HELSINKI UNIVERSITY OF TECHNOLOGY
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ENERGY MANAGEMENT IN THE FINNISH RESIDENTIAL BUILDING SECTOR

Espoo, 19th July 2006

Supervisor: Professor Tuula Pohjola

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ABSTRACT OF THE MASTER'S THESIS

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The Sustainable Development represents the theoretical basement on which each effort that leads to involve the equitable sharing of the benefits of economic activities in the society is rooted. This concept necessarily passes also through the rational and responsible management of energy regulated by international agreements at global level, such as Kyoto protocol, and by national energy strategies and policies at local level. The residential building sector has important responsibilities in energy consumptions of each nation and for this reason in the 2001 the European Community passed the Directive 2001/91/EC about the energy saving in building constructions.

In Finland, the Energy Conservation Program denotes how energy saving is one of the most important means in the national energy strategies and policies for reaching the targets of Kyoto commitments. The implementation of this Energy Conservation Program in the various economic sectors characterized by an important use of energy is made through the Energy Conservation Agreements. The features of the various agreements depend on the sector in which they operate. As regards the residential building sector the Energy Conservation Agreement focuses on the diffusion of the Energy Audit, considered as the fundamental method to achieve rapid improvements in energy efficiency in all the energy processes belonging to the life cycle of a residential building.

The research shows the interconnections between Finnish energy strategies and their applications in the residential building sector. The Energy Audit is analyzed, trying to describe his general features and its energy saving potentialities for residential constructions; moreover the main energy saving measures, adopted by building companies, are studied, describing the engineering principle on which they operate.

The study is supported by books which come from a literature review and documents\interviews given by members of Finnish either private or governmental organizations which operate in residential building sectors. The research is open to deeper analyses and new investigations from point of view which is different from the one used.

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Preface

I'm still surprised at how extraordinary and exiting the development of my thesis in Finland has been in these months.

I cannot conceal, as a matter of fact, that the start was not easy because of my fears, in part due to my condition of foreigner in a country which is so different from the mine, and in part due to my initial difficulty with the use of English.

With the passing of time everything changed completely.

I have always perceived this progress, but only now that I have completed my work, I have the right instruments to analyse it. Nowadays, I know that this change was caused by the passion for the topic of my research, which grew and intensified as I went on in my study. And this feeling supported and motivated all my efforts, transforming them in enthusiasm and curiosity, which, beyond the new and important knowledge learnt, are, in my opinion, the most meaningful things that I will bring back in Italy with me.

For all this I am deeply grateful to Professor Tuula Pohjola who, welcoming me with all my limits and fears, has given me the possibility to know and to develop my passions. I thank all the members of her team who have made me feel one of them during these months. Finally, I thank my family, and my sister Margherita in particular, my old friends in Italy and the new ones in Finland for having shared my fears and rejoiced at my achievements.

Francesco Paolo Ippolito

Espoo, 19/07/2006

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1 Introduction

1.1 Background of the research

With the beginning of the industrial age human activities have influenced more and more the global environmental equilibrium and as a matter of fact the industrial development has also led to a deterioration of the quality of people's lives. Many interventions have become necessary on world scale in order to reverse the trend. These interventions include strategic and political decisions which are supported by technical decisions strongly connected to the specific field or sector in which they are applied.

The general purpose which has steered the interventions is the concept of sustainable development which is not only about the environment, but about economy and society as well. It was expressed for the first time in 1987 by the Brundtland Report (World Commission on Environment and Development 1987) of the United Nations Commission on Environment and Development. Sustainable development is defined in the report as follows:

> Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable Development encourages the conservation and preservation of natural resources and of the environment, and the management of energy, of waste and of transportation in order to involve the equitable sharing of the benefits of economic activity in the society, to enhance the well-being of humans, to protect health and to alleviate poverty.

After 1987, tools have been developed to involve in practice the idea of Sustainable Development; the most important of them is the Environmental Management System (EMS). An EMS provides a method to manage systematically the activities, with an environmental impact and helps to achieve environmental obligations and performance goals.

The concept of “ecologic footprint”, elaborated by Mathis Wackernagel and William Rees, represents a useful parameter for understanding the impact of different human activities in the ecosystem as a whole and for implementing the Sustainable Development in effective way (Wackernagel M. and Rees W. 1996). The estimation of the “ecologic footprint” is based on the calculation of the following rates per each human activity:

- Utilization Rate of renewable resources: in a Sustainable Development point of view this rate should not pas the Reproduction Rate of the same.
- Utilization Rate of not renewable resources: in a Sustainable Development point of view this rate should not the Development Rate of alternative renewable resources.
- Pollution Rates: in a Sustainable Development point of view this rate should not pas the capacity of the ecosystem to absorb the pollutant elements.

Applying the concept of “ecologic footprint” to the different human activities, it is easy to recognize in the activities connected with transformation, transport and utilization of energy, those which have the deeper footprint in the ecologic system. For this reason the Sustainable Development necessarily passes through a rational and responsible use of energy, regulated by international agreements at global level, such as Kyoto protocol, and by national energy strategies and policies at local level.

The building sector is a field which has got important responsibilities in the energy global consumption and overall it has a fair margin of improvement in the environmental compatibility and in particular in energy efficiency. The policy of European Community aims especially to a reduction of energy consumption for guaranteeing a more efficacy energy management of the building.

In 2001 the European Community passed the Directive (Directive 2002/91/EC) about the energy saving in building construction which has been effective since the beginning of 2003. The purpose of the Directive is to create a normative picture which is able to regulate energy policy about the building sector of each member state. The main elements of the Directive are:

- Creation of a common method of calculation for estimating the energy performance of the buildings.
- Application of norms about the energy savings for the new buildings.
- Creation of an Energy Certification for new and old buildings; the certification is based on the result of the calculation of energy performance.

- Creation of an Energy Audit functions for keeping under control the energetic consumption during the use of the building.

Recent estimations, which consider the application of these measures, show that the energy saving in the building sector can lead to a decrease of 22 per cent of energy consumptions in the sector in comparison to the actual level of the consumptions.

1.2 Research targets and questions

The target of the research is to study the energy management in the Finnish residential building sector.

This work is based on an exploration of the general features of the energy Finnish system and wants to create a comparison from the energy point of view between the Italian realty of the residential building sector and the Finnish one.

It is possible to group the questions that the thesis aims at answering into three main units:

1. What is the current Finnish energy scenario? What is the possible evolution of this scenario? Which are the energy strategies and policies that the Finnish Government has undertaken in the last ten years? What is the possible evolution of the scenario in the light of these energy strategies and policies? What are the importance and the role of the energy saving system trough the Finnish energy strategies and policies?
2. How are Finnish energy strategies and policies implemented inside the residential building sector? Which are the main methods of this implementation? Which are the methods and the models used for estimating the energy consumption of a residential building and for finding the relative saving measures?
3. Which are the main residential building procedures for involving in practise the previous methods and models? Which are the building techniques for increasing the energy saving? Which are the building features and technologies for decreasing the energy consumptions?

These previous questions constitute some referent points for addressing all the work.

1.3 Structure of the work and research methods

It is possible to recognize three main parts which constitute the thesis work.
This research begins from an overview of the energy Finnish system; besides the current Finnish energy scenario, the analysis includes the study of Finnish energy strategies and policies in the light of international agreements and European regulations. The work presents also the main principles, standards and schemes which form the basement for the implementation of the strategies and policies in the economic sector in which companies, whose activities have a deep environmental impact and high energy consumption, operate. This part constitutes a frame inside which the thesis is developed.
The research, then, focuses on the implementation of the energy strategies and policies in the residential building sector. In this phase the common measures and processes for increasing the energy conservation inside the building Finnish companies are analyzed, emphasising the distinctive characteristics of each of them. It is also presented the method and the relative models for estimating the energy consumption of the residential building; this is the most important stage for estimating the efficacy of the measures.
The last part of the work aims at understanding which building techniques are used by the Finnish building companies in order to involve in practise the mentioned method. These best practises are analyzed and the efficacy and limits of each them are emphasized, trying also to formulate a personal judgement about the effectiveness and the possible margin of improvement.
The method adopted for leading the research is based on a top-down approach. This approach was firstly developed in 70's (Wirth Niklaus 2001) for strategies of information systems, mostly for software; later, thanks to its good adaptability, it was successfully adopted by other scientific and also humanistic fields by extension.
This approach consists in formulating a general overview of the system that it is going to be studied, without going into details for any part of it. Then those parts of the system that are more connected with the objective of the research are deepened by studying them in detail. Later on, other new parts may then be refined again, defining them in a yet more detailed way. This method helps to fix the boundaries of the research and to gradually to focus on

the main points of study, giving a global vision of the treated subject, avoiding to neglect any important logical connection.

The analysis of the Finnish energy system is based on a descriptive method. Descriptive research is used to obtain information concerning the current status of the phenomena, in order to describe "what exists". Beginning from a survey which describes the “status quo”, the method investigates the relationship among the descriptive variables of the system, leading the research inside the situation which is the objective of the study.

The other two parts of the research are characterized by the use of a phenomenological approach. The purpose of the phenomenological approach (Husserl Edmund 1907) is to illuminate the specifics and to identify phenomena which characterize the system, taking into consideration how they are perceived by the actors which operate inside the system. This approach is supported by inductive, qualitative methods such as interviews, discussions and collecting specific documents concerning the analyzed subject in order to:

- Emphasize the importance of personal prospective and interpretation of the system.
- Focus the attention on the particular feature which concerns the solutions adopted by actors.

The prepared interviews are two and are characterized by different aims.

The first one aims at getting information about the common principles and rules of energy saving which steer the planning of residential buildings; it is addressed to organizations which collaborate with the Government for the implementation of the national energy strategy and policy in the building sector.

The second one aims at discovering the effective building techniques for decreasing the energy consumption; it is addressed to companies which operate in the residential building sector.

1.4 Contents list of the work

The content list of the thesis is developed considering structure of the work. It is organized as follow:

Chapter 2: analysis of the Finnish energy scenario. Begging from a general overview of the Finnish energy system, the analysis is focused on the study of the national energy strategy and policies; it also provides the main tools such as management methods and standards for understanding the implementation of the energy strategy.

Chapter 3: analysis from the energetic point of view of the Finnish residential sector. In this chapter the method for implementing the national energy strategy and policies and the relative models are studied, emphasising the benefits and the limits of each model.

Chapter 4: study of the building techniques for the energy saving adopted by companies which belong to the residential building sector.

Chapter 5: final evaluation of the results of the research, analysis of the possible application of the work for the building company and suggestions for future research in the same field.

2 *Finnish Energy Scenario*

2.1 Energy in Society

Energy can be broken down into different primary energy sources which are available from the nature.

The most important of them are coal, crude oil, natural gas, uranium, peat, biomass, hydro, sun and wind.

Primary energy is transformed into more convenient forms of energy, such as electrical energy, heat and oil products; these forms are called secondary energy.

A part of primary energy sources is not converted because of losses during the conversion phase connected whit the second principle of the thermodynamics; moreover, also a portion of the secondary is dissipated during its transportation.

The effective energy used is called serviceable energy. It is used by society for different aims and in different sectors just like industry, transport, household, services and agriculture.

The energetic rendering during the total transformation process is the ratio between the amount of primary energy and the amount of serviceable energy. Its value depends especially by the technological feature of the transformations process. For example the efficiency of the process of thermal generation of electrical energy is presently 35 per cent on average, although the efficiency value of about 82 per cent can be obtained with hydroelectric generation.

In the process of converting primary source into useful energy forms several outputs other than useful energy occur. They are classified as:

Atmospheric emission: product that leaves the converter site by entering the air.

Liquid emission: products that leave the converter site and enter the earth’s waterways.

Solid residue: product that leaves the converter site in the solid form.

Thermal emission: energy that leaves the converter site which is different from the useful energy product. Thermal energy may leave with liquid, gas, or solid product.

This classification defines the pollutant by the streams which carry it away from the energy conversion site (Bailie 1978).

Each emission has a different impact on the environmental system; it depends especially on the control and the containment of this pollutant.

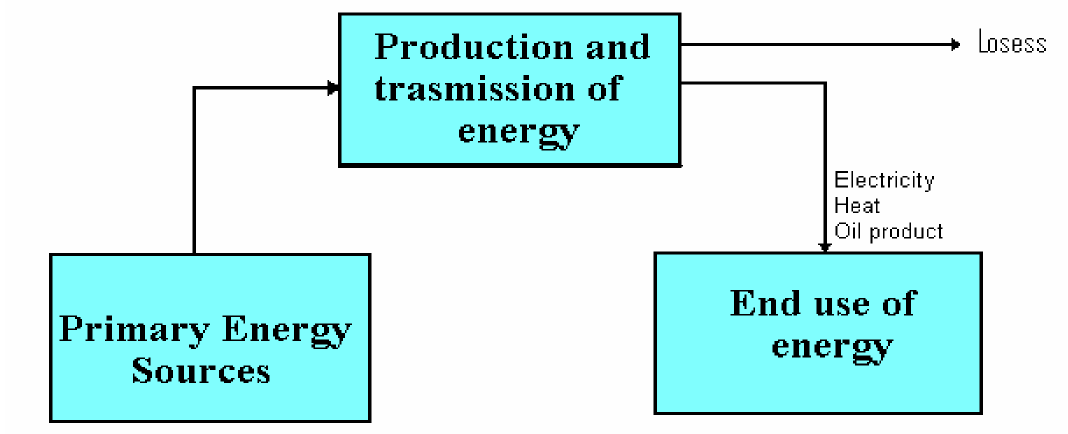

Figure 4: From primary energy to usable energy

From the Second Industrial Revolution which began in the early part of the previous century, in the industrial countries there was the very rapid increase of energy consumption. As the inanimate energy was necessary for industrialization as the improvement in well being was dependent on the use of energy.

The increase of energy consumption and consequently the use of primary source is connected with the trend of the well being of the society; this because the developed societies are highly dependent on continuous inputs of energy to provide goods and services associated with a high standard of living.

Jerrold H. Krenz tries to find an empiric connection between the well-being of society and the increasing of energy consumptions (Krenz 1976).

According to him, the concept of entropy, which is related to order of a system, is applicable to processes which are not normally associated with the thermodynamics.

Cultural devolvement and industrialization represent a movement of society from less order to a greater order which produce a decrease of entropy. That is the reason why the efforts in civilization and in a common welfare lead to a decrease of entropy of the system in which we live.

In a closed system (as the system earth-sun) the decrease in entropy of part of the system is possible only if there is an increase in the remainder part of the system. That is why the low source of entropy (primary source of energy) and their utilization for producing useful energy are necessary for the accumulation of knowledge and of the development of social economic system.

However technological system frequently produces undesired form of disorder and not manageable energy, which is pollution. For example, atmospheric emissions are a source of disorder because they can contribute to change the global conditions, giving rise to dramatic change in climate and see level.

The great and not controlled consumption of energy produce at the same time a reduction of the social well being.

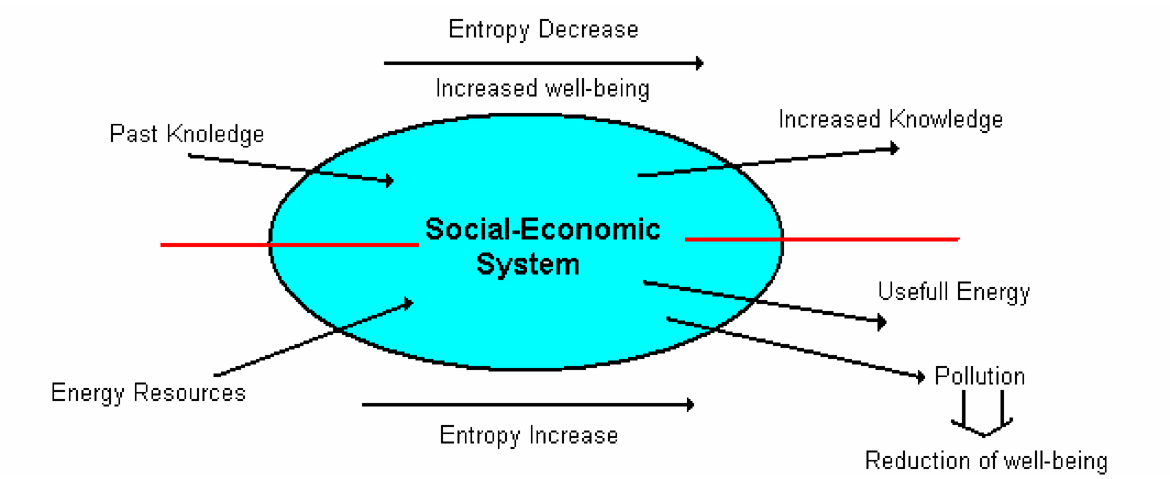

Figure 5: The Social-Economic System

Krenz´s idea is that the relationship between the energy consumption and well-being is explained by the function of marginal utility which is well-known by the economist. The improvement of social condition doesn't continue indefinitely with increase of energetic consumption; when it reaches the peak (zero marginal utility) a further rate of energy consumed produces a decline of the function.

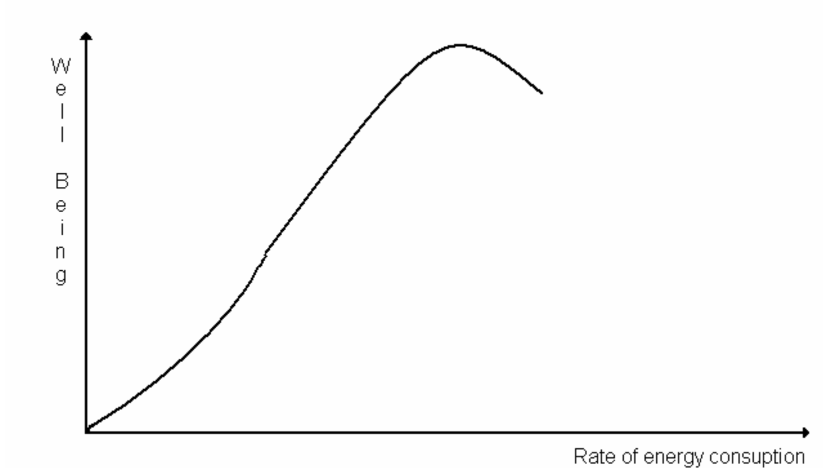

Figure 6: Probable relation between Well-being and Energy Consumption

The crucial problem is to determine the peak and not to surpass it.
The international community is trying to give a common answer to this global problem. This answer becomes concrete trough the national energetic strategies and policies of each countries.

