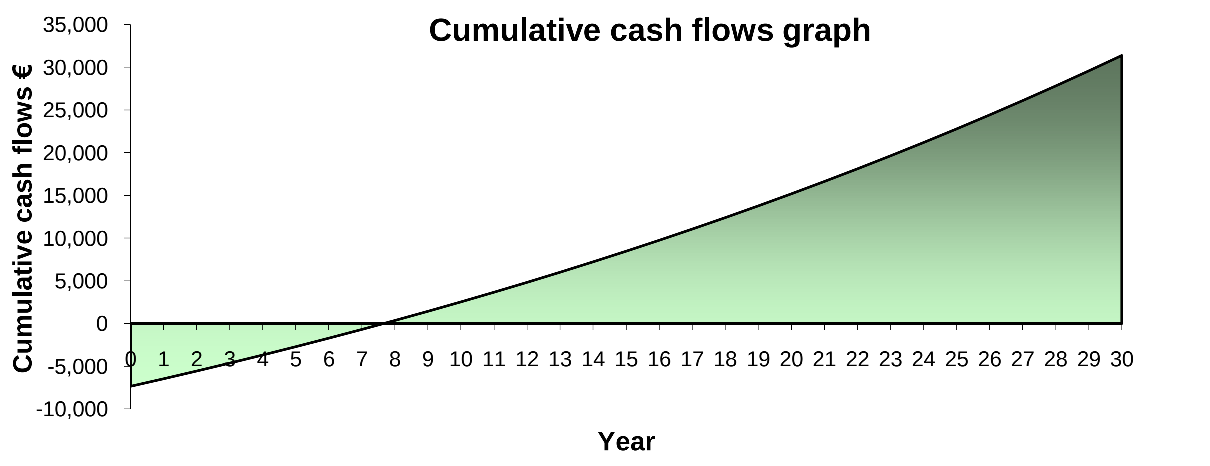
Source: Florides et al. (2001)

From the above table, it is obvious that the introduction of insulated material to the external wall of a building construction has positive impacts. Cooling load is decreased by 44%, while the heating load is decreased by 71%. The above example shows the importance, the effectiveness and the strong relation of U-value of a material with the heating/cooling loads.

Good insulation of the opaque envelope costs much less than in the case, for example, with windows. Increasing the insulation levels may cost only €30 to €50/m^2. Generally the rate of increase in costs relative to the improved insulation levels is very moderate. A technical and financial analysis was performed for the above example using RETScreen software. The results are presented in **Table 4.10** below:

Table 4.10: Results of simulation from RETScreen software

Technical characteristics of opaque elements (inputs to RETScreen software)	
Walls area	160 m^2
U-value of external wall without insulation	1.416 W/m^2K
U-value of external wall with insulation	0.586 W/m^2K
Incremental initial costs	€5500
Roof area	190 m^2
U-value of roof without insulation	1.5 W/m^2K
U-value of roof with insulation	0.558 W/m^2K
Incremental initial costs	€5000
Fuel for Heating system	Liquefied petroleum gas (LPG)
Fuel for Cooling system	Electricity
Incentives and grants	€3150 (30%)
Results from RETScreen software	
Fuel saved	1217.3 kg
Fuel cost savings	€ 861
Simple payback	8.5 years
Equity payback	7.7 years



4.2.1.2 Window improvements

During recent years, the penetration of double glazed windows is considerable high in Cyprus. The type that is normally used is an air filled double glazing window with 12mm cavity is normally used by building constructors, which has a U-value equals to 2.8 [W/m^{2}K]. The U-values of windows can be further improved by:

- Increasing the number of panes (cavities);
- Increasing the width of each cavity;
- Changing the gas in each cavity;
- Using glass with low emissivity coatings.

A window's thermal performance depends on a number of factors, including design, the materials used and the combination of components. Indicative U-values for a range of window types (with wood or PVC frames) are given in **Figure 4.15**.

Window glazing (clear)	Indicative U-value for stated gap (W/m^2.K)		
	6mm	12mm	>16mm
Single glazing	4.8	-	-
Double glazing (air filled)	3.1	2.8	2.7
Emissivity = 0.2	2.7	2.3	2.1
Emissivity = 0.05	2.6	2.0	1.8
Double glazing (argon filled)	2.9	2.7	2.6
Emissivity = 0.2	2.5	2.1	2.0
Emissivity = 0.05	2.3	1.8	1.7
Triple glazing (air filled)	2.4	2.1	2.0
Emissivity = 0.2	2.1	1.7	1.6
Emissivity = 0.05	1.9	1.5	1.4
Triple glazing (argon filled)	2.2	2.0	1.9
Emissivity = 0.2	1.9	1.6	1.5
Emissivity = 0.05	1.7	1.4	1.3

Figure 4.15: Indicative U-values for windows with different glazing (CIBSE, 2006)

High performance windows (triple glazing) are already part of Northern Europe standards and practice. A comparison of typical U-value of windows in different countries can be seen in **Table 4.11**.

Table 4.11: Countries windows U-value

	U-VALUE (W/m²K)					
	Windows					
Country	1.25	1.75	2.25	2.75	3.25	3.75
Sweden						
Norway						
Finland						
Denmark						
Lithuania						
Ireland						
Russian Federation						
UK						
Netherlands						
Austria						
Germany						
Switzerland						
France						
Belgium						
Italy						
Portugal						
Spain						
CYPRUS						

Source: TEBUC – Towards an European Building Code

Standard windows with double glazing and wooden or plastic frames are available today for about €150/m^2. High performance windows are available for about €350 to €500/m^2. It is obvious that high performance windows are, at present, a high cost item.

In Cyprus (like other Southern countries of Europe), and mainly in summer, solar radiation penetrates windows causing an immediate energy gain which must be removed by the cooling system. One way to avoid using high performance windows (and avoid high cost) and face the problem of overheating is by make use of shading devices. The three main groups of shading devices are[27]:

1. Exterior devices, such as overhangs, awnings, Venetian blinds, fabric screens, shutters and solar control film on glass;
2. Interpane shading devices inside the window construction between two panes or, in some cases, inside a sealed glass unit;

[27] Sustainable Solar Housing, Volume 2: Exemplary Buildings and Technologies by Robert Hastings, Maria Wall.

3. Interior devices such as Venetian blinds, pleated curtains, fabric screens, roller blinds and solar control film on glass or as roller blinds.

Naturally, external shading devices have much greater potential to reduce cooling loads and unwanted solar gains, since the absorbed heat is mostly dissipated to the outdoor air. **Table 4.12** shows the effectiveness of some solar protection systems.

Table 4.12: Solar radiation reduction factors for some kinds of shading devices

Glazing	Without shading device	External awning		Internal curtain		External blind		Internal blind	
		Light	Dark	Light	Dark	Light	Dark	Light	Dark
Standard glazing	0.95	0.25	0.30	0.50	0.60	0.15	0.20	0.60	0.70
Double glazing	0.90	0.20	0.25	0.45	0.55	0.12	0.16	0.66	0.65
Triple glazing	0.80	0.15	0.20	0.40	0.50	0.10	0.13	0.50	0.60

Source: ALTENER Project - Promoting solar air conditioning (2002).

4.2.2 Quality of domestic appliances

The presence of major domestic appliances in households (see **Figure 4.7: Household penetration of major appliances in Cyprus**) makes them a powerful tool for energy savings in the residential sector and for the implementation of European commitments on the Kyoto Protocol targets. In the last decade, the production of higher-efficient and better eco-friendly appliances has performed outstanding progress. Today, the energy efficiency of many types of large appliances is close to the technological limit[28].

By replacing appliances in use since 10 years or more, a significant reduction in consumption of energy but also of water can be achieved, while at the same time money will be saved on the energy bill. Despite all the proven economic savings, it seems that are not enough to motivate all consumers to replace old appliances with new high-efficient ones, therefore some incentives should be given on replacing outdated appliances.

A possible way to calculate the energy saving potential from domestic appliances is by replacing all the existing outdated appliances with the higher energy class appliances of the same size and capacity (e.g. ideal case).

4.2.2.1 Room air-conditioners (RAC)

Air conditioning represents a significant share of the total electricity consumption of households especially in countries of South Europe. The air conditioning EU market has been flooded with very low cost and very inefficient units (Almeida and Fonseca, 2006). The

[28] CECED, Energy-Efficiency a Shortcut to Kyoto Targets. The Vision of European Home Appliance Manufacturers. 2005.

Energy Efficiency Ratio (EER[29]) is used for air conditioners to define the energy classes for the energy labelling.

The A class limit for RAC (up to 12 kW) is set at EER of 3.2. Nowadays, some new models have been introduced on the European market with EER above 4 (**Figure 4.16**). But there are still several E and D class models on the European market, with EER at around 2.5 (Bertoldi and Atanasiu, 2007).

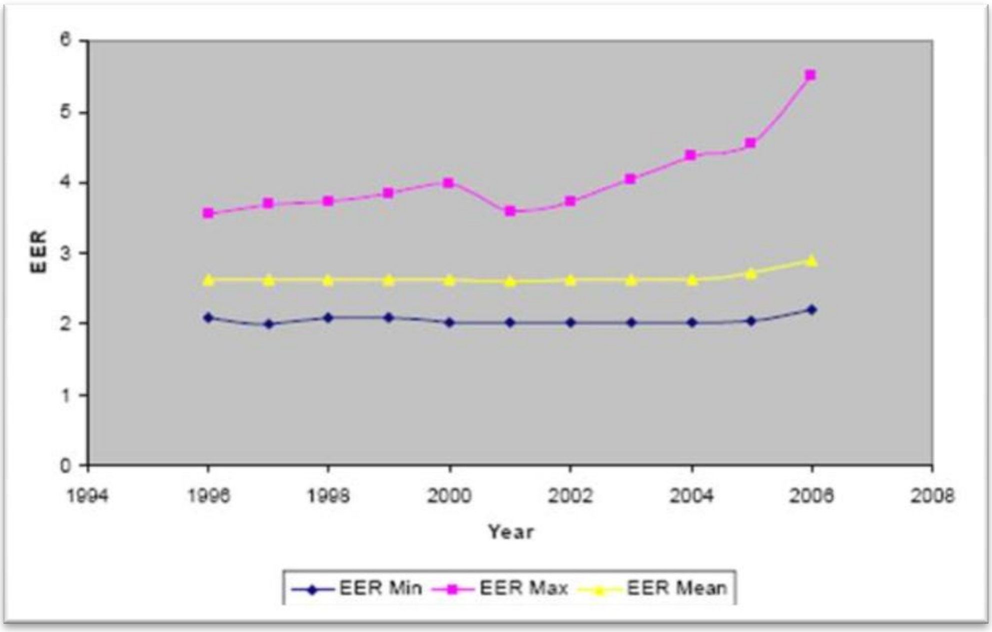


Figure 4.16: Evolution of energy efficiency of split, non ducted, air-cooled air conditioners up to 12kW in the EU

Source: Bertoldi and Atanasiu, 2007

4.2.2.2 Refrigeration appliances

A study commissioned by Ceced[30] to the Öko-Institut shows that an average new refrigeration appliance (today's state of art fridge) uses 70% less energy than an average model of 15 years ago, 55% less energy that an average model of 10 years ago and 45% of 5 years ago (**Table 4.13**). The same numbers apply for refrigerator-freezer models (many people preferred to buy the combined model nowadays).