2.2 Finnish Energy Market

2.2.1 Analysis of Energy Supply in Finland

Finland has not many primary energy sources, and it is highly dependent on imported energy; more than 70 per cent of energy sources necessary for meeting the inner demand are foreign.
Russia is the most important energy row supplier because it covers 50 per cent of the imported energy. The net value of the importations from Russia was 3,538 million Euros in 2004. The value of total energy imported was 5,061 million Euros in the same year.
Renewable energy sources, that are no fossil energy sources like wind, solar, geothermal, biomass, represent the 5/6 of the indigenous energy sources.
In spite of a lack of primary energy sources, most of processed energy and energy products are domestically produced: district heat is completely produced in conversion sites inside of the nation, just like 90 per cent of all electricity and 75 per cent of all oil products. Also the

energy distribution is provided using only Finnish infrastructures. Finnish energetic market is divided in four most important sectors with different features:

- Electrical sector: Finland, Denmark, Norway and Sweden constitute a market (Nordic Power System) which is available for electrical private company for generating and selling energy; about 11000 GWh per year is also imported from Russia. A single operator (Fingrid) provides for the distribution of energy which operates in a natural monopoly controlled by the Energy Market Authority.
- Space heating sector: district heating competes in this sector with other forms of heating like electricity, light/heavy fuel oil and wood. It consists in hot water, which circulates from the power plant out to the heat exchangers of customers and back again; from the heat exchanger, heat is transferred to the service water and radiator network of the building. District heating network can reach the most part of the population which lives in Finnish main cities.
- Natural gas sector: natural gas sector used in Finland comes from the western Siberia zone. In the 2005 the natural gas imported from Russia was 4.6 million m^3. The natural gas network is managed by some private companies; the Energy Market Authority controls that the price required by these companies for the service is not excessive. A new gas network between Europe and Finland is going to be created.
- Oil refining sector: The oil supply situation in Finland is good. The national production is sufficient for covering the inner demand and for competing in external markets such as Sweden, Germany and United States; approximately 40 per cent of the production is exported actually. The most important refineries belong to Neste Oil Corporation and they are located in Porvoo and in Naantali; the total production from both refineries was 13.6 million tons in 2004.(Statistic Finland 2005 and Report by the Finnish energy sector for the Government analysis 2005)

Many of large energy companies, such as Neste-Gasum (the oil gas conglomerate) and Imatran Voima Oy (the largest electricity producer) and the peat producer, Vapo Oy, are majority state-owned.

It is important to notice that the Government has encouraged the merger between energy companies in order to create a supplier of sundry energy products and services. For example, in 1997 the Finnish Ministry of Trade and Industry made a proposal to combine

Neste and Imatran Voima Oy into a new energy group. It becomes a reality with the appearance of the new company Fortum in 1998[1].

The Council of State has, however, established a number of performance requirements for state-owned companies (International Energy Agency 1999). It is required that:

- The companies be profitable
- They pay dividends comparable to the general practice in the market
- They are allowed to operate in commercial grounds, similar to privately-owned companies
- They receive the same state aids of the privately-owned companies

In the recent past, several consecutive Governments have undertaken reforms of Finnish energy market. The reforms have led to more privatization of state-owned companies and to the introduction of competition where it was possible. Every privatization decision, which required a mandate from the parliament, was made according to the situation of market conditions.

Moreover, the Government has considered the international dimension of energy market very important and for this reason it has encouraged competition and it has removed unnecessary financial, technical and institutional barriers.

In each sector there have been a large number of operators, none of them having a dominant position on the market. This policy has led to the situation where Finland has had a diversified energy supply structure, both in terms of companies and of energy sources.

2.2.2 Analysis of Energy Demand in Finland

In 2004 total consumption of primary energy amounted to 1,487 petajoules (one petajoule is equivalent to a thousand trillion joules) and remained on the same level of the previous year.

It is important to notice that, although the total consumption of primary energy did not increase, the final consumption of energy grew of about two per cent in comparison of the previous year.

[1]http://www.fortum.com [accessed 17th July 2006]

This datum is connected with the technological development which reduced the energy loss related to the process of energy transformation and to the energy transmission.

The consumption of energy sources in Finland in 2004 is represented below (Statistic Finland 2005):

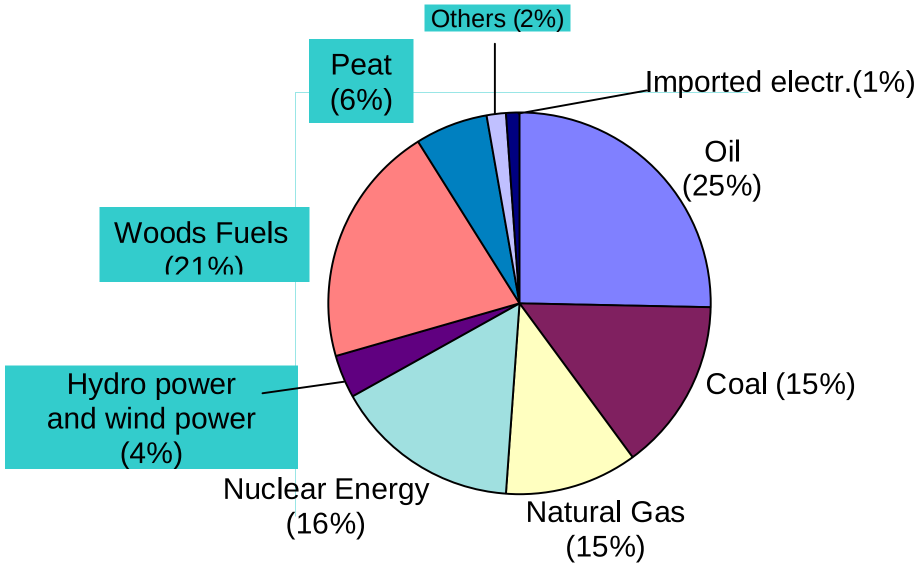

Figure 4: Energy Source Consumption in 2004

In 2004 the country's main required energy source was oil.

Renewable energy sources (which are emphasized in the previous figure) provided to cover more than 30 per cent of the national energy consumption. The share of renewable energy consumption was the third higher percentage in Europe.

Bioenergy (energy deriving from biofuels like wood and biomass) accounted for 85 per cent of renewable energy sources; the rest came from hydro/wind power. The share of bioenergy sources was the highest in Europe (Statistic Finland 2005).

These last data made Finland one of the first countries in the world in the utilization of these resources.

The next graphic shows the energetic consumption trend of each energy source in Finland from 1970 to 2004 (OEPT Finland 2004).

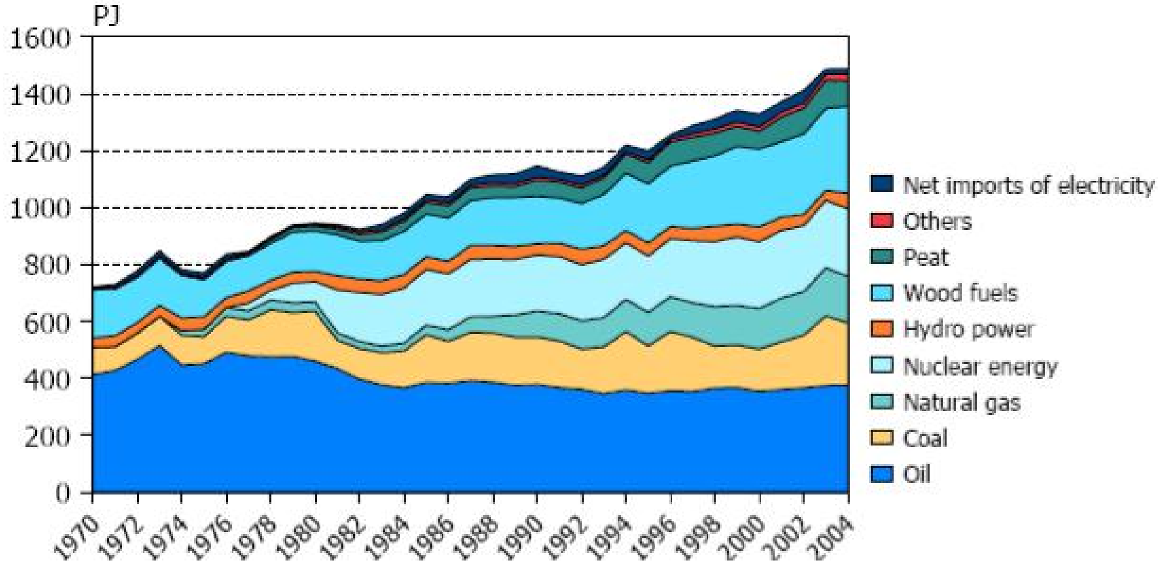

Figure 5: Total Energy Consumptions 1970-2004

Since the energy crises in the middle and in the late 1970s, the gross consumption of energy in Finland has been growing 1.8-fold, reaching the peak of more than 1.4 petajoules in 2002; it continues to grow in the course of the technological development, despite the more efficient use of energy.

Nuclear energy was introduced in the 1970s. After a rapid increase in the consumption of this energy source the use of nuclear energy became stable. Nowadays the two nuclear installations of the country with their 4 reactors supply to 30 per cent of electricity national needs[2].

Coal imports declined in the late 1970s as a result of rapid increases in the generation of electricity from nuclear plants, but they rose again by the end of the century.

The use of renewable energy sources grew only in 2004 of around 12 per cent, because combined heat and power production (CHP) provided opportunities for cost-effective use of renewable sources, both in industry and in district heat plants (Ministry of Trade and Industry 2004).

In the last years the use of natural gases fell of 4 per cent because of the moderate price of electricity which decreased significantly the use of gas in production of condensate

[2] http://www.planetark.org.

electricity (electricity which is produced from fuel sources), and because of the wormer weather (Statistic Finland 2005).

Oil declined notably, but it still accounted for 26 per cent of total primary energy supply (TPES).

Efforts to diversify the energy mix, made by Finnish institutions in the past, have born fruit; five energy sources, accounting for over 10 per cent of TPES each.

The energy consumption in each sector in the 2004 is represented below (Statistic Finland 2005):

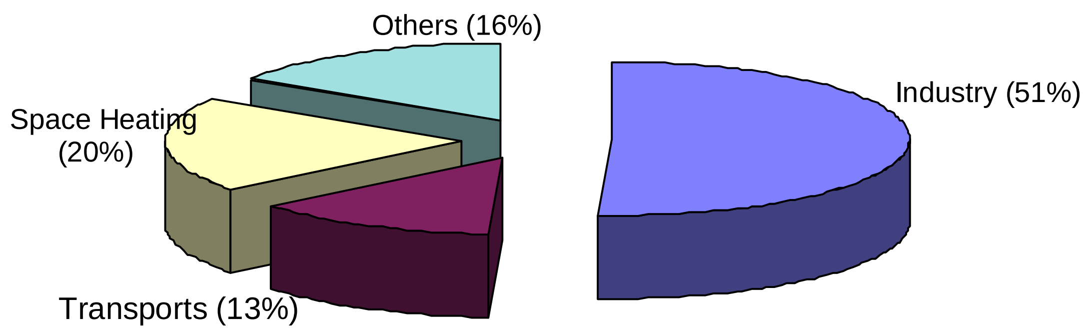

Figure 6: Total Energy Consumption by Sector

The industry is the sector with the most evident energy consumption; the process of industrial automation has made of this sector an energetic-intensive field.

Electricity is the most used energy source in each sector.

Electricity consumption has been growing continuously and it is expected that it will grow 1.7 per cent per year over the next 10 years.

On the other hand, the effectiveness of the use of electricity will intensify at the same time; for this reason it is assumed the growth of electricity consumption will slow down gradually after the next 10 years (Report by the Finnish energy sector for the Government analysis 2005).

2.3 Finnish Energy Strategies and Policies

The Finnish Energy Strategy was approved by the Finnish Parliament in the autumn 1997; it includes the main goals and the guidelines for the long term of energy policy.

This strategy, burnt after the Government's considerations about the energetic market scenario, is characterized by both the growth of inner energy demand within the next 10 to 15 years, and by ecological global problems connected with the use of energy. For this reason the strategy is based on three fundamental elements: energy, economy and environment.

The strategy tries to balance the requirements of an internationally open, competitive energy market place and the imperatives of environmental protection, especially climate change. Thus securing energy supply, protecting a competitive price of energy and keeping constant the arising environmental emissions play a central role in structure of the strategy.

The government focuses its efforts on the following fields of action (RES' legislation in Finland 1998):

- The development of the energy production structure to promote the reduction of carbon dioxide emissions
- The promotion of energy market, especially the competitiveness
- Ensuring a sufficiently diversified and advantageous energy production capacity
- Ensuring the secure supply of energy
- The promotion of energy efficiency and energy conservation
- Ensuring continued sustainable economic growth
- Promoting the use of renewable, especially biomass, and other indigenous energy resources
- Maintaining the high standard of energy technologies

These main objectives of the strategy have been implemented in sub-goals and concrete actions which have been developed by the following Governments through energetic policies.

The Energy Department, which belongs to the Ministry of Trade and Industry, has the co-ordination and planning role and it has the ultimate responsibility for energy policy. It consists of the Climate Change and Energy Strategy Secretariat, the Energy Market and Environment Division, the Renewable and Energy Efficiency Division and the Nuclear Energy Division; this complex operative structure ensures that all energy strategy objectives are considered when policy is being developed.

Other relevant ministers, such as Minister of Finance, of Environment, of Foreign Affairs, and agencies or private companies, such as National Emergency Supply Agency and Motiva Oy, work closely to the Ministry of Trade and Industry and contribute through consultation and delegation of responsibilities for developing new energy policies.

Energy production, generation, transmission and use are subject to light-handed regulations in a liberalized market; in general, energy prices are determined solely by market forces. In this area regulations tend to be ex post; it means that laws ratify retroactively eventual conducts that were legal when were originally performed and that are judged no more tolerable. Regulations ex-post, with a limited number of cases coming before the regulatory body, permit that energetic companies have significant leeway to set their own tariffs (International Energy Agency 2003).

Finland's energy policy has a strong international component. The lack of domestic energy sources is faced making efforts to import fuels and electricity from a variety of countries. After the deregulation of the electricity market, co-operation has considerably increased between Nordic regulatory bodies and other bodies responsible for the security of energy supplies. Nowadays a lot of different energy suppliers provide Finland, securing lower cost. Moreover the removal of unnecessary regulation on the international forefront has created the preconditions for internationalization of energy companies and for the growth of their efficiency.

Safeguarding the availability of imported fuels with stocks is part of maintaining security of energy supply. The Security Supply Act which is the legal basis for ensuring supplies of various basic materials in the case of emergency situations ensures energy stock of imported fuels corresponding to five months consumption. The emergency stocks of imported fuels have been dimensioned largely because the Finnish winters are long and the country's geographical location is remote[3].

On the inner energy production side, the most important energy development is the building of a new nuclear power plant, scheduled to come on line in the 2009. In May 2002, the Parliament ratified the government's earlier decision in favour of the nuclear plant; the new plant would be the first nuclear facility built in a liberalised electricity sector. This new

[3]http:// www.ktm.fi

nuclear facility could help Finland to meet its need for new generating capacity without producing new greenhouse gases.

Finland's membership in the European Union (EU) also influences its energy policy through the directives on the internal market and frameworks and the guidelines on national policies promoting indigenous, fuels, energy efficiency or R&D.

From the environmental point of view, the most important measure taken by Finnish institutions refers to the creation of the National Climate Strategy.

This strategy is compatible with the overall climate change strategy of the European Union that was born after the adhesion of EU as a whole at the Kyoto's Protocol.

2.4 The National Climate Strategy

The National Climate Strategy was launched by the Finnish Government in 2001. It contains the environmental targets and measures necessary to meet the Kyoto commitments that Finland subscribed in 1997, as a Member State of European Union.

The Kyoto protocol is an international agreement on climate change, negotiated in Japan in December 1997. It is based on estimates of scientific community about the climate change connected with the concentration of greenhouse gas emission; this because the gases absorb more of heat radiation of the ground and a part of this heat returns back into the ground, provoking the greenhouse effects. The increase of greenhouse gases such as carbon dioxide, methane, sulphur dioxide, nitrous oxide, hydroflurocarbons, is strongly tied to different human activities, connected with the process of industrialization of the modern society. The treaty states that the industrialized countries reduce their collective emission of about 5.2 per cent compared to the year 1990, during the period which goes from 2008 to 2012. For Finland it means that annual emissions during that period should not exceed the value of 75.2 million of tons which was the value in 1990.

In the figure below, the distribution of Finnish greenhouse gas emissions produced in each economical sector in 2003 is presented (Statistic Finland 2005).The energy sector is the most significant source of greenhouse gas emissions in Finland with over an 85% share of the total emissions.

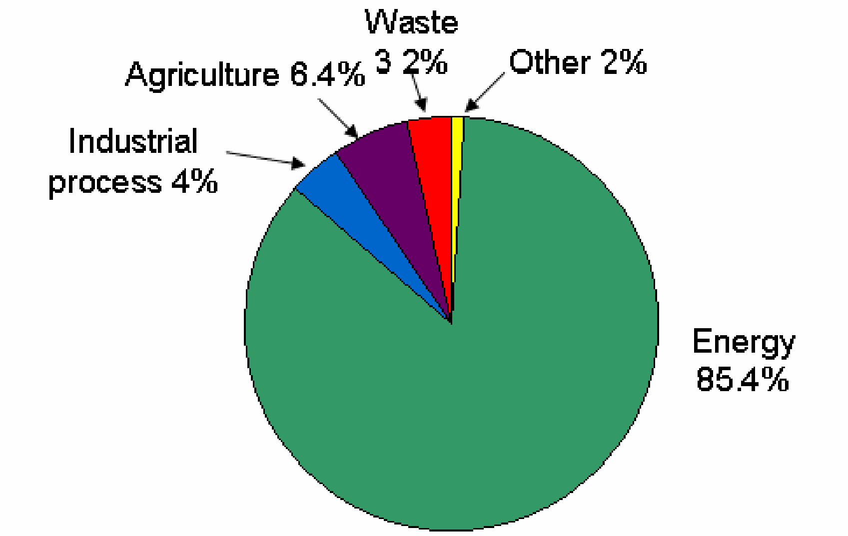

Figure 7: Total greenhouse gas emission by sector

For this reason the strategy is addressed to the energy sector.

The National Climate Strategy is based on considerations and studies about the possible evolution of the climate scenarios according two main alternatives:

- BAU (Business as Usual) scenario involves neither additional energy conservation measures nor any further action to reduce greenhouse emissions
- KIO1 and KIO2 scenarios concerns a program which promotes energy conservation, the use of renewable sources of energy and the reduction of emission greenhouse gases

The main difference between the two KIO scenarios is that KIO1 proposes a shift from coal to natural gas in the generation of electricity and heat while KIO2 proposes a shift from coal to nuclear power in electricity and heat generation.

However, both KIO1 and KIO2 scenarios try to respect of the targets fixed by the Kyoto protocol and for this reason they have a lot in common. Pearls and Kemppi have identified four main general elements that belong to both of them (Pearls and Kemppi 2002):

1. Measures relating to the reduction of greenhouse gases such as the increase of energy and electricity tax both for companies and households
2. The presence of Renewable Energy Program
3. The presence of Energy Saving Program

4. Limitations of use of coal replaced by natural gas (KIO1 alternative) or nuclear source (KIO2 alternative)

Many research projects were launched in Finland at the beginning of 1999 in order to study the environmental future situation according to the different scenarios and in order to evaluate the environmental effectiveness of each scenario. All projects move from the idea that the social and economic effects of the climate strategy depend on the measures adopted for curbing the emission.

The most important of them was led by the Technical Research Centre of Finland (VTT) in collaboration with the Research Institute of the Finnish Economy (ETLA).

The aim of this project was the estimation of the future effects, included the value of greenhouse emission, produced by energy system as a whole (from the transformation process of primary energy to the use of final energy) according to the different elements belonging to each scenario.

The methodology used in this project is based on a model belonging to the family of EFOM models which had been already adopted in EU´s studies about the cost-effectiveness analysis of CO2 reduction (Lehtilä and Tuhkanen 1999). It has a modular structure and each modulo belongs to a specific sector of the energy system.

Each modulo derives from the study of the energy system according to a bottom-up approach and it represents an energy conversion unit or an energy use unit. Each sector is characterized by a technological level: in the supply sector there are large-scale technologies, such as power plant, and in the consumption sector there are small-scale technologies used in large quantity, such as cars, space-heating system and lighting system.

The model shows also the possible interactions between the units which belong to the different sectors of the energy system. The initial assumption, made before the builder of the model, is the level of characteristic detail. In the Finnish EFOM model the energy system has been described on a very general level, especially with regards to supply sector in which it is considered fuel supply only (oil, coal, peat and gas supply) because it is responsible of the most part of greenhouse emissions.

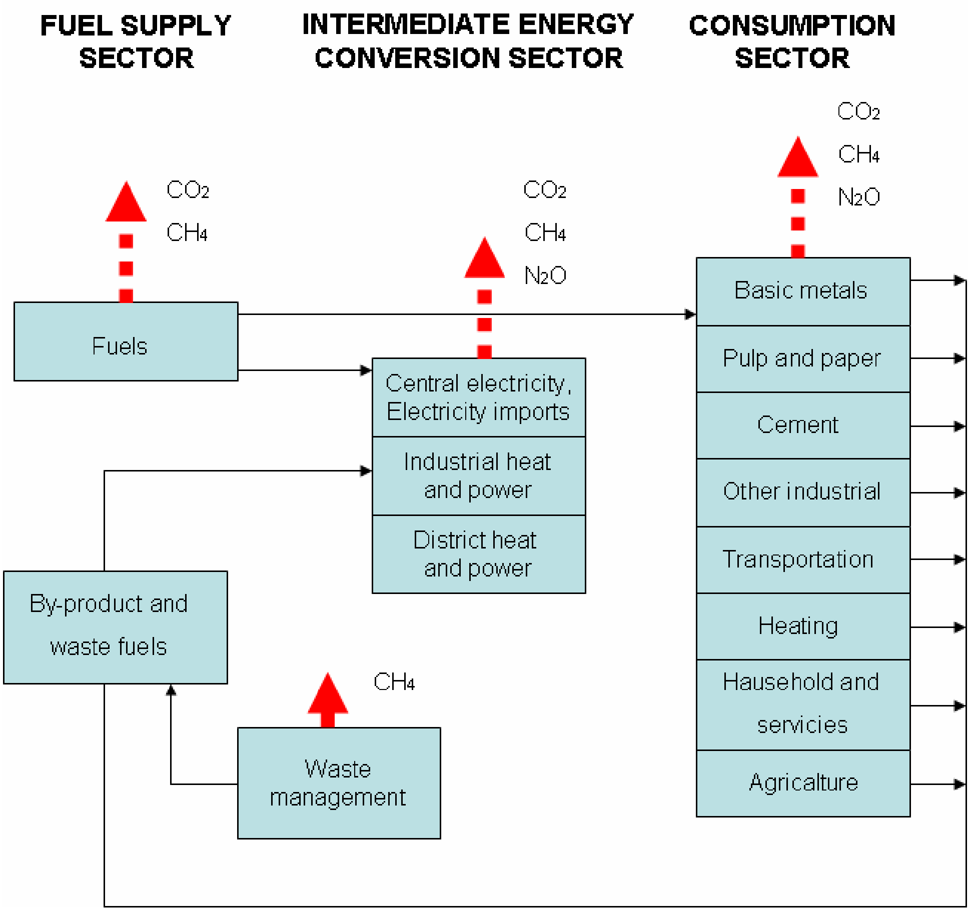

Figure 8: Energy System in EFOM model

The central part of the model application is the definition of the scenario which characterizes the energy system inside the period of 15-20 years. The scenario includes varying assumptions either about characteristics and availability of different technologies (residual equipment and the available technologies for new equipment) or about policy measures (energy taxes or constraints for the amounts of emission and of energy resources). The alternative assumptions influence the value of the following parameters:

- Maximum imports of natural gas
- The cost of renewable energy supply
- The cost of energy technologies
- The cost of energy conservation measures

Beginning from the definite scenario, the development of the energy system inside the considered period can be studied by using the model. The aim of the model is obtained by the global system optimisation that is the optimal use of resources either in energy supply or in energy conversion or in final energy demand over the whole study period under consideration.

The system is optimized by linear programming using the present value cost of the entire energy system as the objective of the function is minimized in accordance with the concept of least cost planning. Least cost planning is the most used approach in the resource planning, especially in the field of energy planning; applying this approach, all significant impacts (costs and benefits), including non-market impacts connected with the implementation of an energy strategy, are considered inside the objective function.

Perhaps the most important disadvantage of the model is that it does not address the interaction between the demand for energy service and the price of energy. The model can capture the extent of price consequent to the introduction of energy conservation program but does not consider more complex microeconomic mechanisms between the economic activities and the demand of energy which influences the final price of energy.

However, the model is very useful for simulating the dynamic of energy system and, in particular, for evaluating the expected value of each greenhouse emission produced by each sector according to the different considered scenarios.

	BAU		KIO1		KIO2	
YEAR	SO_2	NOx	SO_2	NOx	SO_2	NOx
1998	90	252	90	252	90	252
2010	144	187	91	170	88	172
2020	117	182	79	160	84	164

Table 1: SO2 and NOx future emissions according the three scenarios

It is important to consider the future trend of all greenhouse gases in accordance with the different actions belonging to each scenario. The total greenhouse emission of the energy system as a whole is the sum of every single emission value which each sector produces. The graphic below (OEPT Finland 2004) shows which the expected trends of the greenhouse gases are until 2015, starting from the greenhouse emission values before 2003.

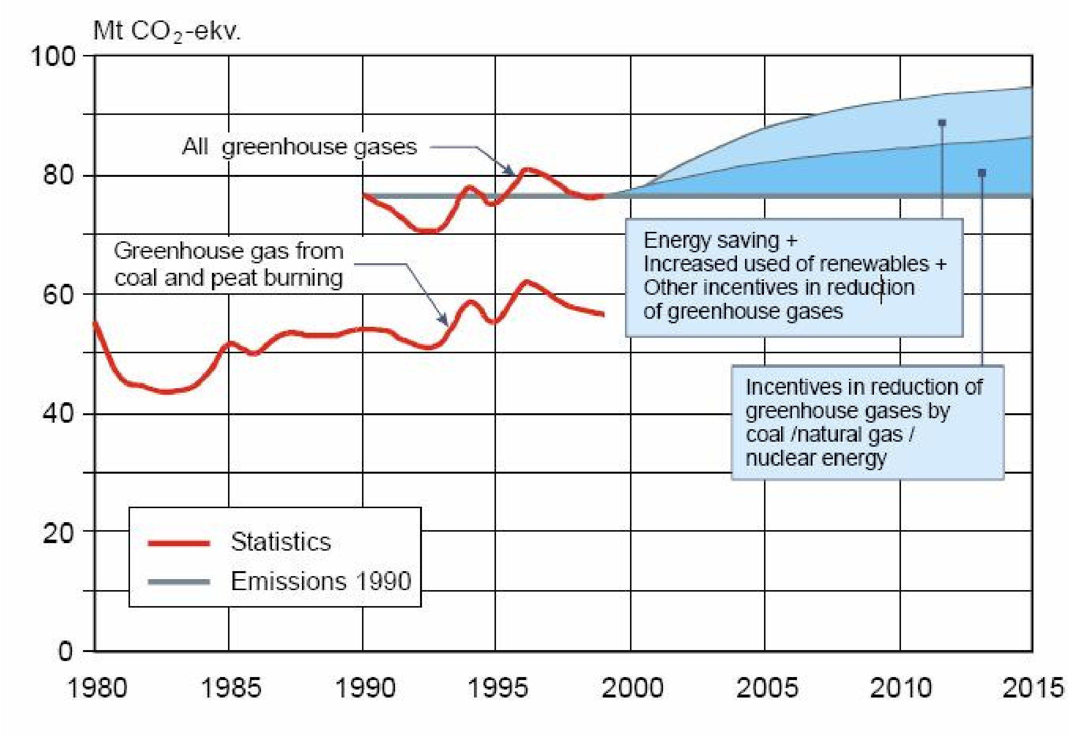

Figure 9: Targeted emission reduction in Finland and role of renewable energy sources and energy conservation

The baseline is emission is the emission value of 1990 (Kyoto's target) and the three different emission trends refer, from the top respectively to:

- Probable trend deriving from no actions undertaken in order to decrease the emission; this trend is in accordance with the BAU scenario
- Probable trend deriving from actions as energy saving and from the use of renewable sources
- Probable trend deriving from further actions such as incentives to reduce the coal; this last trend is in accord with KIO1 and KIO2 scenarios

Once the effectiveness of the National Climate Strategy was verified, it was implemented by aligned actions addressed to realize the studied scenarios.
The Action Plan for Renewable Energy Sources and the Energy Conservation Program complement the National Climate Strategy outline and they are the principal measures of implementation to reach the goals of the strategy. As it is possible to see in the previous figure, these two programs together may account for about a half of targeted emission reductions.

2.4.1 The Action Plan for Renewable Energy Sources

The Finnish Action Plan for Renewable Energy Sources was passed by the Finnish Ministry of Trade and Industry in 1999 and it was revisited by a working group in the end of 2002 in order to update it after the launch of the National Climate Strategy. In the first edition the aim of the plan was to bring an increase of about 50 per cent in the use of renewable energy by 2010 compared to that in 1995. In the revisited action plan the working group sets the objective of increasing the use of renewable energy sources by other 7 per cent in 2010. It means that the use of renewable energy should be increased by the year 2010 by around 30 per cent compared to the year 1999, as it is showed in the graphic below, causing the reduction of carbon dioxide emissions by 4.5-5.5 million tonnes compared to the BAU scenario of 2010 (Ministry of Trade and Industry 2002).

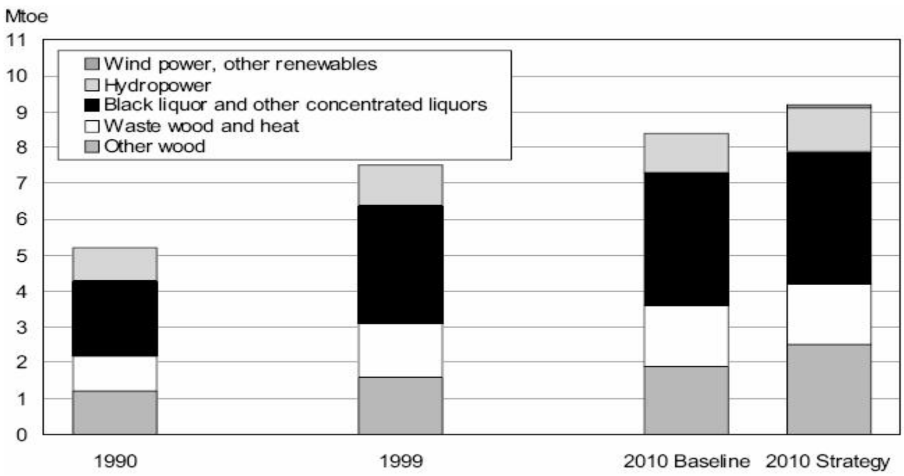

Figure 10: Use of renewable energy sources as sources of primary energy in the years 1990, 1999, 2010, according to the strategy and baseline, Mtoe

This value is obtainable only by making the energy produced with renewable energy sources competitive on the open market.

It is possible to include all measures estimated necessary for reaching the planned target in two key groups:

- development of new technology
- economic means of steering energy market

All the measures that promote the competitiveness of renewable energy sources through long term investments in technology research and development belong to the first group.

From 1995 the Technology Development Agency, TEKES, which is the main public funding organization for research and development in Finland, is responsible for the implementation of energy technology programs. Renewable energy technology, belonging to the sustainable development solutions, is in the strategic focus of TEKES. Annually it funds technology programs for renewable energy R&D for an amount of 10 million of euros. Research on renewable energy resources (RES) is carried out also by governmental contract research centre and several universities in Finland (Helynen 2004).

Energy taxation and investment subsidies are the main economic measures that the action plan adopts in order to steer the energy market towards the use of renewable energy sources.

In Finland energy taxation is regulated by the Act on Excise Duty on Electricity and Certain Fuels and the Act on Excise Duty on Liquid Fuels. The Ministry of Finance is responsible for energy taxation legislation.

Finland was the first to impose the carbon-based environment tax in 1990 by introducing a CO2 tax on fossil fuels. Today the major object of taxation in the production of energy is the use of fuels, especially in the heat production; instead renewable energy fuels are not taxed in heat generation. The fossil fuel taxation is proportional to the carbon content of biogas.

The objective of the investment subsides was fixed by The Council of State decision in the 1999; it has to support investment in production capacity from renewable energy sources in order to increase the commercialization of new technologies based on RES. The Council of State sets the following maximum percentages of total investment of subsidy:

- Wind power investment, 40 per cent.

- Other investments in renewable energy, 30 per cent.
- Energy conservation auditing, 40 per cent.

The Council of State's decision was carried out immediately. In 2001 investment support was 21 million euros, of which about 80 per cent was for renewable energy sources, in particular, wood fuels investments were 13.8 million of euros for 100 plants. In 2002 energy investment support was 25 million euros and the same percentage of the previous year was assessed for RES.

It is important to notice that subsides also from the European Community in accord with the principle contained in the EU White Paper which states:

> The guiding principle for the Commission in assessing aid for the renewable energies [...] is that the beneficial effects of such measures on the environment must outweigh the distorting effects on competition. The commission will consider appropriate modifications in favour of renewable energies in support of its policy in this area during the revision of the present guidelines taking into consideration the Council's Resolution on the Green Paper 'Energy for the future: renewable sources of energy' which states that investment aid for renewable can, in appropriate cases, be authorized even when they exceed the general levels of aid laid down in those guidelines.[4]

2.4.2 Energy Conservation Program

The Energy Conservation Program was first launched in 1992 and revisited and intensified in 1998, 2000 and 2002 in order to meet the needs of the National Climate Strategy; it represents a framework for promoting efficient energy consumption and energy conservation.

The Ministry of Trade and Industry has the principle responsibility of the Energy Conservation Program, but other entities such as Motiva Oy, the Ministry of the Environment and the Ministry of Finance collaborate for implementing it.

[4] *Energy for the future: renewable sources of energy*, EU White paper, 1997, p37.

The program should achieve a reduction in consumption by the year 2010 of about 10 to 15 per cent lower compared to a base case without an active energy efficiency policy change (ODYSSEE 2004).

The measurers proposed for reaching this target can be divided in six categories:

1. Funding the development and commercialization of energy-efficient technology.
2. Using economic steering methods.
3. Improving the efficient use of control by norms.
4. Improving the Voluntary Energy Conservation Agreement among a private and public companies, especially among those companies which belong to sectors characterized by an intensive use of energy.
5. Supporting energy conservation measures with information services, training and motivation.
6. Supporting energy conservation activities of EU and international organizations.