Table 4.13: Evolution of consumption for refrigeration appliances

	Year					
Appliance	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Refrigerators (kWh/year)	360	330	300	250	210	118
Fridge-freezer (kWh/y)	760	610	600	480	430	254
Upright freezer (kWh/y)	700	570	530	500	470	224
Horizontal freezer (kWh/y)	530	410	380	350	310	201

Source: Öko-Institut

[29] This is the ratio between the output cooling (thermal) power and the input electrical power in the cooling mode.
[30] European Committee of Domestic Equipment Manufacturers (CECED)

Since 57% of the surveyed households in this study possess a refrigeration appliance that it is more than 5 years old (see **Figure 4.8: Age of refrigeration and washing machine appliances in Cyprus households**) a replacement with a higher-efficient appliance could reduce the use of energy for refrigeration appliances by 50%.

An important parameter for the consumer to replace the old with a new appliance is the payback period. **Figure 4.17, Figure** 4.18**, Figure** 4.19 and **Figure 4.20** show the results for payback periods from the study conducted by Öko-Institut (for refrigerator-freezer model) for four alternative impacts:

- Cumulated Energy Demand (CED)
- Global Warming Potential (GWP)
- Total Environmental Burden
- Cost

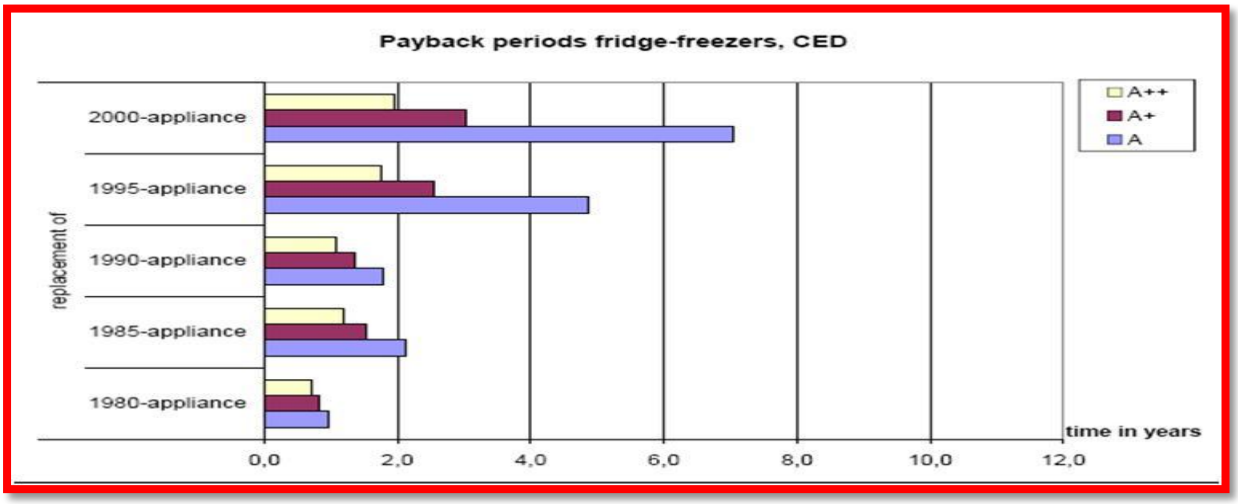


Figure 4.17: Payback periods of the primary energy demand (CED) with respect to the energy efficiency class of the new appliance

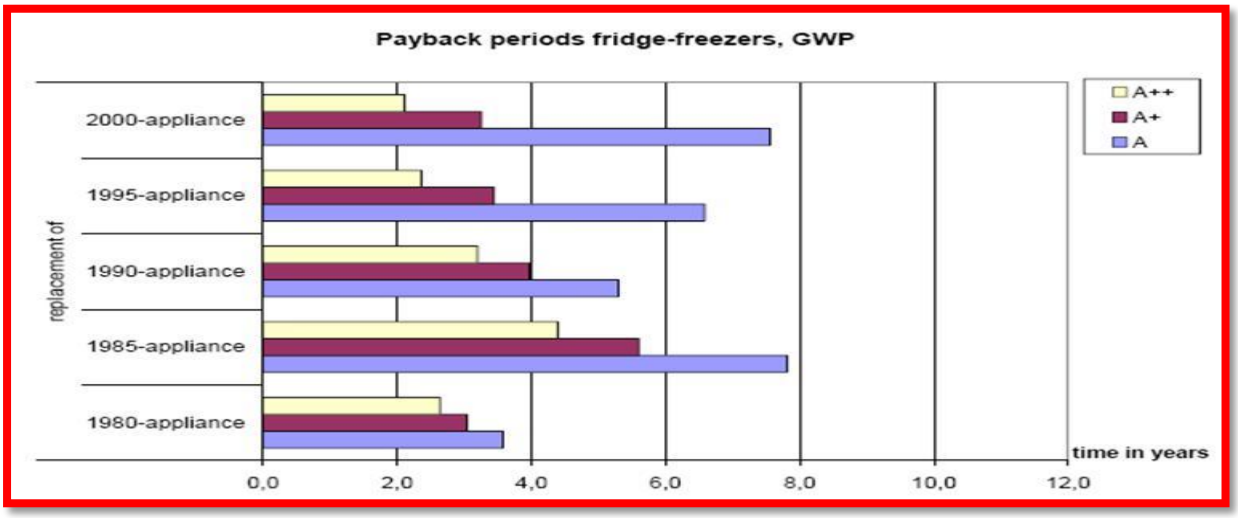


Figure 4.18: Payback periods of the global warming potential (GWP) with respect to the energy efficiency class of the new appliance

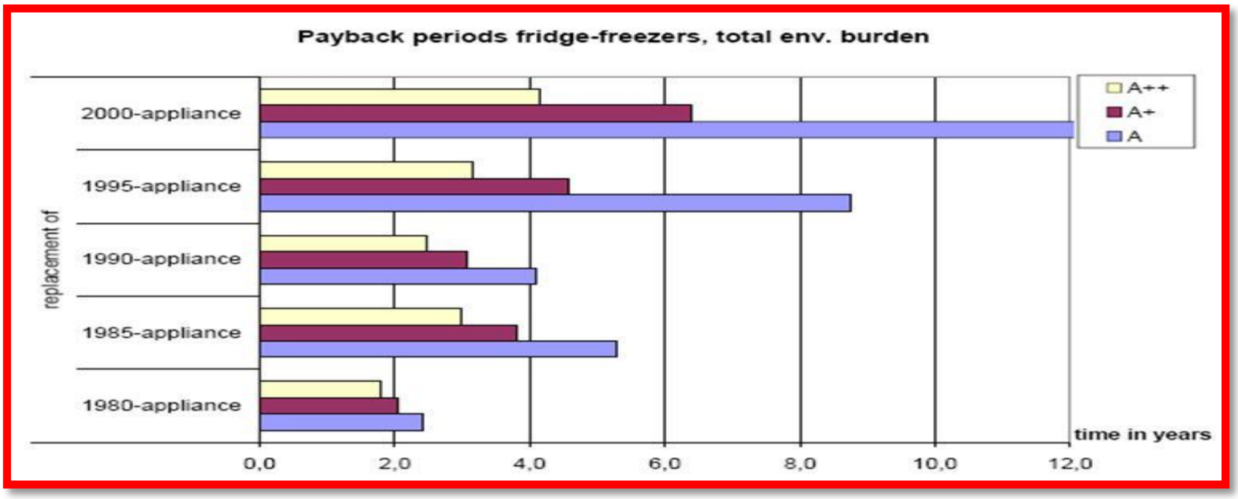


Figure 4.19: Payback periods of the total environmental burden with respect to the energy efficiency class of the new appliance

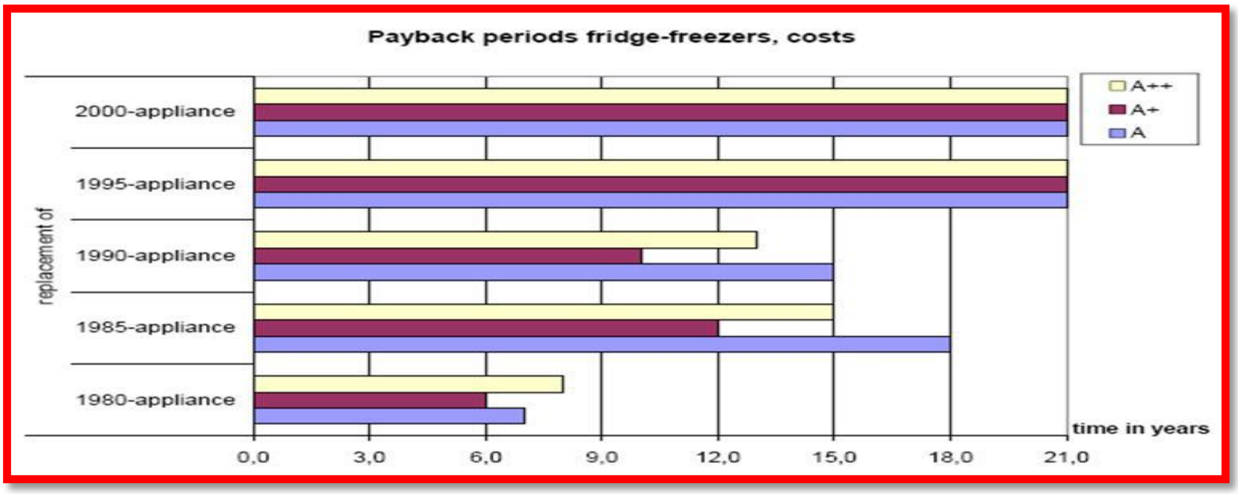


Figure 4.20: Payback periods of the costs with respect to the energy efficiency class of the new appliance

Source: Öko-Institut

The cost payback periods are much higher than the other payback periods. The bandwidth of the purchase prices along with the uncertainty regarding the purchase price dependency only on the energy efficiency class, allow us to deal with the results of the costs with higher degree of uncertainty compared to other impacts.