The Voluntary Energy Conservation Agreement plays a crucial part among these measures; the aim of the agreement is to promote energy efficiency so as to reduce specific energy consumptions. At the end of 2004, there were eight energy conservation agreements in force, concluded between the Ministry of Trade and Industry (MTI) and various branch associations.

The Voluntary Energy Conservation Agreement provides Finnish companies with some important benefits such as (Investment in Finland 2005):

- Cost efficiency and systematic way to property management.
- Corporate image.
- State subsidies to energy audits (40 per cent of costs) and to energy improvements which derive from investments in energy saving (10-40 per cent of costs). As regards subsidies about conventional energy conservation measures, priority is given to projects which save electricity. The investment subsidy is the most important measure on which the Ministry of Trade and Industries has focused the attention for encouraging the entrance of the companies in the agreement. The net value of this subsidy has gradually increased from 0.8 million of Euros in 1998 to 7.3 million of Euros in 2004. The value of the subsidies to energy audit has remained almost constant after an initial increase in 1999.

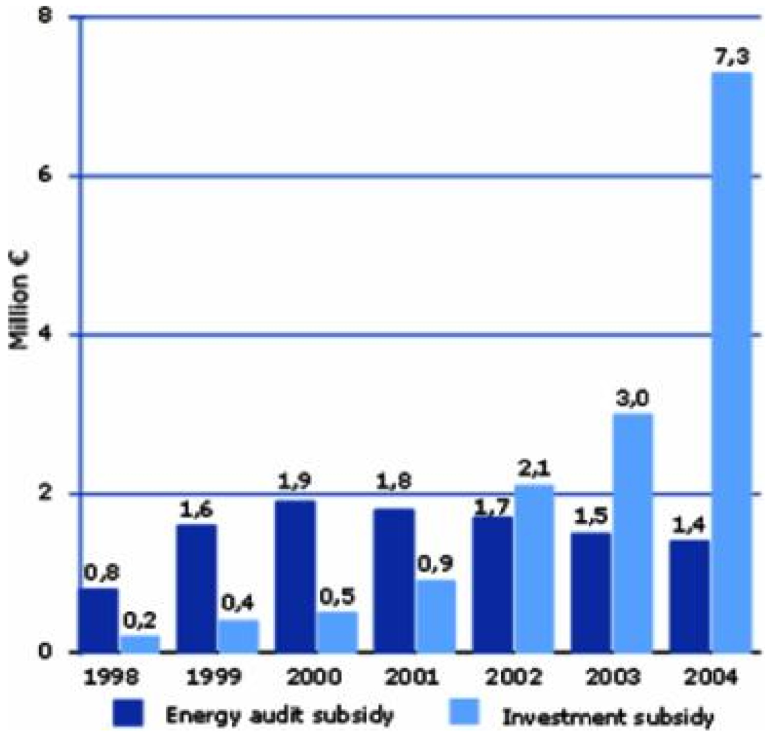

Figure 11: Energy audit and Energy investment subsides granted by the Ministry of Trade and Industry from1998 to 2004

Moreover, companies and communities subscribe voluntary the agreement because it gives a well-working tool for enhancing energy efficiency.

For this reason, during these last years, a lot of companies which belong to high intensive energy use sectors have adopted the agreement.

The coverage of various agreements at the end of 2004 is shown in the figure (Motiva Oy 2004). The coverage of all agreements is presented as the shares of the respective economic sectors to facilitate comparison of the shares. The figure also presents the maximum coverage in Finland of the agreements in the respective sector.

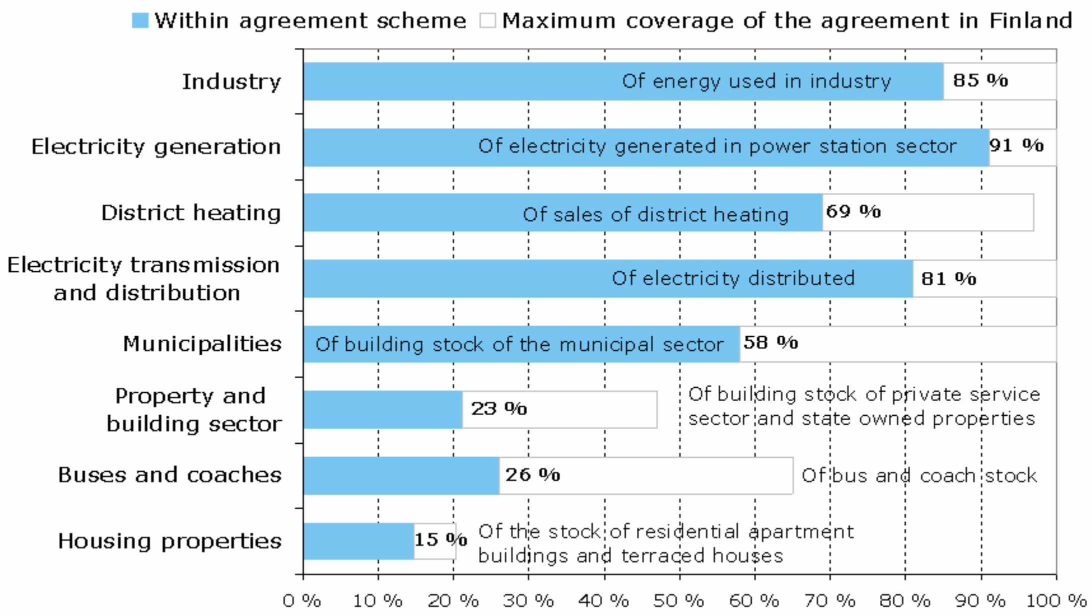

Figure 12: Coverage of Voluntary Energy Conservation Agreement at the end of 2004

The main features of the Voluntary Energy Conservation Agreement in the Finnish environmental policy are (Sairinen and Teittinen 1999):

- Conduct an environmental review considering all environmental aspects of the organization's activities, products and services, methods to assess these, its legal and regulatory framework and existing environmental management practices and procedures
- In the light of the results of the review, establish an effective Energy Efficiency Plan aimed at achieving the organization's environmental policy defined by the top management. The management system needs to set responsibilities, objectives, means, operational procedures, training needs, monitoring and communication systems.
- Implementation of the plan through the creation of an Energy Audit System inside the company. Energy audit is a systematic procedure that evaluates the existing consumption and identifies energy saving opportunities; it consists in a detailed examination of how a general facility uses energy, what the facility pays for that

energy and finally a recommended program for changes in operating practices or in energy-consuming equipments. The plan is also implemented through “ad hoc practices” for energy saving. The use of the agreement is mainly based on ad “hoc practices” and on individual cases rather than on planned strategic decisions at the ministerial or governmental level. This because the energetic features and needs of companies which belong to different economic sectors are extremely different. At last it is important to train the staff to correct execution of the mentioned practices in order to avoid inefficiency and to make an analysis of investments necessary to support the implementation of the Energy Efficiency Plan.

- Divulgation of reached environmental performances through an Annual Report. The report shows the results achieved, the environmental objectives and the future steps to be undertaken in order to improve continuously the organization’s environmental performance.

The Voluntary Energy Conservation Agreement is based on the principle proposed by the Environmental Management System (EMS). An EMS provides organizations with a method to manage systematically their environmental activities, products and services and helps to achieve their environmental obligations and performance goals. ISO defines an EMS as "the part of the overall management system that includes organizational structures, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy."

In other words, EMS provides a method of addressing and of managing immediate and long-term environmental impacts of an organization’s products, services and processes and gives order, consistency and environmental efficacy concerning to the allocation of resources, assignment of responsibility and evaluation of ongoing practices, procedures and processes.

The Energy Conservation Agreement, as it is showed in the figure below, involves the Environmental Management System in practice (Rakli 2005).

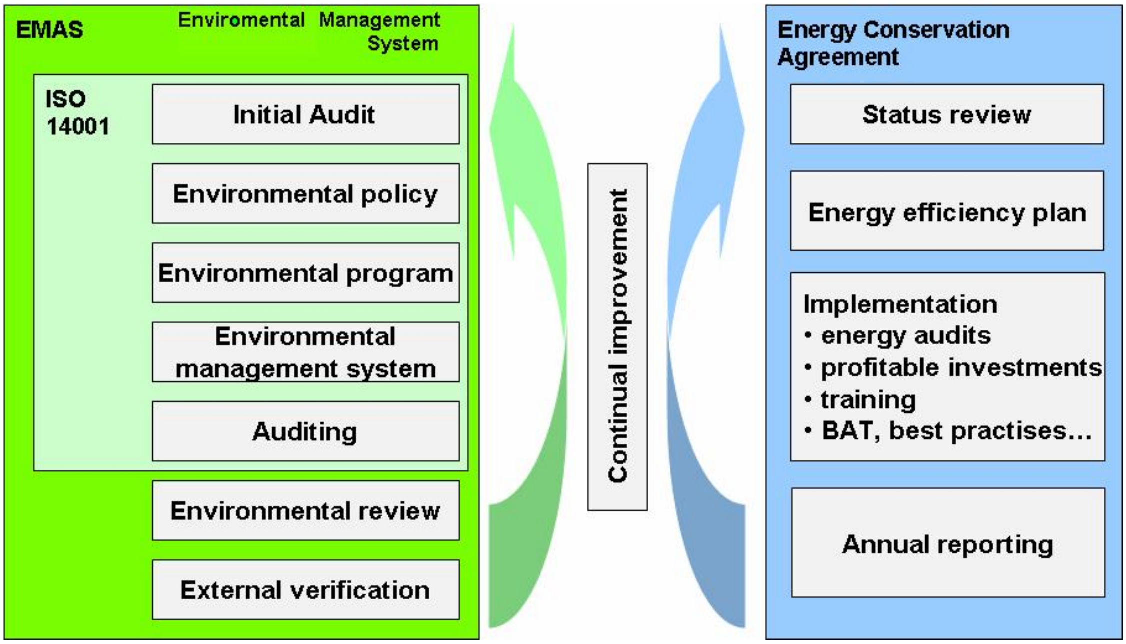

Figure 13: Energy Conservation Agreement involves the Environmental Management System in practice

An EMS can be implemented in many different ways depending on the precise sector or activity and the needs perceived by management, but several core elements are common in each case.

These elements, which are presented in the previous figure, are held in the EU Eco-Management and Audit Scheme (EMAS) which is a management tool for companies and other organizations to evaluate, to report and to improve their environmental performance.

On 7 September 2001, the European Commission adopted a Decision (EC No 2591/2001) by which the Commission becomes politically engaged in the process of applying the EMAS Regulation from each member State. Moreover, in consequence of the Regulation EC No 761/2001 of the European Parliament and of the Council on 19 March 2001, EMAS has been available to all the companies belonging to every economic sector either public or private, which want to implement an Environmental Management System.

These directives gave an answer to the raised problem which interested the European Community and that was well described by the words of Margot Wallström, European Commissioner for the Environment at the time:

> "[…] we will not solve environmental problems by simply adding a few new directives every year to our existing 270 or so pieces of European environmental law, especially if we discover later on that these directives are not implemented by the Member States […] we need an instrument to tackle ever more diffuse sources of environmental pressures […] We need instruments which:
>
> - Promote information, awareness and commitment with citizens and in the business community
> - Give the right incentives for environmental improvements in the market place
> - Ensure the integration of the environment into other policies."

The EMAS represents the instrument which is able to satisfy each of the previous point.
The scheme proposed by EMAS is based on a harmonized scheme throughout the European Union and adopting it, each company commits itself to evaluate and to reduce the environmental impact which derives from the productive process.
Member States are obliged to create the registration and the verification scheme at the national level including competent and accreditation bodies.
To receive EMAS registration an organization must demonstrate that not only their philosophies but also their investment strategies and day-to-day operations are environmentally sustainable.
ISO 14000 standard series fix clearly which requirements are necessary for establishing an environmental policy and, consequently, for obtaining the registration.
By implementing an ISO 14000 environmental management system you are demonstrating that you have identified your organization's environmental interactions and impacts, determined which should be controlled, placed those under control, and monitor and measure those controls to affirm their effectiveness and for this reason you are allowed to receive the EMAS registration; in other word ISO 14001 standard series helps you to meet continually relevant laws and regulations and to meet the needs and expectations of other stakeholders such as customers, regulators, and the general public.

The ISO 14001 standards are a series of international voluntary standards on environmental management. They are being developed by the International Organization for Standardization (ISO) for use by business. The ISO 14000 standard specifies requirements for establishing an environmental policy, determining environmental aspects and impacts of products/activities/services, planning environmental objectives and measurable targets, the implementation and the operation of programs to meet objectives and targets, checking and corrective action, and management review[5].

2.5 ISO 14000

ISO 14000 represents the common theoretical basement is for the implementation of the Energy Conservation Program which happens thanks to the different Voluntary Energy Conservation Agreements characterizing each sector.

According to ISO, the core scope of ISO 14000 standard series is:

> "…to specify requirements for an environmental management system, to enable an organization to formulate a policy and objectives taking in to account legislative requirements and information about significant environmental impacts."

This definition emphasizes the strong connection between the EMS and the standard series. Only the EMS, conform to ISO 14000, provides a consistent and systematic framework for improving environmental performance; this because ISO 14000 is specifically addressed to manage all those environmental aspects which the organization can control and influence. It fixes a method for the implementation of the EMS which involves employees in all departments and at all levels of the organization.

Another important aspect deducible from the definition is that the standards do not set any level of environmental performances, such as the greenhouse gas concentration in the air emission; these targets are connected to regulatory body which characterizes every country.

[5] *http://europa.eu.int/comm/environment/emas*

The objective is to present the key elements of the EMS which lead the environmental performances to meet the national environmental obligation and to pass them.

The basis for ISO 14000 and for the EMS is represented by the dynamic cyclical process which is described by the Plan-Do-Check-Act (PDCA) Cycle, also called the Deming Cycle, which is showed in the figure below.

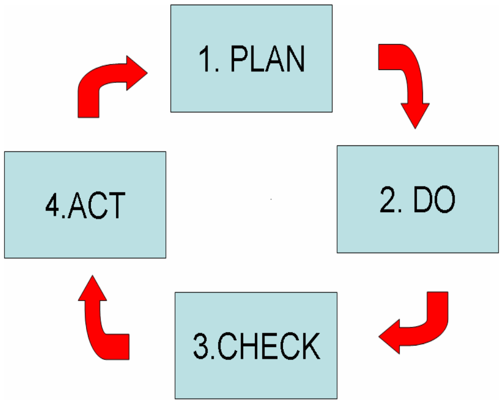

Figure 14: The Deming Cycle

It represents the process which coordinates the actions of an organization in order to continually improve all the performances.

It is possible to resume the way of operating of the PDCA cycle in five points:

1. To plan the Improvement.
2. To do (or to implement) the planned improvement.
3. To check the results to determinate whether the anticipated improvement occurred.
4. Evaluating on the results, to adjust the improvement by going through the cycle again. If it is already satisfactory, to make the improvement permanent and monitoring it.
5. To continue the cycle, refining the improvement or developing new improvements.

The model for EMS proposed by ISO 14000 is a variation of the PDCA cycle; it aims to begin and maintain in the time into an organization context the cycling process which leads to a continual improvement of the environmental performances.

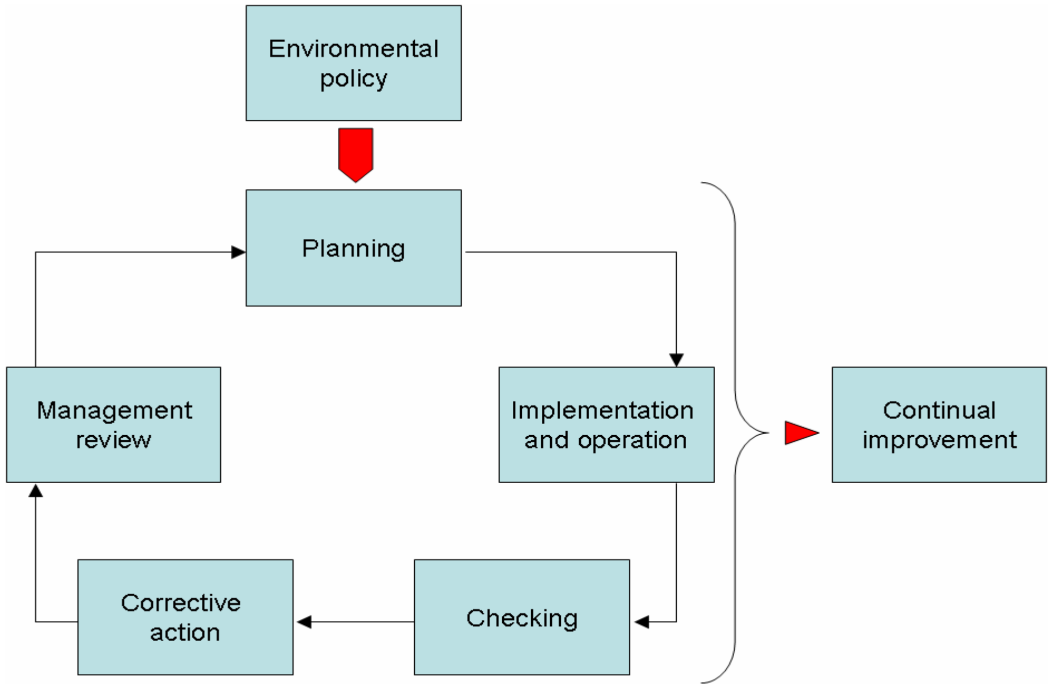

Figure15: Process of continual improvement proposed by EMS

The preliminary statement for the process is the definition of the environmental policy of the organization by the top management. The environmental policy is defined as a statement of the intentions and principles, in relation to the overall environmental performances, which provide to the organization a framework for setting the environmental targets and objectives. To be effective, the policy needs to be understandable to all the employers and for this reason it is documented and rendered available to the public; furthermore it is recommended that the policy be reviewed annually in order to reflect the changes that occur in the organization. It is important to mark that in the policy the goals are not defined but it is a driver for implementing the cycling process which leads the organization to a continual improvement.

The model proposed by the standards resumes the process in the following steps:

- Planning. In this phase the aspects which have significant environmental impacts are preliminary identified, looking at the activities, products and services performed by the organization. After this the environmental objectives are developed in accordance to the legal requirements and the environmental policy; then these objectives are translated in specific and quantified targets. The final phase of the planning is to establish environmental management program, which must identify precisely how each objective and target will be met, including assigned time frames and personal.

- Implementation and operation. The organization defines the EMS structure and responsibilities, through the appointment of the human resources, with the respective role, competence and duty, and economic resources which support and guarantee the effectiveness of the system; the top management has the responsibility in the choice of the suitable people for the purpose and provides to train them. In this phase a network is organized which manages the acquisition and sharing of the environmental performance of the system through an informative system which guarantees the internal and external communications. After that the core elements of EMS are defined, they are documented and summarized in manuals in order to describe how each part of the system operates and to evidence if the action has been performed.
- Checking and corrective actions. In this phase it is firstly led a monitoring of the system; it consists in a data collection and in a continual control of parameters related to the ongoing activities. These parameters are relevant for understanding the real environmental performance of the system and to find the eventual non-conformance which represents deviations from EMS requirements; the answer to these non-conformances is given a by good corrective and preventive action system which provides the best procedure for the problem solving. In this phase an Environmental Management system Audit is also defined. It is a systematic and documented verification process conducted in order to determine whether the EMS implemented inside the organization is conform to ISO 14000 and to determine the eventual gaps. It provides the essential information feedback to management.
- Management review. In light of environmental management system audit results and changing circumstance, the review process addresses the possible need for changes to policy, objectives and other elements of the EMS. The results and effectiveness of the process is strongly connected with the quality of the documentation which derives from the previous phases.

These elements make that continual improvements become a part of an organization because they involve everyone in the organization in changing in better the processes and in maintaining the control of the reached performance of the system. (Kinsella and Mc Cully 2005, Moiso and Tuominen 2003, Getsch and Davis 2001)

3 Energy Auditing

The aim of this chapter is to focus the attention on the implementation of Finnish energy strategy in the residential building sector. Beginning from an overview of the agreement which regulates the energy management in the sector, the main instruments and methods which characterize the agreement are presented and their effective applications in the residential building system are studied. Most contents of this chapter are based on interviews, documents and suggestions given by members of the following organizations:

- Motiva Oy: fully government owned company which represents the energy agency in Finland. The main services provided by Motiva regard the promotion of renewable energy sources and energy saving. One of the most important tasks of the company is the implementation and the promotion of Voluntary Energy Conservation Agreements (VECA) through the company which operates in sectors covered by the agreement. (Husu 2006)
- Rakli: The Finnish Association of Building Owners and Construction Clients. It is an interest group and trade association representing the most prominent real estate owner, investor and service provider in Finland. It collaborated with the Finnish Government in the elaboration of VECA for the property and building sector. (Aalto 2006)
- ASRA Ry: The Housing Estate and Constructor Association which has signed in November 2002 together with the Ministry of Environment and the Ministry of Trade and Industry, the Energy Conservation Agreement for the residential building sector. (Tasa 2006)

3.1 Voluntary Energy Conservation Agreement in the residential building sector

The residential sector in Finland is the second largest sector in the final energy use; in the year 2002 the residential sector represented 18 per cent of the total final energy consumption with 4,9 Mtoe energy use (ODYSSEE 2004).

The main contents of the energy conservation agreements in the residential building sector are the reduction of specific energy consumption and the introduction operational models that serve to make energy efficiency a part of everyday life in residential building companies.

In November 2002 the Ministry of the Environment signed, together with the Ministry of Trade and Industry and the Housing Estate and Constructor Association ASRA, an energy conservation agreement that has had a broad impact on energy conservation promotion in residential buildings. The aim is to reduce energy consumption by 15 per cent in about 290 000 residential dwellings by the year 2012.

The main sub-goals which are necessary for reaching this target are:

- To reduce specific consumption of heating and water by 15 per cent from 1998 by the year 2012 and to halt the growth of specific electricity consumption of properties which will start its decline before the year 2008.
- To audit and to include under consumption monitoring programme 80 per cent of energy consumption of housing property stock of communities participating in the agreement by the year 2010; at the moment the coverage of the agreement is 15 per cent of apartment blocks and of terraced housing stocks.
- To promote the moving over to renewable energy sources, particularly with reference to central heating boilers of individual properties or small-scale district heating systems.

The agreement does not fix only the targets but it purposes to the companies of the sector a method which leads to the satisfaction of the long time objectives. It gives a systematic approach for enhancing the energy management which permits to put the energy related activities inside the Environmental Management System of the company; for this reason, the agreement is rooted to the idea of continual improvement of the environmental performances of the organizations, connected to the analyzed ISO 14000 standard series.

The following four steps summarize the approach proposed:

1. To fix the energy targets and times of the energy saving project of the company which attunes the energy saving targets and times belonging to the agreement.
2. To organize inside the company an operative structure with suitable resources for leading the project.

3. To do the energy audits.
4. To implement the energy saving methods founding on the results of the energy audit.

Energy audits have a key position in the practical implementation of voluntary energy conservation agreements because it has proved to be an effective and concrete method to achieve rapid improvements in energy efficiency in the building process. Motiva Oy has taken a central role in developing energy audit activities and programs in Finland and in Europe too; it coordinated the first European study on energy audit called “Energy Audit Management Procedures” which belongs to SAVE II programme launched by European Community in order to develop and to disseminate ways of ensuring rational use of energy.

3.2 Energy Audit in general

3.2.1 Definitions on Energy Auditing

An Energy Audit is defined as a systematic procedure that obtains a knowledge of the existing energy consumption profile of the site (which is the building in the case it is applied in the building sector), identifies the factors that have an effect on the energy consumption and identifies and scales the cost-effective saving opportunities. This procedure is summarized in three steps which represent the basic requirement of all energy audit (Core Audit):

- Evaluating the present energy consumption.
- Identifying of energy saving possibilities.
- Reporting audit.

Except these steps, the energy audits are extremely different according to the various purposes for which they are designed. A Basic Energy Audit Model is the Core Audit in which the scope, the thoroughness and the aim of the work have been defined.

Moreover the energy audit normally has several additional elements around the Basic Energy Audit that depend on the specifics of the system, in which it is implemented, and that characterized the effective application of the energy audit. The complex system that includes either the Basic Energy Audit Model or its interfaces constitutes the entire Audit System, as it is showed in the next figure (Väisanen 2002).

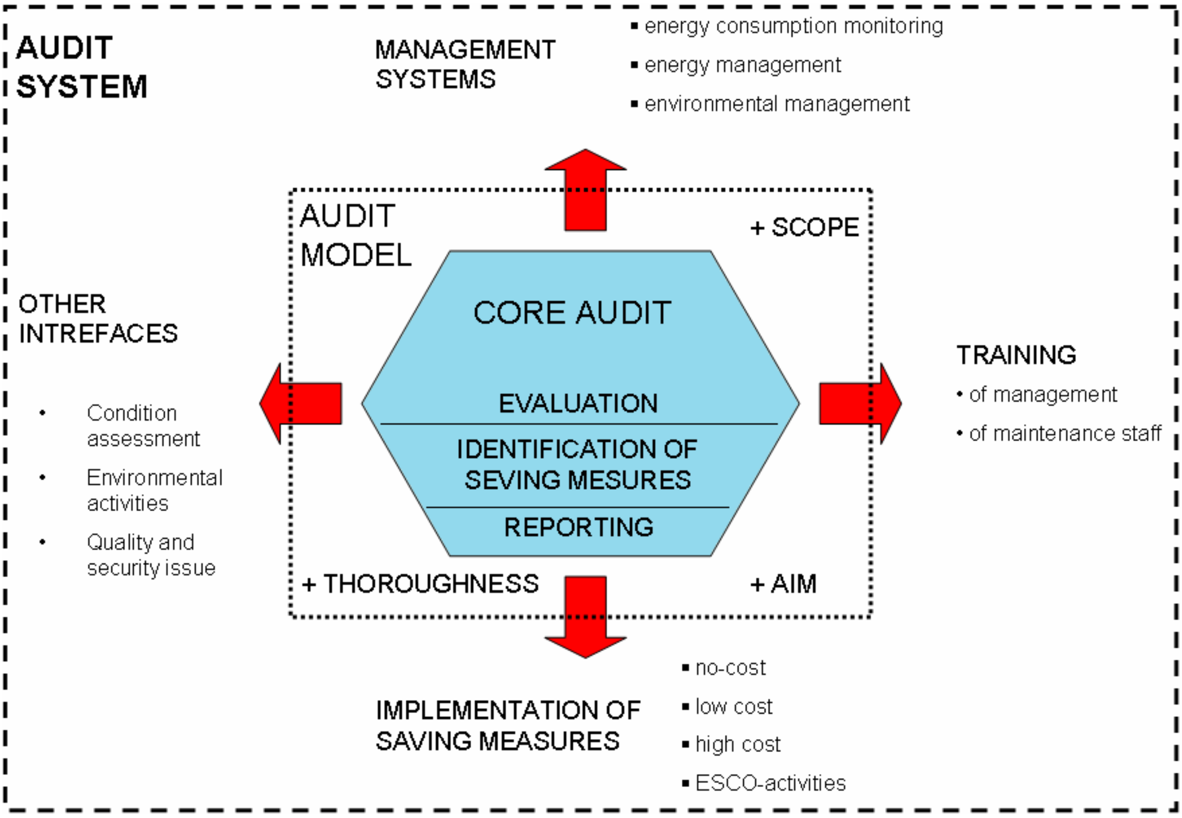

Figure 16: The interfaces of Core Audit

The Energy Audit Programme is the way for implementing the Audit Model in order to support the national energy efficiency and management policy. The programme involves different responsibility levels and different players which work in collaborative way with the aim to guarantee the coherence between the practice of audit and the energy saving targets fixed by energy policy through Voluntary Energy Conservation Agreement.

There are always four key players in an Energy Audit Programme: the Administrator, the Operating Agent, the Auditor and the Audit Client.

The Administrator is the responsible for the execution of national energy policy, setting the Energy Audit Programme goals and guidelines, promoting the use of energy audit model, providing subsides for the energy audits; in Finland the Energy Audit Administrator is represented by the Ministry of Trade and Industry.

The Administrator usually nominates an Operating Agent (OA) to take care of the Every-day activities in the program and who is responsible of the actual running of it. The OA undertakes the monitoring of the results of energy auditing, provides advice and training to auditors, takes care of the quality control and of the information transfer between the Administrator and the auditors. Usually it is represented by a non-profit organization; in Finland the OA for the energy audit program has been Motiva Oy since 1993.

The Energy Auditor is a technical expert in energy end-use issues, such as thermal and electrical issues, and is the one that undertakes the actual auditing work in the client's building. It is certified to perform in energy audit by the OA and could receive some financing by the Administrator.

The Audit Client is the person or organization that is responsible for the energy cost of the building and who expects to gain some profits from the audit. The benefits that the Audit Client has from an Energy Audit can be:

- Financial benefits that derive from the reduction of operating costs connected with the energy saving, from the eventual financial subsides and from the increase of company image length with the company environmental performances.
- Organizational benefits which assist the administrator of a building to improve the productivity and the building process because of the reform of the decision making process.
- Environmental benefits which derive from the reduction CO2 emissions caused by the on-side energy use.

These key players form a closed system aimed to manage the Energy Audit. Except the Administrator, each actor of the system interacts with the previous and following one, sharing information and resources; the Administrator takes care of coherence and integrity of the entire system, interacting and controlling the actions of each actors. The following figure resumes the system, marking the relations between the different key players.

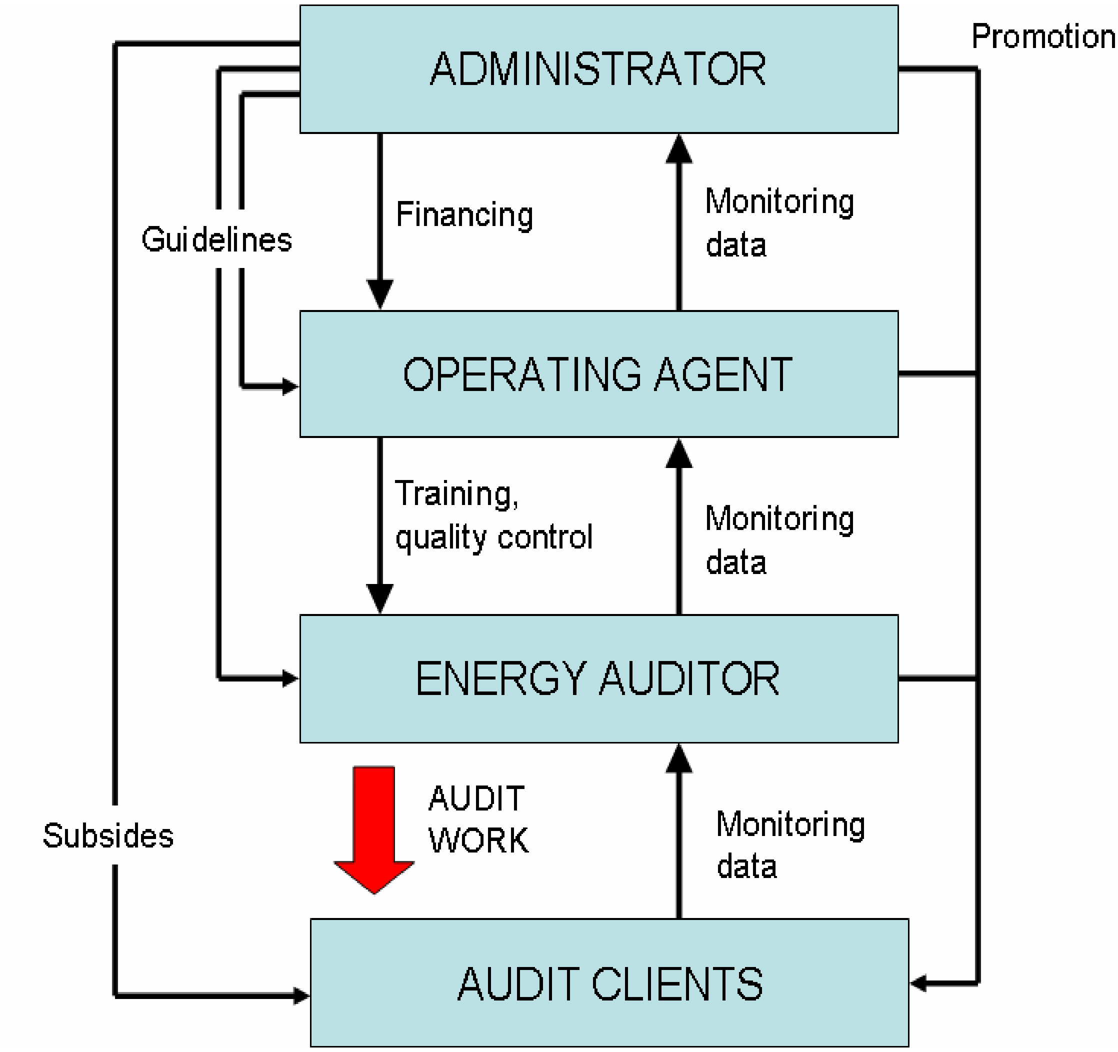

Figure 17: The key players in an Energy Audit Programme and their roles

The data which come from the work of energy auditing of energy use in the site, represent the most important feedback for evaluating the performances of each actor and of the system as a whole; for this reason they ascend the system from the Audit Clients to the Administrator. The results of audit are not only used in the evaluation of the status programme, in fact the main reason of the monitoring is to see what kind of results can be achieved through energy auditing. For this reason the monitoring includes the collection of various data such as audited building volumes, actual energy status of the building and energy saving possibilities.

3.2.2 Basic Energy Audit Models

The choice of the Energy Audit Model to be taken in use is made by the Administrator and it consists in fixing the scope, the thoroughness and the aim of the Audit Program. The choice is made taking in account the main peculiarities which characterize each of the previous features.

The scope of audit may be different because it depends on the ways used for covering the building; at the narrowest the energy audit covers typically only one item or a process of the system and at the widest it covers everything inside the site fence. Between these extremes, there are energy audits that ignore some areas or issues.

Also the thoroughness of audit model, from which depends the thoroughness of the audit, may be different because the auditor can use a fine or a rough comb when he is looking for saving potential. It is directly related to the cost and the time spent to the project.