The outcomes of the study (by Öko-Institut) that in case of refrigeration appliances, the replacement of appliances in stock, which are older than five to ten years and still functioning, environmentally makes sense, if they are replaced by high efficient new appliances (i.e. appliances of the energy efficiency classes A+ or A++).

4.2.2.3 Washing machine appliances

The case of washing machine appliances is very similar with the refrigeration appliances. **Table 4.14** that follows shows the evolution of energy and water consumption of washing machines through years. The same study from Öko-Institut shows that an average new washing machine uses 44 % less energy (0.95 kWh compared with 1.70 kWh) and 62 % less water (49 l compared with 129 l) than a 1985 one.

Table 4.14: Evolution of consumption for washing machine appliances

	Year					
Washing machines	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Energy consumption (kWh) per cycle, 60 ºC coloured	---	1.7	1.35	1.15	1.1	0.95
Water consumption (l) per cycle, 60 ºC coloured	---	130	106	79	61	49

Source: Öko-Institut

From the household energy survey, came out that 44% of the surveyed houses possess washing machines older than 5 years old (33% between 5 and 10 years old and 11% more than 10 years old). By replacing the old washing machines with new high-efficient appliances, it is estimated that the use of energy for washing machine appliances can be reduced by 20%.

The payback periods for replacing washing machines (according to the study by Öko-Institut) are:

- Looking at Cumulated Energy Demand (CED), the replacement of washing machines of the years 1985, 1990 and 1995 with a new model the payback period can be reached in 2 to 5 years.
- When evaluating the Global Warming Potential (GWP)(17) the replacement of washing machines of 1985, 1990 and 1995 with a new model can be reached in 3 to 7 years.
- The analysis of the Total Environmental Burden shows that the replacement of washing machines of 1985 and 1990 with a new model can be reached in approximately 4 to 8 years.
- **The economics of the replacement look rather unappealing for consumers, unless supported by financial incentives.**

4.2.2.4 Desktop PC Vs Laptop PC

For the comparison of energy consumption for desktop PCs against laptop PCs, an energy calculator from EU-ENERGY STAR website[31] was used. **Table 4.15** that follows show the results of the energy calculator.

[31] http://www.eu-energystar.org/en/en_007c.shtml

Table 4.15: Energy consumption comparison between desktop and laptop PC

	Desktop PC/Monitor	**Laptop PC**
Equipment	Value PC/Value 17" LCD	Value laptop PC
Price	500 +180=680	800
Power		
On-mode (W)	100/25	22
Standby-mode (W)	10/1.2	11
Off-mode (W)	5/1.2	3
Hours use per mode		
On-mode	2	2
Standby-mode	9	9
Off-mode	13	13
Electricity price (€/kWh)	0.11	0.11
Product life (years)	6	6
Energy Split-up (kW/year)		
On-mode	75	13.2
Standby-mode	30.2	29.7
Off-mode	33.8	16.3
Total	**139**	**59.2**
Total costs split-up (€)		
Equipment	680	800
Energy	91.8	39.1
Total	**771.8**	**839.1**

From the above example we can conclude that laptop PCs are using much less energy comparing with desktop PCs (135% less energy use and as a consequence the electricity cost reduce by 135% also) for the whole product life. The price difference on purchasing the two equipments offset the above different in energy consumption and make desktop PCs less costly than laptop over their product life. Financial incentives on laptop PCs could bring significant reductions on residential energy consumption.

4.2.2.5 TV Sets

TV sets in Cyprus has the biggest penetration rate from all appliances examined by the household energy survey. It is difficult to reach some conclusions regarding the electricity savings potentials for TV sets due to new technologies, larger screens and the relevance of standby losses. Beside that there is a general tendency to increase viewing hours (Atanasiu and Bertoldi, 2007). TVs are consider to be necessary for living live and there is a tendency through customers not paying attention to energy consumption when buying a new TV.

4.2.3 Residential lighting

Lighting represents a considerable share of electricity consumption in the residential sector of Cyprus (12% of the total residential electricity consumption). Residential lighting offers an opportunity for large energy saving potential. Most people are still not aware about the low efficiency of traditional lamps and they are reluctant to install new efficient lighting technologies. The most important barrier for the introduction of more efficient lighting in households is the purchase price (e.g. price of €10 for a 13 W CFL with a life of 6000 hours, while for the incandescent lamp price would be €0.5 and life of 1000 hours). This can be explained by the fact that the consumers still do not have clear information about the short payback periods (Bertoldi and Atanasiu, 2007).

Table 4.16 presents the benefits and payback period of the replacement of a €0.5, 60 W and life of 1000 hours incandescent lamp with a CFL of €10, 13 W and life of 6000 hours. For the comparison, excel-based software prepared by ENERGY STAR[32] was used.

Table 4.16: Comparison between CFL and incandescent lamp

Initial cost difference	€9.50
Life cycle savings	€45.90
Net life cycle savings (life cycle savings - additional cost)	€36.40
Simple payback of additional cost (years)	1
Life cycle energy saved (kWh)	282
Life cycle air pollution reduction (kg of CO2)	196
Air pollution reduction equivalence (number of cars removed from the road for a year)	0.04
Savings as a percent of retail price	364%

As it can be seen from the above Table, there is large energy savings potential by replacing one incandescent lamp with CFL with a short payback period. Today much cheaper CFL are available (in the range of 3 to 5 Euros), which makes CFL even more cost effective in almost every lighting point.

4.2.4 "Passive house" as a building option for Cyprus

The German/American definition of a "passive house" is: "An (ideal) passive house heats and cools itself in a purely passive way" (Adamson 1987, Feist 1988)[33]. The house heats and cools itself, hence "passive". The principle behind a "passive house" is a dramatically increase in energy efficiency of a building in order to reduce investment. A passive house is cost-effective when the combined capitalized costs (construction, including design and installed equipment, plus operating costs for 30 years) do not exceed those of an average new home. **Table 4.17** and **Figure 4.21** shows some basic features that distinguish passive house construction.

32 http://www.energystar.gov/

33 http://www.passivehouse.com/

Table 4.17: Basic features that distinguish passive house construction

Compact form and good insulation:	All components of the exterior shell of the house are insulated to achieve a U-factor that does not exceed 0.15 W/(m²K).
Southern orientation and shade considerations:	Passive use of solar energy is a significant factor in passive house design.
Energy-efficient window glazing and frames:	Windows (glazing and frames, combined) should have U-factors not exceeding 0.80 W/(m²K), with solar heat-gain coefficients around 50%.
Building envelope air-tightness:	Air leakage through unsealed joints must be less than 0.6 times the house volume per hour.
Passive preheating of fresh air:	Fresh air may be brought into the house through underground ducts that exchange heat with the soil. This preheats fresh air to a temperature above 5°C, even on cold winter days.
Highly efficient heat recovery from exhaust air using an air-to-air heat exchanger:	Most of the perceptible heat in the exhaust air is transferred to the incoming fresh air (heat recovery rate over 80%).
Hot water supply using regenerative energy sources:	Solar collectors or heat pumps provide energy for hot water.
Energy-saving household appliances:	Low energy refrigerators, stoves, freezers, lamps, washers, dryers, etc. are indispensable in a passive house.

Source: http://www.passivehouse.com/

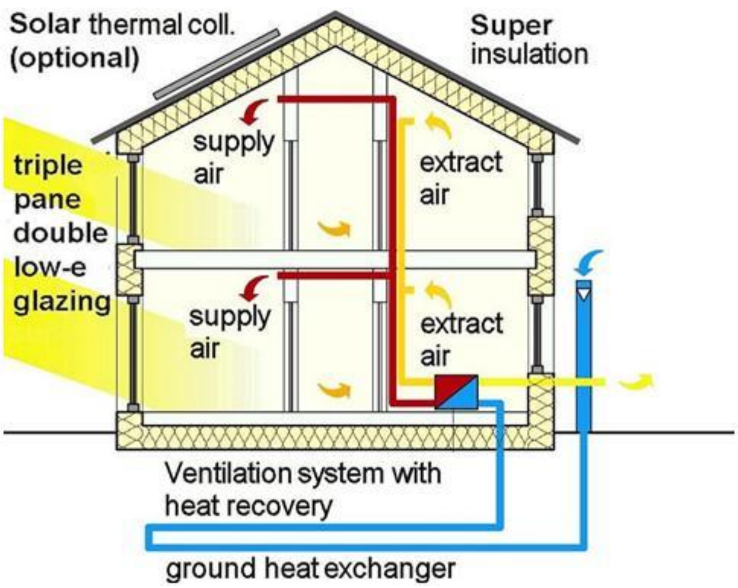


Figure 4.21: Basic features that distinguish passive house construction

For European passive construction, a limited heating energy demand of less than 15 kWh/m² per annum must be satisfied. The combined primary energy consumption of a European passive house may not exceed 120 kWh/m² per annum for space heating, domestic hot water (DHW) and all other electrical equipment combined.

The last ten years has seen increasing interest in North and Central Europe in the "Passive house" construction. In 2005, a project was launched for promotion of "passive houses" in warm climates, called *Passive-On*, which funded within the Intelligent Energy for Europe SAVE programme. The *Passive-On* project examined how to take the "passive house" concept forward, especially in Southern Europe. In these regions the problem of household energy use is to provide warm houses in winter and also (and in some cases more importantly) to provide cool houses in summer. The *Passive-On* consortium formulated six points that define the "passive house" standards for warm European climates:

- Heating criterion: The useful energy demand for space heating does not exceed 15 kWh per m^2 net habitable floor area per annum.
- Cooling criterion: The useful, sensible energy demand for space cooling does not exceed 15 kWh per m^2 net habitable floor area per annum.
- Primary energy criterion: The primary energy demand for all energy services, including heating, domestic hot water, auxiliary and household electricity, does not exceed 120 kWh per m^2 net habitable floor area per annum.
- Air tightness: If good indoor air quality and high thermal comfort are achieved by means of a mechanical ventilation system, the building envelope should have a pressurization test (50 Pa) result according to EN 13829 of no more than 0.6 ach^{-1}. For locations with winter design ambient temperatures above 0 °C, a pressurization test result of 1.0 h^{-1} is usually sufficient to achieve the heating criterion.
- Comfort criterion room temperature winter: The operative room temperatures can be kept above 20 °C in winter, using the above mentioned amount of energy.
- Comfort criterion room temperature summer: In warm and hot seasons, operative room temperatures remain within the comfort range defined in EN 15251. Furthermore, if an active cooling system is the major cooling device, the operative room temperature can be kept below 26 °C.