At last the energy audits are used for different purposes, either for pointing out the areas where saving can be found or for describing in detail the actual saving measures. For this reason the aim may be either scanning the areas of possible energy saving or analysing in detail the individual energy saving measures. These properties of energy audit models are illustrated in the following figure:

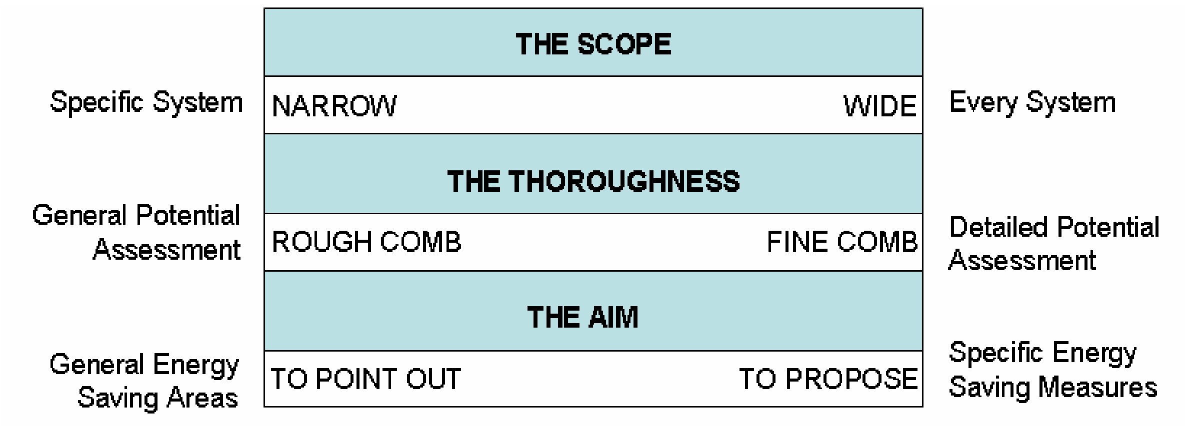

Figure 18: The properties of Energy Audit Models

The Energy Audit Models are divided in two main classes according to the aim: to the Scanning Energy Models and to the Analysing Energy Model. Within these two classes the different models have been specified according their scope and thoroughness.

The main aims of a Scanning Energy Models (SEM) are to point out areas, where energy saving possibilities may exist and also to point out obvious saving measures which could be “good housekeeping” and other no cost measures. The scanning audit does not go deeply into the areas pointed out or into the suggested measures, because it is led having a very limited budget; before any possible action that can be undertaken, it is necessary a further and more specific energy analysis, calculation and measurement. The two main important models which belong to SCM are:

- Walk-Through Energy Audit (WTEA) which is a scanning model typically used in not large site like single family home where the energy consuming systems are quite simple to forecast and the probable areas for potential energy saving measures are known in advance. It mainly consists in giving an overview of energy use in the site, producing an estimation of the obvious saving potential, producing a brief documentation which may include a rough consumption breakdown and some suggestions about the next step for a more detailed analysis. Even if the WTEA may sound like an easy task, it is very typical that the actual time for conducting this kind of audit is very limited and for this reason the auditor should be experienced because s/he is forced to make rapid decisions. The client participation to the audit activity is not essential like in the following model.
- Preliminary Energy Audit (PEA) which is applied in large site such as residential buildings; for this reason, although the main aim of the audit is the same of the previous one, a different approach is required because of the size of the site. In fact in large residential buildings only some areas and systems can be analysed in advance like probable sources of energy saving potential. For this reason most of the work in the PEA consists in building up a reliable breakdown of the present total energy consumption and in defining the areas of the significant energy consumption and usually also of the probable energy saving measures. This kind of audit, carried out by an energy audit team with experts in mechanical and electrical systems and process energy use, requires a strong commitment from the client’s organization and the final report is complete on the energy breakdown but brief on the recommendations.

The Analyzing Energy Audit Models produce detailed specifications for energy saving measures, providing the audit client with enough information for decision-making. Audits of this type are more expensive, require more work and a longer time-schedule but bring concrete suggestions on how to save energy. From the client's point of view the saving potential can be seen and no additional surveys are needed. The analyzing energy audit models can be divided into two subclasses according to their scope: "horizontal" and "vertical" models.

In the horizontal model, the audit covers only one device or process which characterizes more subsystems belonging to the building, and ignores the rest of the site; for example this audit takes in consideration the only production process of the heating energy which is provided to the hot domestic water, heating and cooling subsystem.

The vertical model covers, from the energy point of view, the whole building taking in consideration all devices and processes which characterize all the subsystem belonging to the site.

The figure below explains the differences between the vertical and horizontal audit.

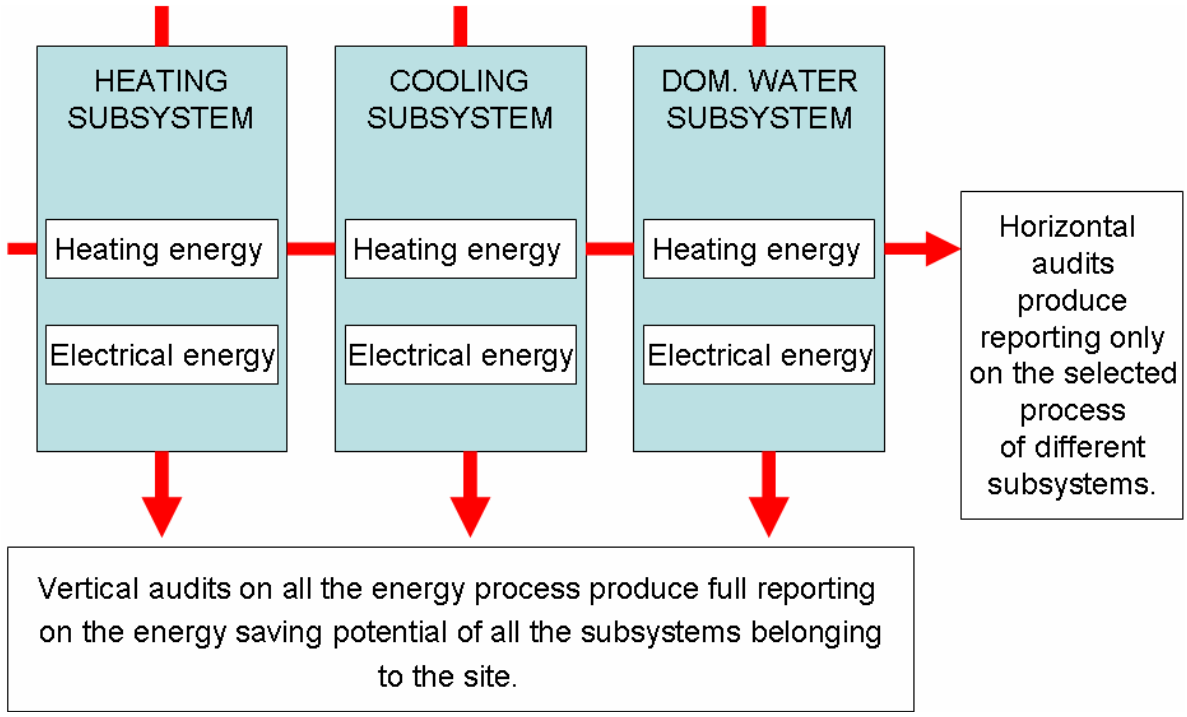

Figure 19: Vertical and horizontal audit

The system Specific Energy Audit belongs to the vertical model. The audit is normally carried out by a specific expert whose knowledge are concentrated on a particular field concerning the building; it produces a detailed description of the system, suggesting energy efficiency measures but it does not comment the total energy use of the site. The benefits of this audit model is that it is possible to have the best expertise on the work but on the other hand some problems may arise in the implementation of the suggested measures, because the building companies are not so motivated to carry out individual measures but prefer a master plan also for energy efficiency improvements.

As regards to vertical models, there are three main alternatives, based on the different decisional freedom of the Auditor in the audit process and on the area considered in the audit procedure. They are:

- Selective Energy Audit where the Operating Agent fix only overall goals and general guideline of the audit and the Auditor has the total freedom to choose which area will actually audited (scope) and the accuracy of the audit (thoroughness). Even if this model belongs to vertical model, the Auditor cold select which subsystem that belongs to the building, will be object of analysis; moreover the model looks mainly for the main and most obvious saving measures, ignoring that one which requires a more detailed analysis. This audit model is very cost-effective especially when it is lead by an experienced auditor but there is always the risk that when something significant is found the rest could be ignored. From the Operating Agent's point of view this model is problematic because the quality control of is difficult.
- Targeted Energy Audit in which the Operating Agent sets detailed guidelines fixing the scope and thoroughness of the audit procedure. The word target means that some subsystems are ignored because they are considered irrelevant by the Operating Agent because they are know to be normally non-cost-relevant; it is necessary to know in advance and in detailed way all the system, in order to exclude some areas. This kind of audit produces an energy consumption breakdown and includes calculation of energy savings measures and investments. From the Operating Agent point of view in the Targeted Energy Audit the quality control is vary important, in fact, if it is neglected, the Auditor's work tempt to move towards the Selective Energy Audit because this model always includes less work.

- Comprehensive Energy Audit which covers all the energy usage of the site, including the including mechanical and electrical systems, process supply systems, all energy using processes, etc. This audit model can also be described as “everything inside the fence” -model because the overall aim is to locate and specify all energy saving possibilities within some range of profitability. The word “comprehensive” in this case means that after the audit there are no areas where the saving possibilities have not been looked for because this audit produce a full diagnostic assessment of the site from the energy point of view. The Comprehensive Energy Audit is very suitable for most residential building. (Lytras and Gasper 2003)

3.2.3 Energy Audit Model Improvement Process

The model adopted for carrying on the energy audit of building might be changed during the time. In fact it is important to remark that the energy auditing process is coherent with the idea of continual improvement which leads every processes dealing with the energy management. The energy audit model improvement process is a dynamic process that can involve all the key players belonging to Energy Audit Programme because it is made possible by the information shared by all the actors. This information that cross the key player’s system represents the fundamental feedbacks for enhancing the energy performance of the site through the adoption of a more effective model. There are two main different reasons for changing the audit model that are:

- Inefficiency belonging to the lower level of key player’s system. This kind or reason for example justify the passage from a Scanning Energy Model to an Analysing Energy Model in the case that the first model is considered no more efficient because it is not too accurate for analysing and improving the energy efficiency of the site.
- Necessities of a new model more suitable for meeting the energy efficiency requirement which come from the energy policy. In this case, a new audit model is developed trying to improve the efficacy of the past ones.

In both case, the main inputs which permits that improvement process of the audit model begun, are the energy feedbacks from auditors and from quality control.

In the first case, especially the Energy Auditor and the Operating Agent are involved in the process, which manly consist in an analysis of the inefficiency of the old model and the chose of a new one, among the existing models, which is able to face and solve that inefficiency.

In the second case, the process is more complicated because of the presence of a testing phase. The Administrator supervises and manages all the process, availing his self of the comments and suggestions which comes from the Operating Agent and the Energy Auditor. The flow chart below summarizes the following steps which lead to the continual improvement of energy audit model in the two cases. (Reininkainen and Väisänen 2002)

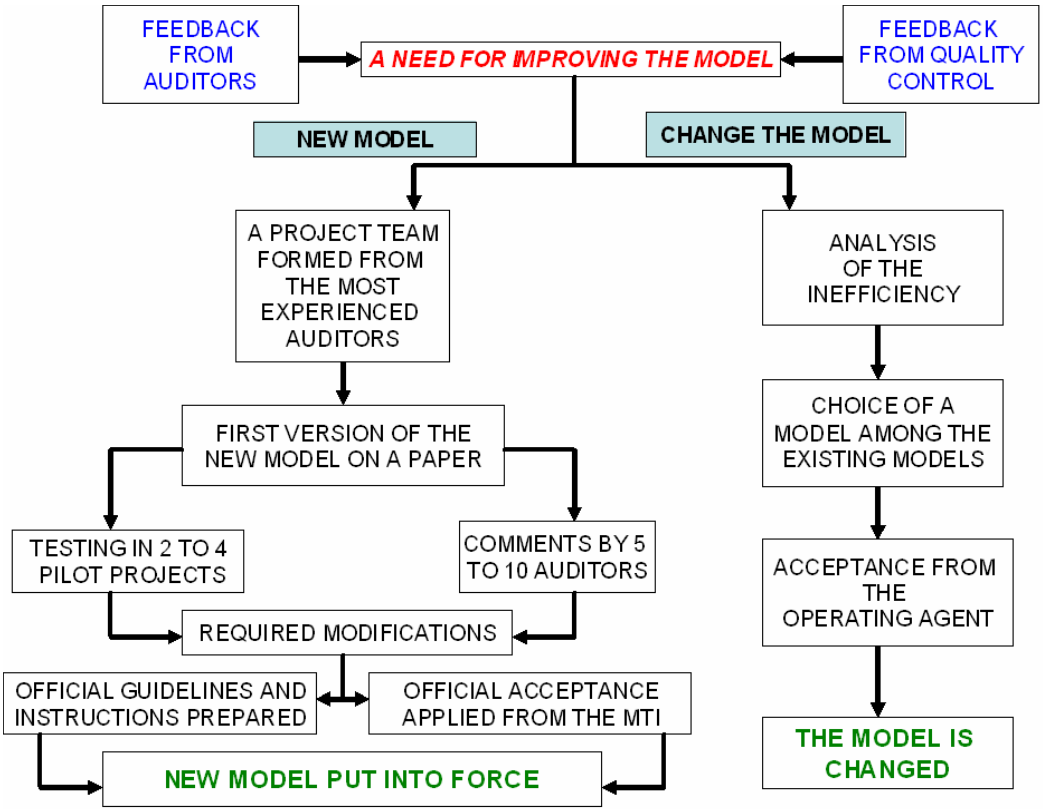

Figure 20 Energy Audit Model Improvement Process

3.3 Energy Audit of Residential Building

3.3.1 Choice of the audit model

The choice of the audit model is the first fundamental stage in the designing phase of the auditing process for a residential building and it is strongly connected with the scope, the thoroughness and the aim of the audit. The definition of the model and the audit tool for supporting it represent the basement for involving the audit activity through a practical procedure.

The "box-model", which is showed in the figure below, is a very useful tool for supporting the choice of the model during the audit designing phase. It schematizes the technical content which belongs to the energy audit; on the basis of this technical content, it is possible to select the model that is more suitable for expressing it.

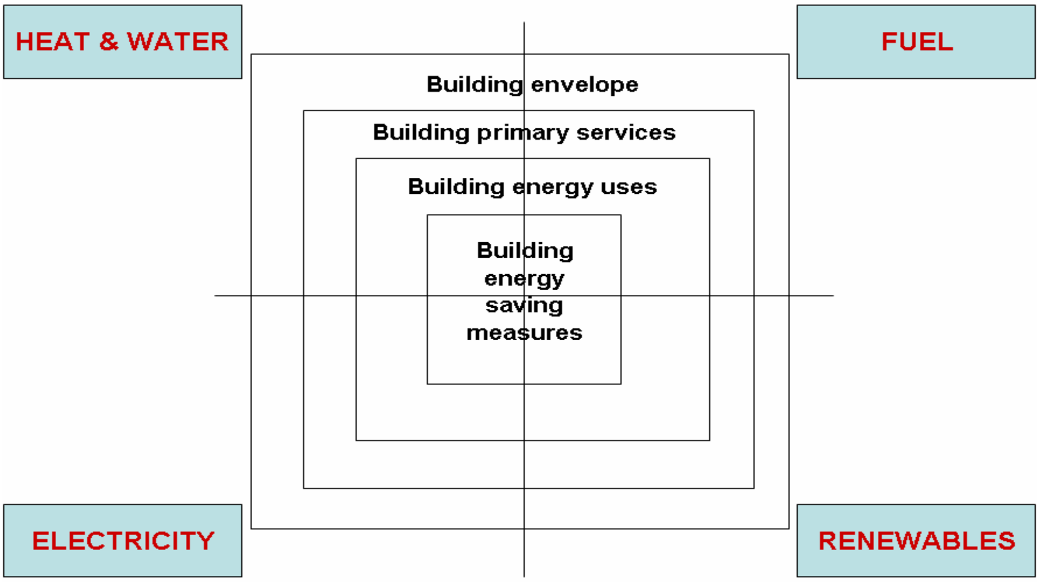

Figure 21: The box-model

In the corner of the model there are the four finally energy sources consumed during the utilization phase of the building, that are heat & water, electricity, fuel and renewable. The heat and water belong to the same category because in the most of Finnish residential constructions the means for transporting the heat inside the building is the water (district heating); moreover the renewable is considered in the scheme, because it represents a valid alternative to the fuel even if its use is not common in the residential sector.

The core of the model consists in the four boxes which represent the main research fields from the energy point of view of a residential building. This means that, the most important energy consumptions of a residential building are connected with these areas which become the research aim of the energy audit, and one or more energy sources could be involved in the energy analysis of each area. The four boxes are:

- Building envelope. In this area the research is focused mainly on the heat & water energy consumptions.
- Building services. These services are guaranteed services, common to each residential building such as streaming water, central heating and electrical system. This kind of services are distributed the buildings thanks to a central provider (such as the pump or the boiler) and for this reason are called centralized services.
- Building energy uses. This research field is connected with the energy consumptions connected with the specific uses of the building services during the running phase of the building. It is important to remark the difference between this research field and the previous one. The research about the building services aims to study, from the energy point of view, the services provided to all the occupants such as the electrical ones; now the study focus the attention on the effective use of this services. For example the electrical appliances are object of analysis, finding the distribution of electrical consumption between them, such as the rate of electrical consumption caused by the lighting system.
- Building energy saving measures. In this area the research takes aim at finding the best alternatives for decreasing the energy consumption, choosing the best solutions in the use of each energy source.

In the energy audit designing phase, the research field and the energy sources involved in the research are chosen, defining the scope, the thoroughness and the aim of the audit. The choice is supported by the use of the “box-model” which gives to it a visible and comprehensible aspect, defining clearly the technical content of the audit which is consequent to the decision; after this, the model that is more able to express the content is selected.

For example if the scope of the audit is to find the potential energy saving main areas among all the energy sources of a residential family house, analyzing only the energy consumption connected with primary services (the thoroughness is rough) and without searching any energy saving measures, the "box-model" appears as follows.