The cost of the proposed "passive house" was also investigated through the *Passive-On* project. **Figure 4.22** shows the lifecycle costs associated with additional passive measures to reduce heating and cooling energy use in standard houses in different European countries.

		France	Germany	Italy	Spain Granada	Spain Seville	UK
Extra Capital Costs (€/m²)		103	94	60	24,1	20,5	73
Extra Capital Costs (%)		9%	6,71%	5%	3,35%	2,85%	5,54%
Total Energy Savings (kWh/m²/year)		55	75,0	86,0	65,5	37,6	39,7
Total Energy Savings (%)		45%	50,0%	65,4%	57,3%	40,7%	26,4%
Extra Costs per saved kWh/m²/year		1,87	1,25	0,70	0,37	0,55	1,84
LCC 10 years €	Standard	143.731	184.716	193.817	101.828	98.385	108.337
	Passive	152.621	190.104	190.437	95.676	96.100	111.988
LCC 20 years €	Standard	160.343	204.942	221.148	117.928	108.689	117.875
	Passive	160.552	200.579	198.458	103.647	102.290	117.256
Cost-Benefit Ratio, 10 years		-0,72	-0,48	0,39	2,13	0,93	-0,65
Cost-Benefit Ratio, 20 years		0,02	0,39	2,63	4,94	2,60	0,11
Discounted Payback Period (years)		19.5	19	8	4	5	19

Figure 4.22: Lifecycle costs of additional passive measures

Source: Passive-On project

The payback period varies from 4 – 19 years for different countries. Most important is that payback period is much lower for countries of south Europe. This is an indication that additional investment can be regarded as very worthwhile.

In a country that had no building codes until now (like Cyprus), it is difficult to introduce at once a concept like "passive house". But as a concept, it is worthwhile to start consider ways to introduce it in the near future (financial incentives, information, regulation, etc.).

CHAPTER 5: RECOMMENDED POLICIES AND CONCLUSIONS

5 RECOMMENDED POLICIES AND CONCLUSIONS

The building sector belongs to a complex commercial chain, involving a wide range of stakeholders, an extended life cycle of products and user preferences implications, making it one of the most complex environmental policy target groups (UNEP 2007). **Figure 5.1** illustrates the most significant commercial relationships in the building supply chain. This complex interaction among several stakeholders constitutes one of the greatest barriers to energy efficient measures for buildings.

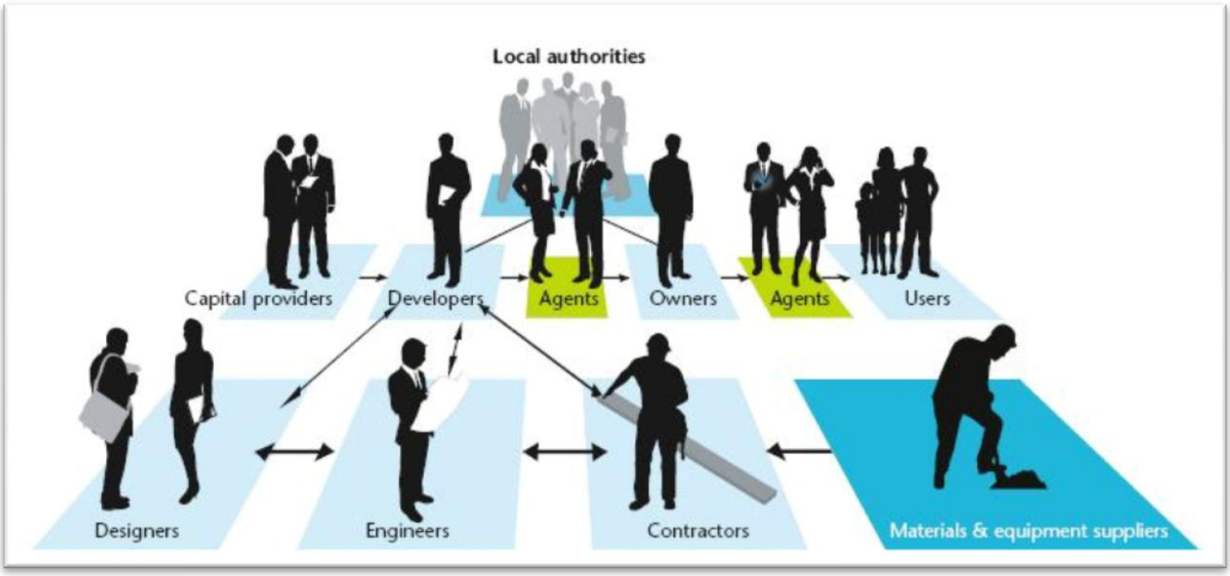


Figure 5.1: The complex commercial chain of the building sector

Source: World Business Council for Sustainable Development (WBCSD)

This chapter presents recommendations on policy measures aiming at improving the residential energy consumption by promoting energy efficiency measures in buildings of Cyprus. The propose policies are mainly market-oriented approaches but also legislative measures. The majority of the propose policies can be also apply to other sectors (industry, tertiary, etc.). This chapter also explores barriers discouraging stakeholders to pursue energy efficiency.

5.1 Overview of energy policies and measures (P&M's)

Policies proposed should be in accordance with the three main targets of EU energy policy (Oikonomou and Patel, 2004):

- Liberalization from the monopolistic states of the electricity markets, while in parallel, to secure the supply for the coverage of needs.

- EU's obligation towards the Kyoto Protocol[34], which requires the reduction of the GHG emissions at a rate of 8% by 2010 compared to the base year 1990.
- Promotion of renewable energy into the energy markets, with a quantitative aim of doubling the EU share of Renewable Energy supplies in gross inland consumption by 2010.

The liberalization of the energy markets in the EU has shifted policies from legislative and regulatory measures (command and control approaches) to market-oriented policy measures. Regulatory approaches are still effective in many cases and can coexist with market-oriented measures.

Oikonomou and Patel (2004) divided the policy measures into four main categories depending on their market approach and the participant's actions required:

- Financial measures, which may include subsidies, grants and taxes;
- Legal or regulatory instruments (e.g. building codes and standards);
- Organizational measures that mainly include the negotiated and voluntary agreements;
- Certificates or the marketable (tradable) permits/quotas (e.g. white and green certificates, emission trading scheme)

Policy measures include also Research and Development (R&D) and measures of awareness, information and communication. **Figure 5.2** puts in order these categories and some of the representatives to an organizing principle.

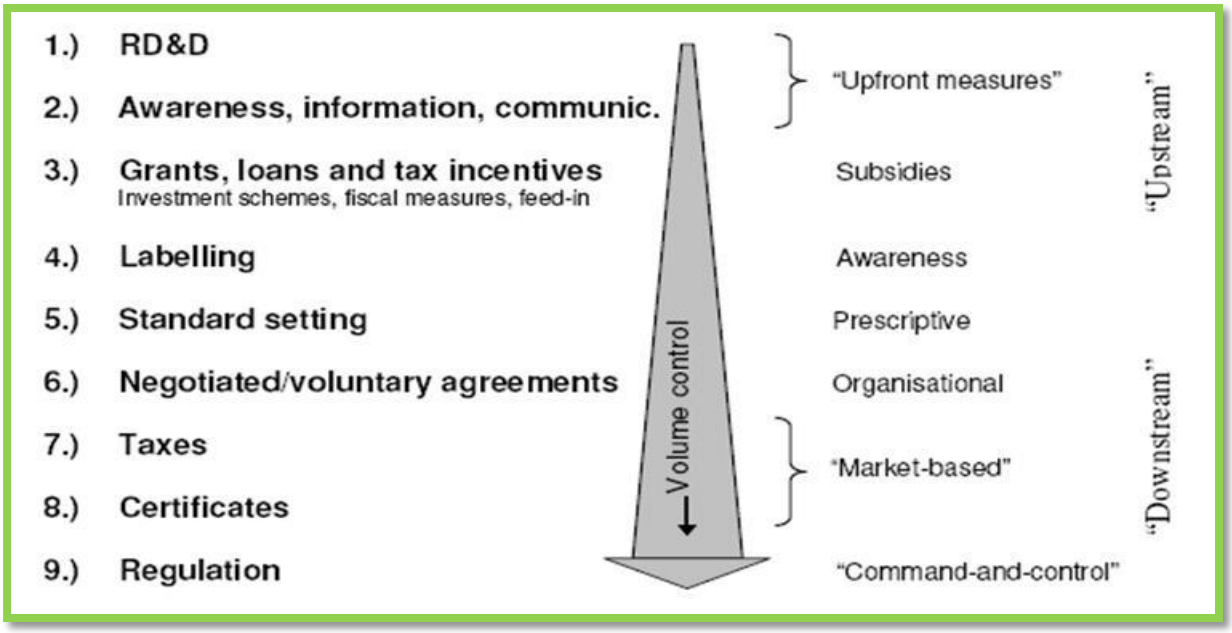


Figure 5.2: Archetypes of policies and measures for energy efficiency improvement

Source: Oikonomou and Patel (2004)

[34] Cyprus has ratified the Kyoto protocol on 16/7/1999 but has no emissions limitation commitments. Despite this the country fully supports the European Commission in leading all 27 member states towards ambitious reductions in greenhouse gas emissions.

5.2 Existing energy policies and targets in Cyprus

Existing energy policies are presented in **Paragraph 2.6.2**. Cyprus is perhaps the only Member State which had not any energy performance regulations (building codes, minimum efficiency standards for equipment, etc.) until recently (December, 2007). The main existing policies for producing energy efficiency measures in the residential sector is the energy performance regulations for new and existing buildings and a financial support scheme providing grants and subsidies for energy savings and RES investments in the building sector. The existing policies (financial support scheme) are not functioning successfully for two major reasons: the procedures are time consuming due to bureaucracy and the level of subsidies is low.

Cyprus has adopted an energy savings target of 10% of average final consumption, which corresponds to 185 000 toe by 2016. The intermediate target is 60 000 toe by 2010.

5.3 Barriers to energy efficiency improvements in buildings

There are a number of barriers to the introduction of energy efficiency improvements in buildings. **Table 5.1** shows major barriers to energy efficiency in the building sector together with some examples of each barrier (Koeppel and Ürge-Vorsatz, 2007).