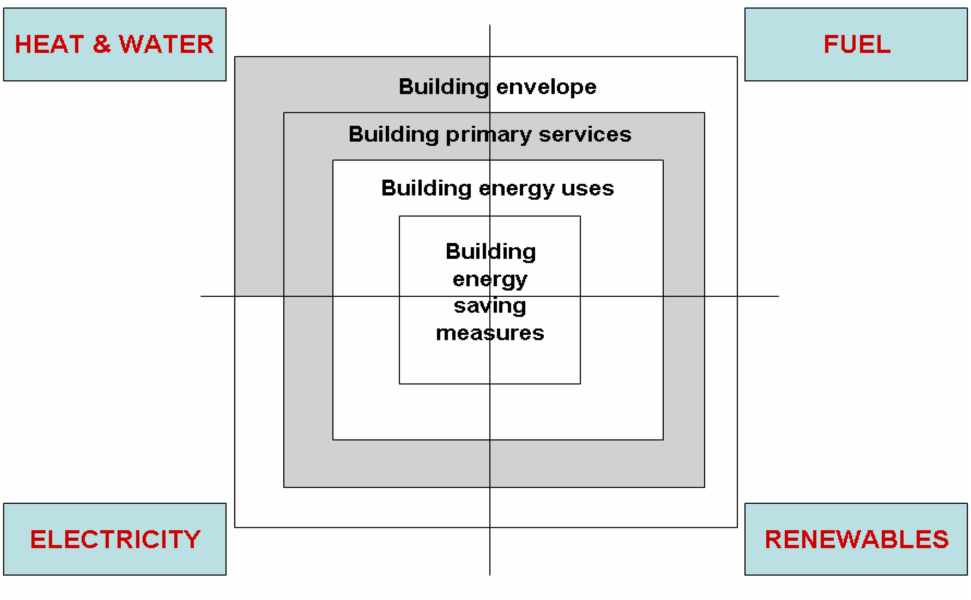

Figure 22: First example of the box-model application

In this case the audit model that is more suitable for expressing the technical content resulting from the previous choice certainly belongs to the family of Scanning Energy Models such as a Walk-Through Energy Audit.

If the scope of the audit is, in the beginning, to find, inside the building, the main consumptions of all energy resources and after to focus the attention on the electricity resources, researching also the saving electrical measures, the resulting "box-model" appears as follows.

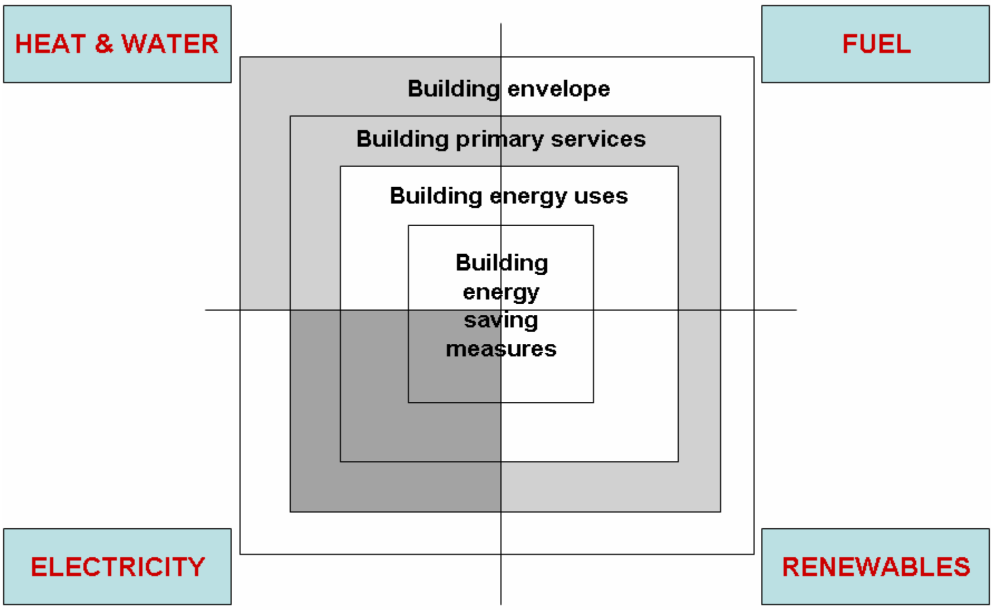

Figure 23: Second example of the box-model application

In this case, the energy audit is led, in the beginning, on the basis of a model belonging to Scanning Energy Models in order to individuate the main energy consumption sources; after, a more deeply and accurate research in the area of electricity consumption is supported by an Analysing Energy Model. Moreover, since the research involves only a specific energy source, the suitable model is a Horizontal Model such as a Specific Energy Audit.

Comprehensive Energy Audit is the most used audit model in the residential sector because it is the most exhaustive but also time-consuming energy audit type. The technical content of a Comprehensive Energy Audit is illustrated by the following “box-model” which remarks the “everything inside the fence” quality of this model since it covers all the energy usage of the building.

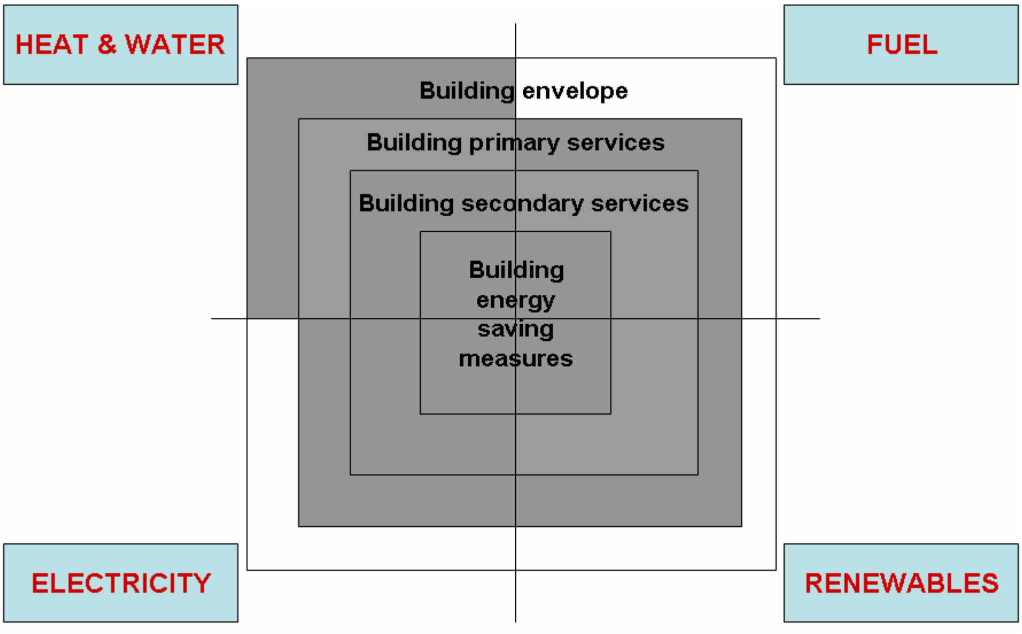

Figure 24: Third example of the box-model application

This kind of model will be analyzed after in details. (Väisanen 2002)

3.3.2 Choice of the audit tools

Once that the model has been chosen, the main audit tools for implementing it are selected. It is possible to group these tools in two classes.

The applications that are common to the energy audits applied in all of the energy sector (not only of the residential one) belong to the first class; they are intended to facilitate the work of auditors in view of both minimizing audit costs and maximizing audit quality. These kinds of applications are mainly documents and they are used also in order to give a documental prove, during the quality control, of the effectiveness of the auditor's work and to support the process of continual improvement of all the audit processes and procedures beginning from the acquired and standardized knowledge.

The principal examples of tools that belong to this class are:

- Audit guide and energy management handbook. These documents are the basis for the training sessions. They explain and describe how an audit is to be made, how the calculations are to be conducted, the types and contents of the most frequently proposed energy conservation options (ECOs). Although auditors are supposed to have a fair background in thermodynamics (and also electricity), these handbooks frequently entails a section of reminders of these energy related topics.

- Energy check-lists. These supports are developed in order to facilitate the work of the auditor, assuring in the same time both quality and rapidity of the survey. The check-list is a list of actions and features that should be considered during the audit process because they help the auditor to better understand what s/he is evaluating and to choose the best energy saving measures. Moreover, what it is specified in the EA model as expected results should be reported because the check-list is an easy way to verify that the work has thus been done accordingly to the specifics. In the energy audit of the residential building the energy check-lists mainly focus the attention especially on the research of areas that are responsible for the most important energy consumption, indicating also the technical solutions and best materials for improving the energy performance of the construction.
- Data bases on energy conservation options (ECOs). One difficult part of the audit is having detailed information on costs and implementation side aspects or consequences of energy saving recommendations. A data base of ECOs encompassing this information will save a lot of time and money to the auditor and thus helps to lower the cost of the audits with a maintained quality. Keeping the data up to date requires quite a lot of work from the operating agent auditor which is the figure responsible for the managing of the data base.

The second class includes the energy audit tools which are strongly connected to the residential sector. Specifically, it includes:

1. The instruments to measure energy use for the whole building and for some energy system within the building such as the lighting or heating system.
2. The use of computer simulation program in order to evaluate the different energy saving opportunities.

The techniques available to perform measurement for an energy audit are diverse and they depend on the kind of data which is the object of the analysis. During an on site visit, hand-held and clamp-on instruments can be used to determine the variation of some building parameters such as the indoor air temperature, the luminance level, and the electrical energy use. It is evident that these techniques are useful if the analyzed data can be collected thanks to a direct measurement. Other kinds of data require the study of the temporal trend provided by long-term measurement. In this case sensors used for the survey, are connected to the data-acquisition system in order to store and check remotely the measured data. Recently, non intrusive load monitoring (NILM) techniques are preferred for leading these measurements. The NILM techniques can determinate the real time energy use of significant electrical loads in a facility using only a single set of sensors at the facility service entrance to monitor the energy consumption. In contrast to other systems based on the traditional sub-metering approach which requires separate set of sensors to monitor energy consumption for each end-use, the NILM reduces sensor costs by using relatively few sensors strategically located, like in electrically service entry. It is evident that the long-term measurements necessitate more costs, even if they produce more useful data for the auditing process especially for the phase of research of saving measures; for this reason this kind of measurements are preferred when the audit model adopted belongs to the family of the detailed audit model (Analyzing Energy Audit Models).

Computer simulation programs used in energy audit of residential building can provide the expected energy consumption trend which results from the adoption of different energy saving measures. In Finland the most common software tool for an energy auditor is MOTIWATTI 2.0 developed by Motiva Oy. The building to be audited is modelled into the programme trying to reproduce the energy feature of the construction. When all systems have been reproduced and the theoretical consumption equals the measured consumption, the auditor can be quite sure that the model is coherent with the real case; then s/he can start the simulations on individual energy saving measures in order to evaluate the energy effectiveness of each of them. Moreover the emissions of used energy sources can be defined and in addition to energy units and costs, the software will also calculate reductions in CO2 for each energy saving measure. The MOTIWATTI 2.0 has also the two standard reporting tables, which are required from the auditor as a part of the reporting.

The following flow-chart describes which the locations of the audit tools are, through the different phases of an energy audit of a residential building.

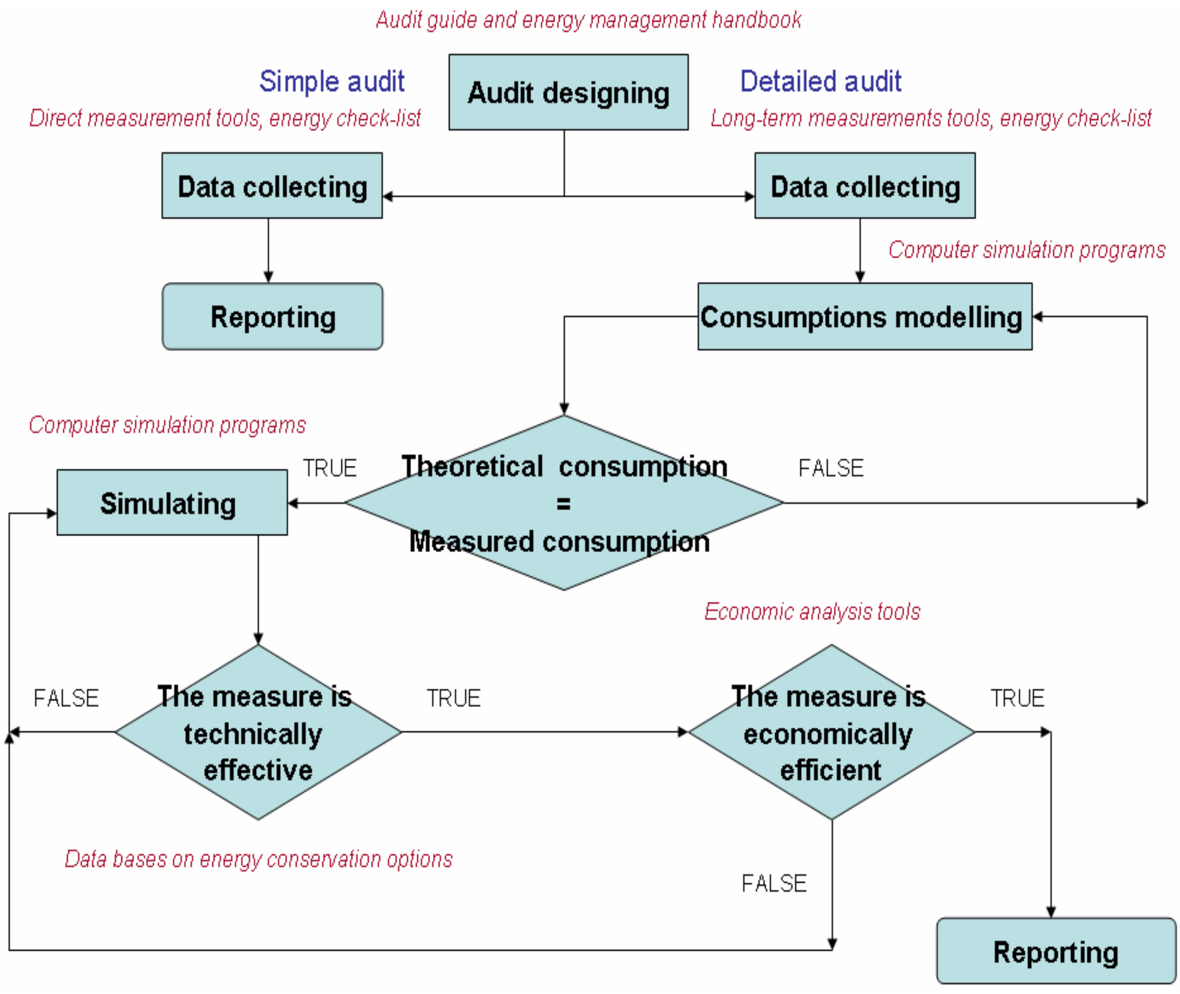

Figure 25: Location of energy tools through the different phases of an Energy Audit

As it is showed in the flow-chart, the choice of energy saving measures is not only related to the results of the simulations provided by the software; in fact the technical effectiveness has to be joined to the economic efficiency and for this reason a rigorous economical evaluation of the energy conservation measures is performed. Specifically, among the economic analysis tools, the life-cycle cost analysis is usually preferred to the simple payback period analysis because it takes in count a bigger number of economic parameters such as interest, inflation and tax rates.

3.3.3 General procedure for a Comprehensive Energy Audit

After the choice of the audit model and tool, the auditing process, could be implemented in practical actions which form the auditing procedure.

As it is reported in the pervious paragraphs, the Comprehensive Energy Audit is the most accurate energy audit model of residential buildings; for this reason the procedures that refer to other models can be considered simplifications of that auditing procedure. The procedure for a Comprehensive Energy Audit of residential building is articulated in a sequence of three steps, which are:

1. Building Energy Data Collection and Analysis;
2. Construction of a Building Energy Model;
3. Identification and Evaluation of Energy Saving Measures.

During the first step the energy data are collected and after analysed in order to get an energy scenario of the building as a whole which will be the basement for further research in the field of saving measures. The building energy data, which are the object of the analysis, belong to two different typologies of data: data concerning the energy features of the building and data concerning the present energy use in the building. The first typologies of data are deducible, besides from building structural characteristics, from the energy use pattern which allows the energy auditor to determinate if there are any seasonal and weather effects on the building energy use through the analysis of the historical variations of the energy use. The building characteristics can be collected from the architectural/mechanical/electrical drawings and/or from discussions with building operators and the energy use patterns can be obtained from the collection, over several years, of facility energy bills. Some of the tasks that can be performed in the analysis of these kinds of data are presented below with the key results expected from each task noted:

- Collect of the building energy consumption data of the last three years, in order to identify a historical energy use pattern
- Identify the energy sources used (electricity, oil, natural gas, etc) in order to determinate the energy sources that accounts for the largest energy use
- Perform the energy analysis of the building facilities in order to understand what rate of energy consumption is due to each subsystem and services

- Analyze the effect of the weather on energy consumption in order to find any variation of energy use related to weather conditions

The data concerning the present energy consumption are collected through an on-site survey and the main tasks involved in their analysis are:

- Check the current operating and maintenance procedure of the building services which are responsible of the main energy consumption of the building
- Determinate the existing operating condition of major energy use equipment such as lighting, HVAC system, motors, pumps, etc.
- Estimate the energy behaviour of the building occupiers through the analysis of energy consumptions imputable to equipment and lighting. This kind of estimation is led determining the energy use density of the building [kcal/mˆ2], which is the ratio between the average of global daily energy consumptions and the total mˆ2 of the building which are available to the occupant.

In the table below the main results that derive from the Building Energy Data Analysis are summarized. The results are divided by typology of data analyzed and only those ones that interest the thermal and electric systems are considered, because these systems are responsible of the most important consumptions in a residential building.