Table 5.1: Major barriers to energy efficiency in the buildings sector

Barrier categories	Definition	Examples
Economic/financial barriers	Ratio of investment cost to value of energy savings	• Higher up-front costs for more efficient equipment • Lack of access to financing • Energy subsidies
Hidden costs/benefits	Cost or risks (real or perceived) that are not captured directly in financial flows	• Costs and risks due to potential incompatibilities, performance risks, transaction costs etc.
Market failures	Market structures and constraints that prevent a consistent trade-off between specific energy efficient investment and energy saving benefits	• Limitations of the typical building design process • Fragmented market structure • Landlord/tenant split and misplaced incentives • Imperfect information
Behavioural and organizational barriers	Behavioural characteristics of individuals and companies that hinder energy efficiency technologies and practices	• Tendency to ignore small energy saving opportunities • Organizational failures (e.g. internal split incentives) • Tradition, behaviour and lifestyle, corruption

Information barriers	Lack of information provided on energy saving potentials	• Lacking awareness of consumers, building managers, construction companies, politicians
Political and structural barriers	Structural characteristics of the political, economic, energy system which make energy efficiency investment difficult	• Process of drafting local legislation is slow • Gaps between regions at different economic level • Insufficient enforcement of standards • Lack of detailed guidelines, tools and experts • Lack of incentives for energy efficiency investments • Lack of governance leadership/ interest • Lack of equipment testing/ certification • Inadequate energy service levels

Source: Koeppel and Ürge-Vorsatz (2007) based on Carbon Trust (2005) and IPCC (2007)

5.4 Proposed energy policies and measures

5.4.1 Energy performance of buildings regulations

Recently (December 2002) the European Directive of Energy performance of buildings came into force (EPBD). In the European Union, all member states apply energy regulations to buildings. A study by Beerepout (2007) on energy regulations for residential buildings in 11 European member states distinguishes four main energy regulation categories (**Figure 5.3**).

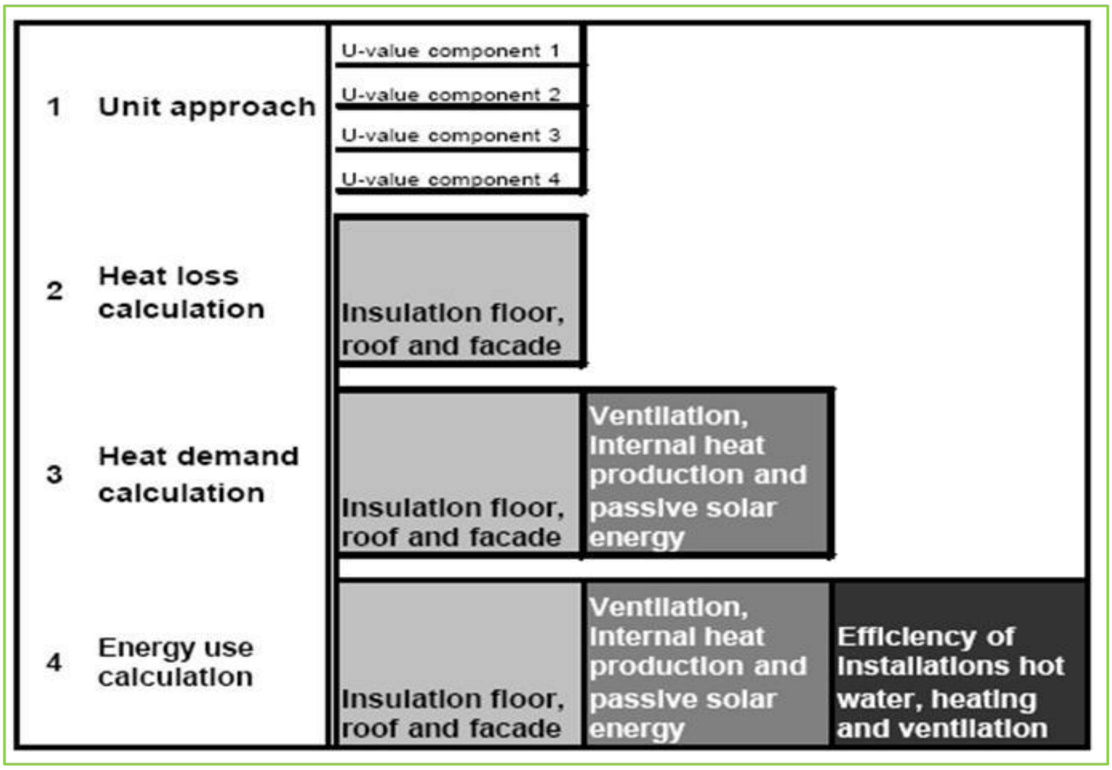


Figure 5.3: Framework for categorising energy regulations

Source: Beerepoot (2007)

The first category of regulations, the "unit approach", focuses exclusively on the transmission of heat through the individual components of the building envelope. The second category, the "heat loss calculation", calculates a single value for heat transmission, using the entire building envelope instead of separate building components. The third category, the "heat demand calculation", require a calculation based on identifying heat loss, by considering transmission and ventilation losses, and heat gain, by means of passive solar energy and internal gains, resulting in the heat demand of a building. The fourth category, the "energy use calculation", require the most complex calculation based on calculating heat demand and combining that with energy supply features, resulting in an estimate of the actual energy use of a building by building-related features (Beerepoot, 2007).

Cyprus recent legislation on energy performance of buildings can be categorized as a "unit approach" by introducing minimum performance requirements for building components such as walls insulation, windows, roof and floor insulation (see **Table 4.1**). Since it is the first attempt of introducing standards into the building sector, this approach can be characterized as a satisfactory first step. The values (U-values) introduced for building components by the new law for energy performance of buildings could be more stringent. **Table 5.2** shows the recommended U-values. An incremental standard-setting approach is also recommended to be followed. This means a regularly update of minimum performance requirements for building components (no more than 3 years).

Table 5.2: Recommended U-values for different building components

Building element	Recommended maximum U-values[35] by this thesis [W/m^{2}K]	Maximum U-value after the introduction of the law [W/m^{2}K]
Walls	0.60	0.85
Roof	0.50	0.75
Floor	0.50	0.75
Windows	2.80	3.80

It is recommended that in the near future, a shift from prescriptive standards (or "unit approach") to performance-based standards (e.g. "energy use calculation" approach). The advantage of performance standards is that they offer more cost-effective solutions than prescriptive standards.

Two examples of the "energy use calculation" approach are the Dutch and French energy performance regulations. Dutch energy performance method which includes in the calculation method, even more aspects (e.g. "cooling" and "lighting") than those mentioned in the EU directive. An important feature of this method is that it stipulates the use of "green" electricity (photovoltaic energy systems), by allowing the extraction of "green" from the "grey" electricity calculated in the energy performance calculation. The output of an energy performance calculation is an energy performance coefficient (EPC, a non-dimensional figure that expresses the energy efficiency of a building). The EPC is calculated by comparing the

[35] Estimated average valued of warm southern climatic zone.

characteristic energy use of a building to the standardized energy use (depends on the size and shape of the building) (Beerepoot, 2007).

The second example is from France, where energy regulations require an energy performance standard for buildings and a standard for thermal comfort in summer (Beerepoot, 2007). This example may be more appropriate for Cyprus, since the island belongs to the countries of southern Europe where the energy demand for space cooling is more imperative than energy demand for space heating.

In order to achieve positive results on energy savings in buildings not only legislative policies (energy performance standards) should be applied but a combination of information (or communication), fiscal and regulatory policies. **Figure 5.4** shows the interrelation between those three policy instruments in the framework of EPBD.

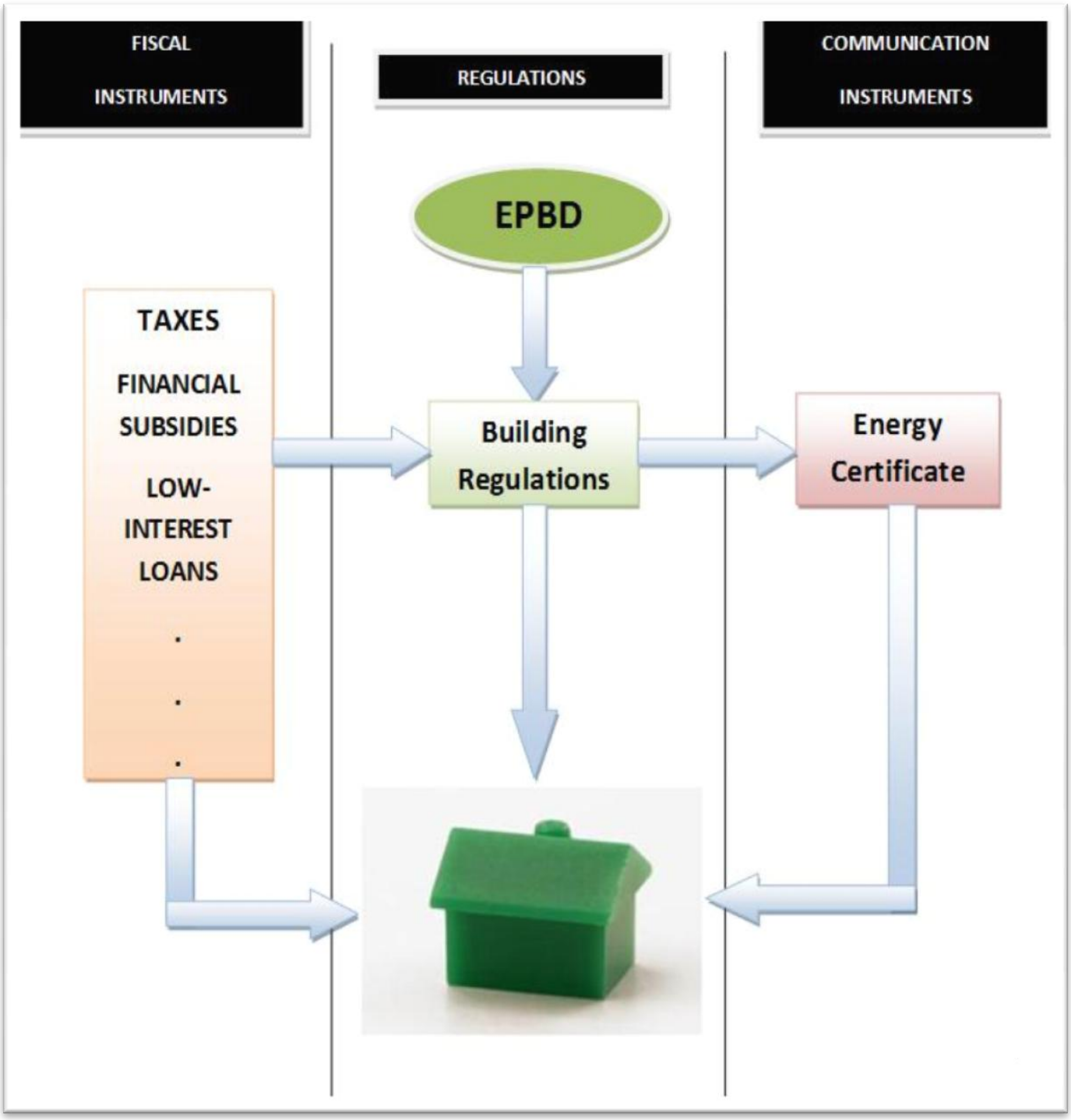


Figure 5.4: Interrelation of policy instruments in the context of EPBD

Financial measures give the opportunities to households and the housing companies (construction or selling) to improve the energy efficiency of the buildings by lower the initial costs and shortening the payback period. As already mentioned, Cyprus government operates a financial support scheme, providing grants and subsidies for energy savings and RES investments in the building sector with not great success. The financial support scheme is therefore recommended to be revised and transform it to an attractive measure by increasing grants and subsidies and change the procedures to less time-consuming processes. The financial support scheme should not only allocate a fixed subsidy per selected measure but also to stimulate investments of high energy efficiency (e.g. low-energy houses, "passive houses") by providing extra subsidies to such investments. The financial support scheme should be accompanied with a proper information campaign, since frequently the target groups of those measures (e.g. low-income households) are not taking advantage of them because they are unaware of their existence. This information campaigns need a periodic reinforcement otherwise slack practices infiltrate and diminish the impact.

It is recommended that investments dedicated to improve rational use of energy of the building sector to be entitled to tax deductions (reduction in VAT rate). Such investments could be: the replacement of old boilers (more than 20 years) by new more efficient ones (e.g. condensing boilers), the installation of double glazing, roof and wall insulations of existing dwellings, the installation of a central heating regulator and also energy audits.

Another policy measure that is recommended is the introduction of the *soft loans* instrument. Soft loans are loans offered at subsidised interest rates (i.e. lower than the market rate) to consumers who invest in energy efficient technologies. Soft loan scheme is a measure targeted at consumers.

According to EPBD all building constructions, sell and rental constructions will have to be accompanied by an energy performance certificate that is no more than ten years old. The energy performance certificate should operate as an incentive for Cyprus government to introduce a labelling system. As an instrument, the energy label increases the awareness about the energy consumption of a building.

5.4.2 Investments schemes / fiscal measures for electrical appliances

The goal is the replacement of outdated appliances (more than 10 years old) with new ones at the top levels of efficiency and performances. The focus should be on refrigeration, washing machine appliances and air conditioners.

It is recommended cash rebates to consumers purchasing higher energy efficient domestic appliances (e.g. washing machines being Class A and higher). Through this financial measure, subsidies are given to the price of the energy efficiency appliance, lowering the cost of purchase of the product to the consumer, since higher energy efficient appliances are in general more expensive than appliances of lower energy efficiency.

A significant case-history of a successful programme in Europe, aimed at achieving a permanent transformation of the market is the Energy Premium Scheme (EPR) for domestic appliances in the Netherlands (Ceced, 2005). The EPR works like this: the consumer buys an energy-efficient appliance in a shop or by mail order. In the shop, the consumer can get a form (or order the form from a utility), which, when completed and sent in with a proof of purchase, results in a rebate payment by the utility. The rebate for appliances was set at €45–50 for most A-rated appliances and €100 for better than A-rated appliances, with the exception of A-rated clothes dryers and washer-dryers, for which a higher rebate applied. The effects were impressive. In the first year of the scheme (2000), more than 50% of the sold washing machines and dishwashers were A-rated products. This statistic increased further in 2001, when the market share for A-rated washing machines rose to 88% (Wiel and McMahon, 2005).

A measure like this needs also an extensive informative campaign aiming the information of consumers. An information campaign could include advertisements in TV, advertisements in national newspapers and magazines, and information on local media (radio, TV, newspapers, magazines).

This measure could turn to be very costly. The funds for the cash rebates to the customers could be raised through an energy tax (see **Paragraph 5.4.3** about energy taxes).

5.4.3 Energy Tax

The energy tax should be focus on small-scale energy consumption users: households and small commercial establishments. These are target groups, which are difficult to reach with policy instruments such as long-term agreements or environmental permits. The energy distribution companies (at the moment the only electricity distribution company in Cyprus is Electricity Authority of Cyprus, but this is expected to change in near future) are usually paying this tax, which in turn they charge their customers for it.

The purpose of energy tax is not to raise overall government income but to raise the awareness of households and small commercial establishments to improve residential and commercial energy efficiency. So the revenues from the energy tax should be integrally recycled by lowering other taxes. The recycling of the revenues is crucial for the social acceptance of the energy tax and the tax reform. The raised funds from the energy tax could be use as financial incentives in other energy efficiency policies too.

The meaning of this measure is that tax rate should only apply to the so-called “avoidable” consumption. Since in practice is impossible to determine the amount of “unavoidable” consumption of each taxpayer, a tax allowance must be introduced. It is recommended that a tax allowance at 800 kWh of electricity should be introduced. Customers using “green” electricity should entitle an exception from this tax. By this way, a promotion of renewable energy could also be achieved. This is a measure (energy tax) that can be introduced also to oil-products distribution companies.

5.4.4 Energy Service Company – ESCO

Energy service companies (ESCO's) are important agents to promote energy efficiency improvements. In Europe, ESCO's have been operational on a large scale since the late 1980s early 1990s. ESCO's usually offer the following services (WEC, 2008):

- Development and design of energy efficiency projects;
- Installation and maintenance of energy efficient equipment involved;
- Measurement, monitoring and verification of the project's energy savings.

The difference of ESCO's from other companies offer energy efficiency (e.g. consulting firms and equipment contractors) is the concept of performance-based contracting. Energy Performance Contracting (EPC) is a form of "creative financing" for capital improvement which allows funding energy efficiency upgrades from cost reductions (**Figure 5.5**). The approach is based on the transfer of technical risks from the client to the ESCO based on performance guarantees given by the ESCO (Bertoldi and Rezessy, 2005).

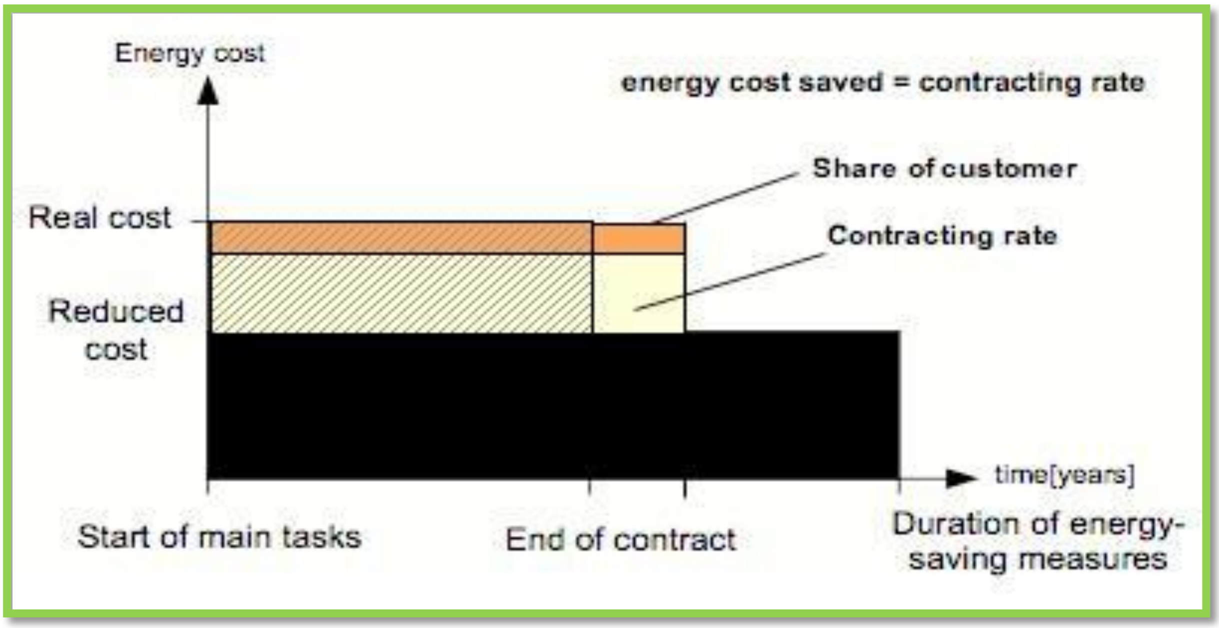


Figure 5.5: Energy Performance Contract (EPC) - General idea

Source: Berlin Energy Agency[36]

There are two common models of performance contracting: the guaranteed savings model, where the ESCO guarantees a certain level of energy savings to the customer and the shared savings model (**Figure 5.6**), where the cost savings are shared by the ESCO and the client at a prearranged percentage for a fixed number of years.

[36] http://www.berliner-e-agentur.de/

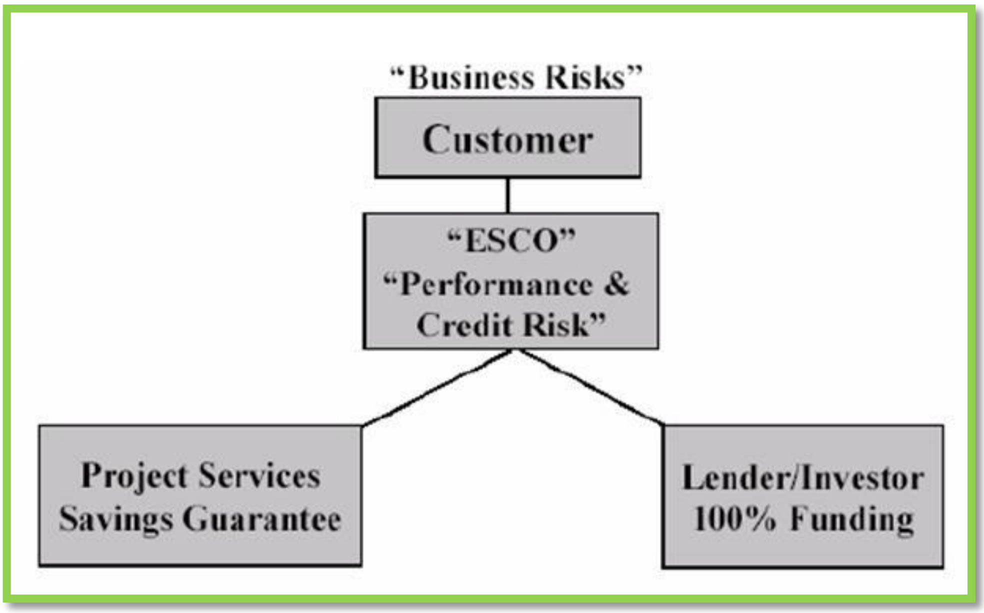


Figure 5.6: Performance contract model (shared savings)

Source: Dreessen 2003, adapted by Bertoldi and Rezessy (2005)

The financing part of the energy efficient investment can either be provided by the internal funds of the ESCO or by the customer, or by a third party funding (TPF), in which a financial institution allows a credit either to the ESCO (**Figure 5.7**) or directly to its client.

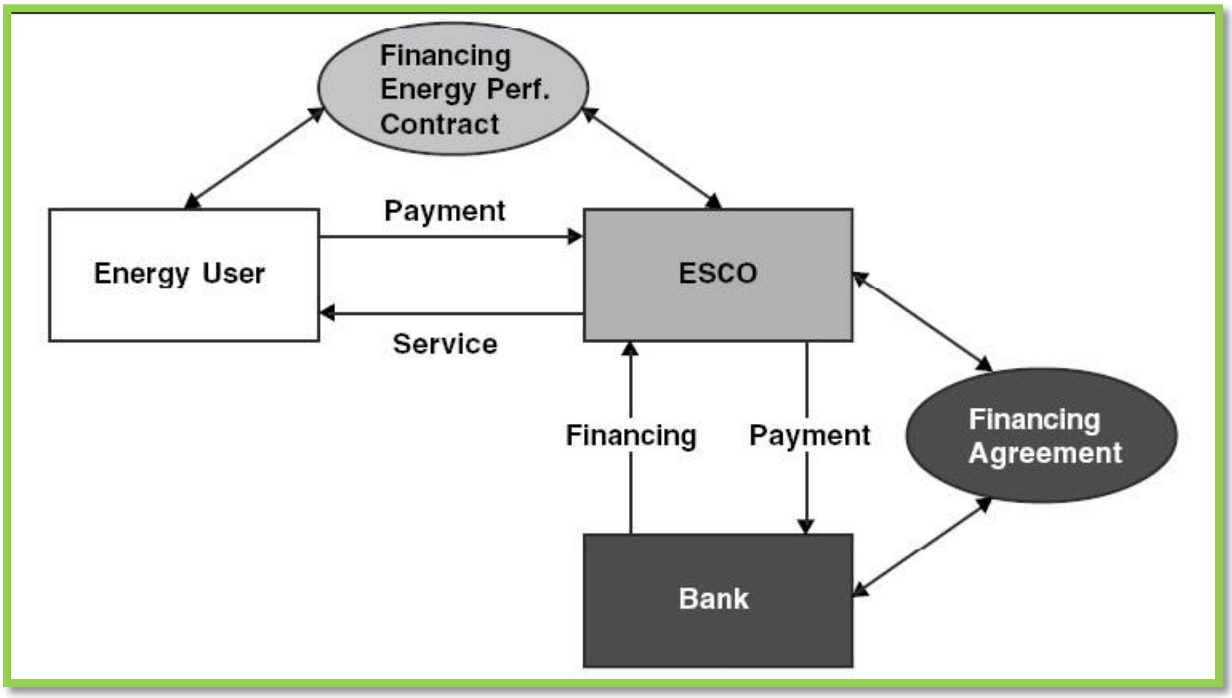


Figure 5.7: Mode of operation of ESCO's

Source: WEC, 2008

For the design of an ESCO in Cyprus, it is proposed that an entity with quasi-public body nature should be created. ESCO of this nature can use a variety of means of delivering the services which they have been set up to perform, including contracting with the private sector (e.g. banks, energy efficient equipment suppliers). The financing type that is proposed is by a third party funding (TPF), where the ESCO being the borrower of the financial resources needed for project implementation. Under this ESCO model a third party financier provides the necessary project financing to the ESCO via a loan contract, the ESCO provides the service via a performance contract, the customer pays the ESCO if the project meets its performance standards, and the ESCO repays the bank for the project loan (see **Figure 5.7**).

The recommended performance contract model is the shared savings contract, where the cost savings are split for a predetermined length of time in accordance with a prearranged percentage. The percentage division is dependent by the cost of project, length of contract and risk accountability. The shared savings concept is a good introductory model in new markets because customers assume no financial risk.

5.4.5 Other proposed policies and measures

In this section four preliminary policies and measures are proposed that can contribute to energy efficiency improvements in the building sector. These are:

1. Development of a national website which will give the consumers access to information about how their homes or businesses use energy, what energy-saving opportunities are available, and which products are energy-efficient and cost-effective choices. Some good website examples are:

- http://www.energystar.gov/, a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy.
- http://www.sei.ie/index.asp, Sustainable Energy Ireland (SEI), Ireland's national energy agency.

2. An "energy education" exercise should be established and coordinated, starting from elementary and secondary schooling and long-lasting to professional and technical training for those whose jobs involves energy-related issues. The education should include a basic understanding of how energy is used, the economic, environmental and social costs of energy production and use, and the main opportunities to improve energy efficiency.

3. More involvement to networks and joint projects supported by the European Community and International Agencies. Some examples are:

- **E^{n}R** is a voluntary network currently numbering twenty three European energy agencies, with responsibility for the planning, management or review of national research, development, demonstration or dissemination programmes in the fields of energy efficiency and renewable energy and climate change abatement.
  http://www.enr-network.org
- **Energie-Cités** is the association of European local authorities for the promotion of local sustainable energy policies.
  http://www.energie-cites.eu/
- **Sustainable Energy Europe Campaign** is a European Commission initiative in the framework of the Intelligent Energy - Europe (IEE) programme, which aims to raise public awareness and promote sustainable energy production and use among individuals

and organisations, private companies and public authorities, professional and energy agencies, industry associations and NGOs across Europe.
http://www.sustenergy.org

4. Finally, a development of a national programme is recommended to promote experimental low-energy building projects in order to demonstrate sustainable and low-energy building (R&D policy measure).

5.5 Policies to be considered in the future

In the near future a liberalization of the energy market of Cyprus is expected and also an increasing contribution of RES to electricity production (6% of the total electricity production until 2010). Based on those two trends, this section describes briefly two policies which could be introduced in the energy policy framework of Cyprus in the future.

Recently, there is an increasing attention of policy makers throughout Europe, in introducing energy savings obligations on certain types of market players coupled with tradable certificates for energy savings (TCES). Under this market based mechanism fall the White and Green Certificates.

5.5.1 White Certificates scheme

White Certificates (WhC) is a relatively new policy instrument to increase energy efficiency using market-based mechanisms. The basic principle of this policy measure is that the authorities impose energy efficiency obligations on power suppliers (hence the necessity of liberalization of energy market), which can then decide whether to implement energy efficiency measures themselves or to buy WhC, depending on their marginal costs (Oikonomou et al., 2007).

The key stakeholders that play the role in this new market concept are: regulatory authority, suppliers and/or distributors of electricity (or gas), ESCO's, households and brokers (see **Figure 5.8**).

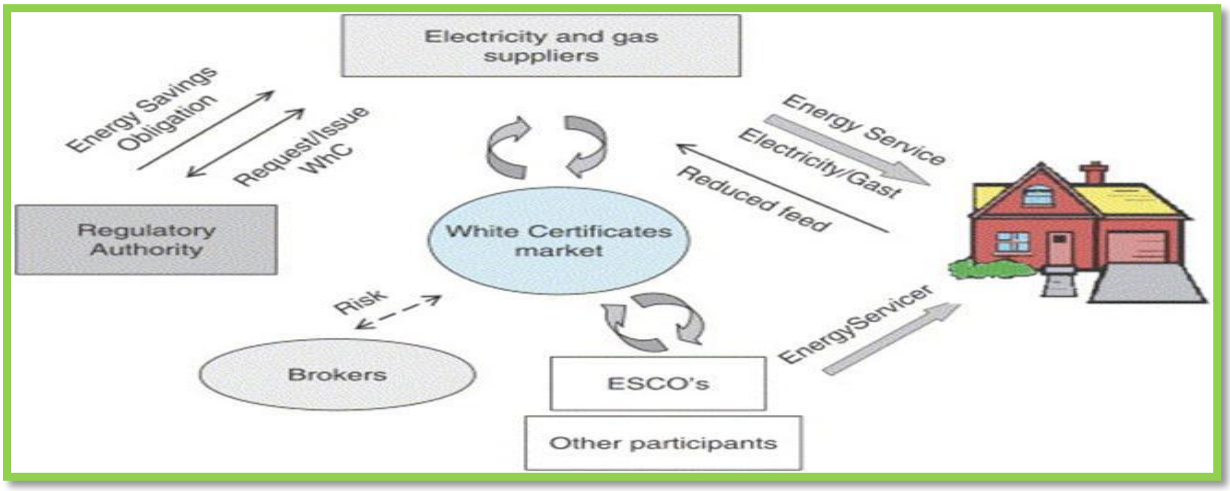


Figure 5.8: White certificate energy market

Source: Oikonomou et al. (2007)

5.5.2 Green Certificates scheme

Tradable Green Certificate (TGC) is a new market-based, cost-efficient instrument to regulate the use of renewable energy. The purpose of these certificates is to guarantee that a specific volume of electricity is generated from RES.

In principle, TGC schemes work as follows: a quantified obligation (quota) is imposed on one category of electricity system operators (generators, producers, wholesalers, retailers, or consumers) to supply or consume a certain percentage of electricity from renewable sources. On a settlement date, the operators must submit the required number of certificates to demonstrate compliance. Certificates can be obtained in one of the following ways. First, operators can own their own RE generation, and each defined amount of energy (e.g., each 100 KWh) produced by these facilities would represent a certificate. Second, operators can purchase electricity and associated certificates from eligible renewable electricity generators. Third, operators can purchase certificates without purchasing the actual power from a generator or trader or via a broker, i.e. certificates that are traded independent from the power itself (Bertoldi and Huld, 2006; Bertoldi and Rezessy, 2006).

Figure 5.9 shows the operational logic of TGC schemes. The owner of the certificate can redeem it to meet its obligations or to get tax incentives that authorities may pay to power producers for development of additional RES generation capacity (Bertoldi and Rezessy, 2006).

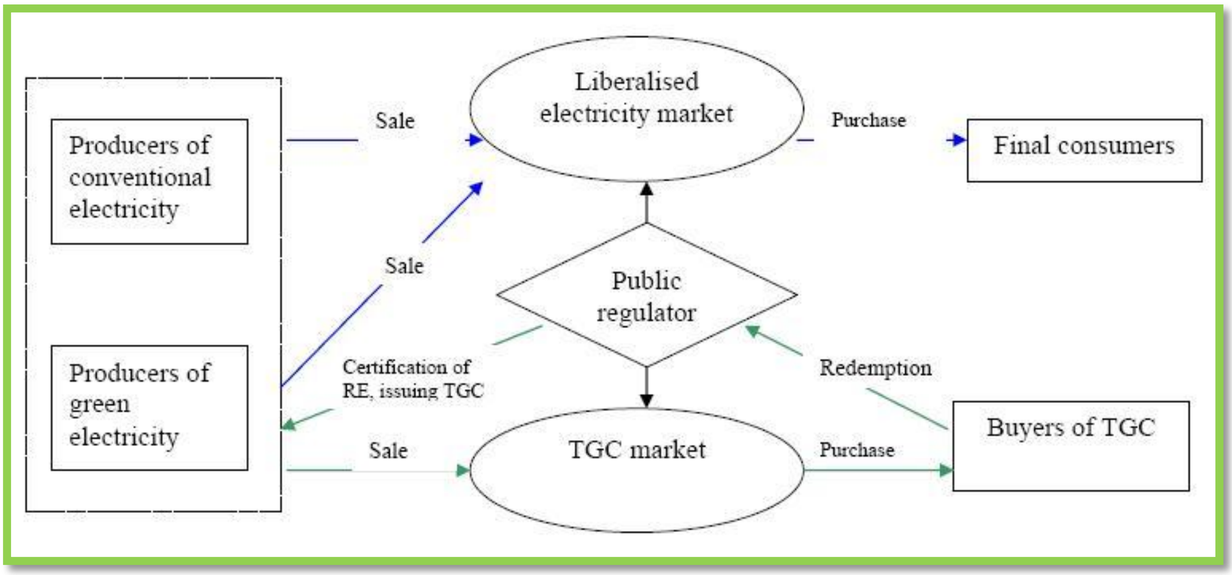


Figure 5.9: Tradable green certificate markets

Source: Bertoldi and Rezessy, (2006)

5.6 Conclusions

The building sector belongs to one of the most complex environmental policy target groups. Cyprus, in the case of energy policy measures, is still in the infancy period. Prior to the accession in European Union (2004), Cyprus did not have a comprehensive energy efficiency policy, with national legislation, building regulations with energy requirements, targets and other such facets. For those reasons, a vigilant and detail plan of energy policies and measures should be implemented for maximum benefits.

The introduction of EU Directives to Cyprus legislative system (e.g. energy performance of buildings directive) could make a big contribution to energy saving and could lead also to many other benefits for the economy and employment. Cyprus government should give great importance to energy savings and energy efficiency programmes as a means to achieve energy policy objectives because of its national peculiarities (small and isolated grid system, without interconnections to European or other energy networks).

After studying the energy situation of the residential sector of Cyprus, a set of policies and measures for energy efficiency improvements and energy savings are recommended. **Table 5.3** summarizes these policies and measures.

Table 5.3: Recommended energy efficiency policies and measures

RECOMMENDED ENERGY EFFICIENCY POLICIES AND MEASURES		
Policy Instrument	**Scope**	**Details**
Regulatory instrument	**Energy performance of buildings regulations**	• More stringent U-values for building components • Regularly update of minimum performance requirements for building components • Shift from prescriptive to performance-based standards
Fiscal measures		• Revised of the present financial support scheme • Fixed subsidy per selected measure • Extra subsidies for high energy efficiency investments • Tax deductions for investments dedicated to improve rational use of energy of the building sector • Soft loans to consumers who invest in energy efficient technologies
Awareness, information and communication		• Energy performance certificate (introduce of a labelling system)
Fiscal measures	**Electrical appliances**	• Cash rebates
Fiscal measures	**Energy efficiency measures**	• Energy Tax
Policy tool		• Energy Service Company (ESCO)
Awareness, information and communication		• Development of a national energy website • “Energy education” • Involvement to networks and joint projects supported by the European Community and International Agencies
R&D instrument		• Experimental low-energy building projects
POLICIES FOR FUTURE CONSIDERATION		
Certificates or the marketable (tradable) permits/quotas	**Energy efficiency measures**	• White certificate scheme • Green certificate scheme

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APPENDICES

APPENDIX A: HOUSEHOLD ENERGY QUESTIONNAIRE

Appendix A: Household Energy Questionnaire

PART A: HOUSEHOLD DETAILS

1. Location?
   Post code: _________
2. What type of building do you live in?
   ☐ Single family house
   ☐ Apartment
3. When was your house built in the following construction periods?
   Pre-1960 ☐
   1960-1990 ☐
   1990 onwards ☐
4. How many persons live in the household in the following age groups?
   Age 12 and less: ________
   Age from 13 to 18: ________
   Age from 19 to 69: ________
   Age more than 65: _________
5. What is the highest education level in the household?

6. What is your total housing area (floor area) in square meters?
   ☐ m^2
7. How many rooms (total) exist in your house?
   ☐
8. What is your status of residence?
   ☐ Ownership
   ☐ Rental
9. How much is your household income per annum?
   Less than 20000 Euros: ☐
   20000 - 30000 Euros: ☐
   30000 - 40000 Euros: ☐
   More than 40000 Euros: ☐
10. **What was your electricity consumption invoiced by electricity company for a month?**
    In Euros:
    Summer: ________
    Winter: _________
    In kWh (if known):
    Summer: _________
    Winter: __________

PART B: WATER HEATING

1. What to you use for water heating?
   Electric heater:
   Solar heater:
   Other (please specify): ________________
   If you use electric heater, how many hours per day is turn on?
2. How many showers (total) you do per day?
3. Do you have solar collectors?
   Yes
   No
   If yes please answer the following questions about solar collectors (if known):
   How many square meters the collectors are? m^2
   Do you know the efficiency of the collectors? No, Yes
   Are you satisfied with the operation of the collectors? No, Yes
   Do you know if you save energy and how much? No, Yes

PART C: HEATING/COOLING FACILITIES

1. What device(s) do you use for heating the space?
   Central heating
   Split units
   Gas stoves
   Kerosene stoves
   Electric heaters
   Fireplace
   Other (please specify): ________________________________
   None
2. What device(s) do you use for cooling the space?
   Central air-condition
   Room air-condition (split units)
   Number of a/c
   Energy class (A++, A+, A, B, C, D, E, F, G, Not known)
   Other (please specify): _______________________________
   None

PART D: REFRIGERATION APPLIANCES

1. Do you have one or several refrigerators **with or without** a freezer compartment?
   Yes
   No
   If yes, please specify the age, the volume and the energy class if known:
   1) Age: Less than 5 years , Between 6 and 10 , More than 10
      Volume (in liters):
      Energy class (A++, A+, A, B, C, D, E, F, G, Not known):

2) Age: Less than 5 years , Between 6 and 10 , More than 10
Volume (in liters):
Energy class (A++, A+, A, B, C, D, E, F, G, Not known):

3) Age: Less than 5 years , Between 6 and 10 , More than 10
Volume (in liters):
Energy class (A++, A+, A, B, C, D, E, F, G, Not known):

2. Do you have one or several freezer(s)?
Yes
No
If yes, please specify the age, the volume and the energy class if known:
1) Age: Less than 5 years , Between 6 and 10 , More than 10
Volume (in liters):
Energy class (A++, A+, A, B, C, D, E, F, G, Not known):
2) Age: Less than 5 years , Between 6 and 10 , More than 10
Volume (in liters):
Energy class (A++, A+, A, B, C, D, E, F, G, Not known):
3) Age: Less than 5 years , Between 6 and 10 , More than 10
Volume (in liters):
Energy class (A++, A+, A, B, C, D, E, F, G, Not known):

PART E: WASHING/DRYING APPLIANCES

1. A. Have you got a washing machine?
Yes
No
If yes, please specify the age, the capacity and the energy class if known:
Age: Less than 5 years , Between 6 and 10 , More than 10
Capacity (in kg):
Energy class (A, B, C, D, E, F, G, Not known):

B. How many times per week do you usually use it?

2. A. Have you got a drying machine?
Yes
No
If yes, please specify the age, the capacity and the energy class if known:
Age: Less than 5 years , Between 6 and 10 , More than 10
Capacity (in kg):
Energy class (A, B, C, D, E, F, G, Not known):

B. How many times per week do you usually use it?

3. A. Have you got a dish washer?
Yes
No
If yes, please specify the age and the energy class if known:

Age: Less than 5 years ☐ , Between 6 and 10 ☐ , More than 10 ☐
Energy class (A, B, C, D, E, F, G, Not known): ☐

B. How many times per week do you usually use it? ☐

PART F: EQUIPMENTS/APPLIANCES

1. Please fill what equipments you have in the house and an average time of use per day.

TV

Small TV (<21 in.): ☐ Average time of use per day (hours): ☐
Large TV: ☐ Average time of use per day (hours): ☐
Small LCD TV (<21 in.): ☐ Average time of use per day (hours): ☐
Large LCD TV: ☐ Average time of use per day (hours): ☐
Plasma TV: ☐ Average time of use per day (hours): ☐

Home cinema: ☐ Average time of use per day (hours): ☐

VHS recorder/player: ☐ Average time of use per day (hours): ☐

DVD recorder/player: ☐ Average time of use per day (hours): ☐

Hi-fi: ☐ Average time of use per day (hours): ☐

Video game: ☐ Average time of use per day (hours): ☐

Satellite box: ☐ Average time of use per day (hours): ☐

PC: ☐ Average time of use per day (hours): ☐

Laptop: ☐ Average time of use per day (hours): ☐

Coffee machine: ☐ Average time of use per day (hours): ☐

Other (please specify):

PART G: COOKING APPLIANCES

1. Please fill what cooking appliances you use.

Electric oven: ☐

Electric hobs: ☐

Gas hobs: ☐

Microwave: ☐

Toaster: ☐

Mixer: ☐

Other (please specify):

PART H: LIGHTING

1. Please specify the **number** of light bulbs of each type that you use.


Incandescent:


Low wattage halogen:


High wattage halogen (>70W):


Compact Fluorescent:

PART I: GENERAL POINTS

1. Please rank the following criteria from 1 to 6 according to their importance when you purchase a new domestic appliance (1: more important, 6: not important).
   - Price
   - Design/style
   - External dimensions
   - Capacity
   - Electricity consumption
   - Ease of use
2. Why do you think it is necessary to save electricity? (1: more important, 5: not important)
   - Financial savings
   - Depletion of energy supplies
   - Greenhouse effect/Global warming
   - War risk due to electricity crisis
   - Other (please specify)
3. Have you heard about electricity savings from any of the following sources?
   - TV
   - Magazine/Newspaper
   - School
   - Internet
   - Radio
   - Conference
   - Work
   - Friends/family
   - Other

4. Have you ever consider to save energy and how?

5. Do you use photovoltaics?

6. Do you use any other renewable energy system (e.g. solar central heating, geothermal etc.)?

7. Will you consider using photovoltaics (or other renewable energy system) if it is economically feasible?

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