Typology of data	Thermal systems	Electric Systems
CONCERNING ENERGY FEATURES	• Thermal energy use profile • Thermal energy use per unit area • Thermal energy use distribution • Fuel type used • Weather effect on thermal energy use • Facility rate structure • Construction materials(thermal resistance)	• Electrical energy use profile • Electrical energy use per unit area • Electrical energy use distribution (cooling, lighting, equipment, fans) • Weather effect on electrical energy use
CONCERNING ENERGY USE	• HVAC system type • Domestic Hot Water (DHW) System • Hot water use for heating • Hot water used for cooling • Hot water for DHW • Hot water for specific application	• HVAC system type • Lighting type and density • Equipment type and density • Energy use for heating • Energy use for cooling • Energy use for equipment • Energy use for water distribution

Table 2: Main results of Building Energy Data Analysis

The main purpose of the second step is to develop a base-case model that represents the existing energy use and operating condition for the building. This model is to be used as a reference to estimate the energy saving incurred from appropriately selected energy conservation measures. The major tasks to be performed in this step are:

- Obtain a review architectural, mechanical, electrical, and control drawing.
- Inspect, test and evaluate building services for efficiency, performances and reliability.
- Obtain all occupancy and operating schedules for equipment.
- Develop a basic model for the building energy use.
- Calibrate the basic model using more accurate data.

The first three tasks could seem to be similar to those ones belonging to the previous step but the point of view of the auditor is different; in fact, if during the Building Energy Data Analysis, the data were collected in order to be analyzed for leading a qualitative study of the energy scenario of the construction, now the data are used for building a model which can reproduce the real situation in an effective way. The main difference consists specially in the accuracy of the data that increase during this step so that the model may forecast the evolution of the building energy scenarios according to different saving measures.

In the last step, a list of cost-effective energy conservation measures is determined using both energy saving and economic analysis. To achieve this goal the following tasks are recommended:

- To prepare a comprehensive list of energy conservation measures, using the information collected in the first step.
- To determinate the energy saving which due to the various energy conservation measures pertinent to the building, using the energy simulation model developed in the second step.
- To estimate the initial cost required to implement the energy conservation measures.

- To evaluate the cost-effectiveness of each energy conservation measures using an economical analysis method such as life-cycle cost analysis.

In the table below the main results that derive from the Evaluation of Energy Saving Measures are summarized, focusing the attention on the thermal and electric system. (Krarty 2005)

Phase	Thermal systems	Electric Systems
EVALUATION OF ENERGY CONSERVATION MEASURES	• Heat recovery system • Efficient heating system • Temperature Setback • Energy Management Control system • HVAC system retrofit • DHW use reduction • Cogeneration	• Energy efficient lighting • Energy efficient equipment • Energy efficient motors • Energy Management Control system • HVAC system retrofit • Temperature Setup • Energy efficient cooling system • Thermal Energy Storage system • Power factor improvement • Reduction of harmonics

Table 3: Main results of Evaluation of Energy Saving Measures

4 Energy Saving Measures

The aim of this chapter is to show the common measures and techniques adopted by the building companies either in the designing phase or in the maintenance phase of a residential building, for decreasing energy consumptions.

A big part of the content of this chapter has been elaborated on the basis of the information acquired from interviews given by members of the following Finnish companies that operate in the residential sector:

- Skanska Oy. Skanska Oy is a global Finnish construction services group committed to find innovative solutions for its customers. (Nuorkivi 2006)
- NCC Oy. NCC Oy is one of the leading Finnish construction and property development companies which operates in the entire Nordic region. (Hautamäki 2006)

The choice of the saving measures is the last stage of the energy auditing process and for this reason it is strongly connected with and dependent on the work led in the previous stages.

The “box-model”, used for choosing the audit model, expresses the technical content which shall belong to the audit. This technical content is summarized by the research areas and the future audit work is conducted inside the fence of the chosen areas. For this reason also the energy saving measures too could be grouped, according to the research areas from which they come from, in:

1. Saving measures which interest the building envelope.
2. Saving measures which interest the building primary services.
3. Saving measures which interest the building energy uses.

They represent the concrete results of the entire audit process whose performances are judged through the evaluation of the efficacy and efficiency of these measures.

In the following paragraphs of this chapter the most important techniques that belong to each group are presented trying to mark the main characteristics for each of them.

4.1 Building envelope saving measures

The building envelope is constituted by walls, roofs, windows and doors and it can have an important impact on energy consumptions for residential buildings. Indeed the energy use of residential buildings is dominated by weather since heat gain and/or loss from direct conduction of heat or from air infiltration/ex-filtration surfaces accounts for the major portion of energy consumptions (from 50 per cent to 80 per cent).
The energy auditor, during the energy data collecting phase, should determine the present characteristics of the building envelope through the analysis of its components. During the survey, a descriptive sheet for the building envelope should be established; it includes information about materials of construction in order to deduce the level of insulation of walls, floors and roofs, and about the location, the occupied area and the number of building envelope assemblies (for example the type, the position of the windows and the number of pans for windows). The audit is useful, not only to determine the potential for energy saving but also to ensure the integrity of the overall condition. For instance the thermal bridges, if present, can lead to heat transfer increase and to moisture condensation. The moisture condensation is often considered more damaging and costly than the increase in heat transfer since it can affect the structural integrity of the building envelope.
There are three main classes of saving measures which are adopted to improve the building envelope energy performances:

- Insulation of poorly insulated building envelope components.
- Window improvements.
- Reduction of air infiltration.

4.1.1 Insulation of building envelope components

The more effective measures belong to this class, in fact these measures are more able to decrease the energy consumption connected to the building envelope.
The aim of the insulation of building envelope components (walls, roofs, doors and windows) is to reduce the heat transfer from the building envelope which can mainly occur because of convention, conduction and radiation. As regard the components, the walls and

the roofs are mainly involved in the heat dissipation; moreover, convention and conduction are the most important dissipative mechanisms.

Specifically, the heat transfer by conduction from a homogeneous wall or roof layer can be calculated as follows using the Fourier law:

$$\dot{q} = \frac{k}{d} * A * (T_i - T_o) \tag{4.1}$$

Where:

- A is the area of the layer.
- T_i is the inside layer surface temperature.
- T_o is the outside wool surface temperature.
- k is the thermal conductive of the wall or roof.
- d is the thickness of the wall or roof

To characterize the heat transfer presented by the Eq. (4.1), a thermal conductive resistance R-value or U-value is defined as follows:

$$R_{cond} = \frac{d}{k} = \frac{1}{U} \tag{4.2}$$

It is easy to understand from the Eq. (4.1) that the transferred heat is inversely proportional to the R-value which depends from the constitutive material *(k)* and from the thickness of the wall or roof.

The concept of thermal resistance can be extended to convection heat transfer that occurs at the outer or inner surfaces of the building envelope:

$$R_{conv} = \frac{1}{h} \tag{4.3}$$

Where h is the convective heat transfer coefficient of the surfaces. It is possible to calculate, for a wall or roof formed by a single layer, the total heat transferred defining an R-value that takes conduction and convection into account:

$$R_{tot} = R_{cond} + R^{i}_{conv} + R^{o}_{conv} \tag{4.4}$$

Where R^{i}_{conv} and R^{o}_{conv} are R-values of inner and outer surfaces.
In buildings, as it is shown in the next figure, a wall or roof consists of several layers of different but homogeneous materials.

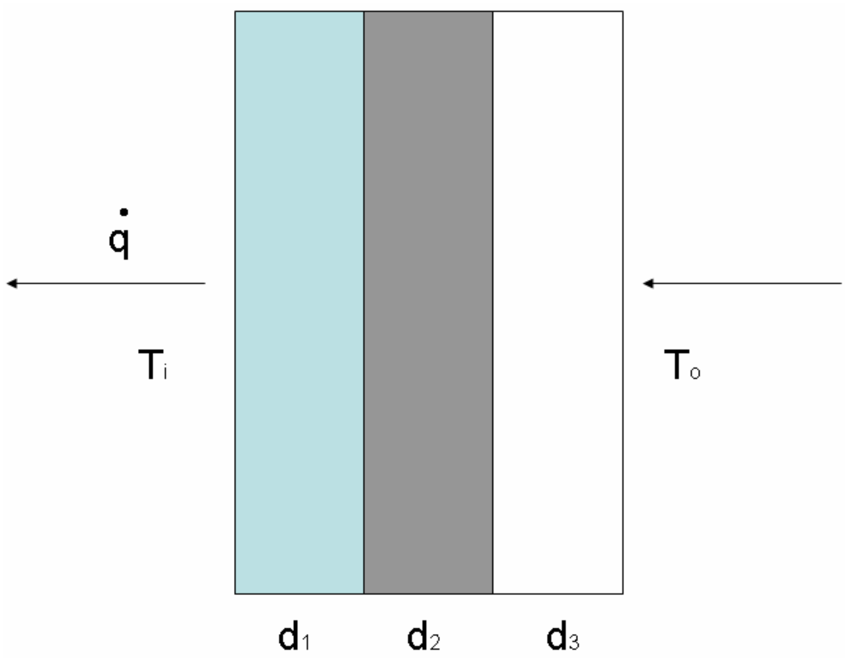

Figure 26: Heat transfer from a multi-layered roof or wall

The heat transfer from a multi-layered wall or roof can be found by determining first its overall R-value:

$$R_{tot} = \sum_{j=1}^{N} R_j \tag{4.5}$$

Where:

- *Rj* is the R-value of each homogeneous layer part. It includes the R-value due to convection at both inner and outer surfaces of the wall or a roof.
- *N* is the number of layers (including the convection boundary layers) that are a part of the wall or a roof assembly. For instance, in the wall assembly presented in the previous figure, $N=5$ (three conductive layers and 2 convectional layers).

To characterize the total heat transmission of the entire building, a Building Load Coefficient (BLC) is defined to account for the entire building envelope components (not only walls and roofs but also doors and windows):

$$BLC = \sum_{i=1}^{N} \frac{A_i}{R_{tot,i}} \tag{4.6}$$

Where:

- Ai is the area of each component of building envelope.
- $R_{tot,i}$ is the total R-value of each component of the building envelope.

Now, it is possible to define the heat transfer for an entire building as

$$\dot{q}_{Build} = BLC * (T_i - T_o) \tag{4.7}$$

How it is possible to understand from the Eq. (4.7), in order to reduce the thermal dissipation of a building it is necessary to reduce the BLC of the entire building and this means, according to the Eq. (4.6):

1. to decrease the area of the components,
2. to increase the total R-value of the components

The saving measures that refer to the first point aim at:

- Reducing the area of thermal exchange of those components characterized by a low thermal resistance. These components are called thermal bridges and in a building they are represented by doors, balconies, building corners or wall connections; it is not possible to avoid these thermal bridges but it is possible to limit their effects, designing some technical solutions that, for example, aim at restricting their area.
- Reducing the dimension of the entire construction, building constructions with "smart apartments" characterized by a rational design of the spaces.

As regards the saving measures concerning the increase of the R-value of the components, they mainly consist in:

- Adopting components composed by materials with a high R-value, as suggested by the Eq. (4.5), such as components containing glass-wool which has a well-known heating insulating property.
- Designing the building considering the interchangeability of the components. In fact the components, which are easy to change, consent the renovation of the building in order to maintain and increase in the time the insulating performance in parallel with the technical progress in the field of building components and materials.

Finally, it is important to notice from the Eq. (4.7) that the heat transfer is reducible also through the decrease of the Δ of temperatures between the outer surfaces of the building and the inner ones.

This is possible:

- Making the user of the building aware of a correct use of the heating system, in order to avoid high indoor temperature.
- Designing the building in order to receive the shadow from natural shelters, such as trees, on the wall that are exposed to the sun during the hotter hours of the day. (Brookes 1990)

4.1.2 Window Improvements

Window improvements, such as installation of high-performances windows, windows films and coating, or storm windows, can save energy through the reduction in the building heating and cooling thermal loads.

In fact windows represent a significant portion of the exposed building surfaces and using more efficient windows can be beneficial both in the reduction of energy use and in the improvement the indoor comfort level.

Improvements in windows can impact both the thermal transmission and the solar heat gain. In addition, energy-efficient windows create a more comfortable environment with distributed temperatures and quality lighting. Energy-efficiency improvements can be made to all the components of a window by:

- Insulating the spaces between glass pans to reduce conduction heat transfer.
- Installing multiple coatings or film layers to reduce heat transfer by radiation.
- Inserting argon and krypton gas in the space between the panes to decrease the convection heat transfer.
- Providing exterior shading devices to reduce the solar radiation transmission to the occupied space.

Some examples of technical solutions based on the previous points are the high r-value windows, low-emissive glazing and air tight windows.

But, since the fenestration can impact the building energy consumption through other mechanisms different from the heating transfer, in order to determinate accurately the annual energy performance of windows retrofits, dynamic hourly modelling techniques are generally needed.

All of them take into account the location and dimension of the windows that influence strongly the energy consumption connected with the lighting system; in fact, during the designing building process it is necessary to consider these aspects in order to allow the use of the natural light for an as larger number of hours per day. (Krarty 2005)

4.1.3 Reduction of air infiltration

Air can flow in or out of the building envelope through leaks. This process is often referred to as air infiltration or ex-filtration. Thus infiltration (and ex-filtration) is rather an uncontrolled flow of air unlike ventilation in which air is moved by mechanical system. Typically, air infiltration is considered more significant than ex-filtration for low-rise buildings, such as residential buildings, for the reason that the indoor pressure is generally maintained higher than the outdoor pressure by mechanical systems in larger buildings and, for this reason, the airflow from the outside to the inside of the construction is prevented.
Infiltration can considerably affect energy consumptions because of the decrease of thermal comfort connected with structural damages such as rotting and rusting of the building envelope materials due to the humidity transported by infiltrating and ex-filtrating air.
The biggest problems that occur in facing air infiltrations are the estimation of the importance of the phenomenon and the determination of the location of the leaks in the building envelope. The process of estimation is important because the repair interventions for this kind of problems could be very expensive and it should be justified by a real necessity. The target of the process is to determine the relationship between the airflow and the difference between the inner and external pressure. The relation is a linear one and it is well expressed by the following empirical equation:

$$\dot{V} = C * \Delta P^{n} \tag{4.8}$$

Where:

- $\dot{V}$ is the airflow expressed in m³/ min.
- ΔP is the difference of pressure expressed in bar.
- C and n are the correlation coefficients.

In order to determinate the coefficients the "blower test" is used. It consists in the revelation of the different airflow values (relieved by blower fans opportunely positioned inside the closed house) that are obtained increasing the inner pressure. Through the interpolation of the data obtained by the test, it is possible to determine the coefficients and the needed relation. If the trend of the relation shows a rapid increase of value of airflow with the increase of the differences of pressures, it means that the infiltration is consistent and the same measures are indispensable.

Moreover the leaks are found by holding a smoke source and watching where the smokes leave the house.

Once that the leaks are discovered the main solutions adopted are:

- Caulking: Several types of caulking such as urethane, latex and polyvinyl can be applied to several envelope leaks. This measure is effective especially for those leaks that interest the windows and the door frame and any wall penetrations such as water pipes.
- Weather striping: By applying rubber with adhesive backing windows and doors can be air sealed.
- Landscaping: This is a long term project and consists in planting shrubs and/or trees around the building to reduce wind effects and to reduce air infiltrations.
- Air insulators: These systems consist of one or more air-impermeable components that can be applied around the building outer shell to form a continuous wrap around the building walls. There are several air insulators types such as liquid-applied bituminous, liquid-applied rubber and sheet plastic. (Binamu 2001)

4.2 Primary energy services saving measures

As it is reported in the previous chapter, the building primary energy services are services distributed by a central provider in the building; this is the reason for calling these services centralized building services.

The main services that belong to this category are:

1. Electrical System.
2. Water Services.
3. Heating Ventilation and Air Conditioning System.

In the following paragraphs the energy saving measures that interest each point will be analyzed. It is important to remark that in this paragraph only those general saving techniques and measures, useful for decreasing energy consumptions not linked with effective use of these services, will be taken into count. For example, the saving measures dealing with the electrical system will be analyzed avoiding those specific measures connected with a particular use of the electrical system, such as lighting saving measures; these aspects will be treated after because they deal with those saving measures which interest the uses of building services.

4.2.1 Electrical system

The electrical system is designed in order to provide electrical energy to the utilization equipment in safety. The figure below shows a typical on-line diagram of an electrical distribution system for a residential building.

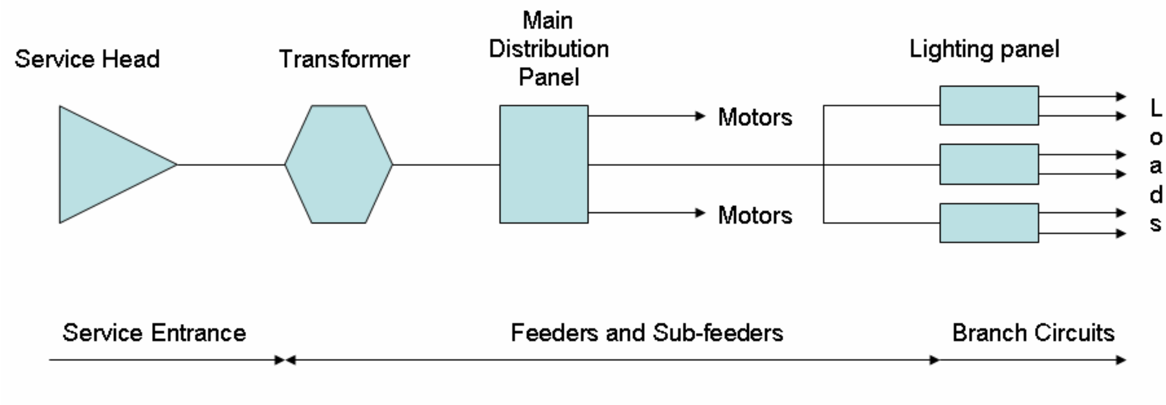

Figure 27: An electrical distribution system for a residential building

The energy saving measures involve each main part of the electrical distribution system.
The electrical power is supplied through service entrance conductors at medium voltage; for this reason a transformer is required in order to step down the voltage to the utilization level.
The transformer is an electrical static machine whose aim, in residential buildings, is to convert the voltage from a value of entrance (Ve) to lower value of exit (Vu). In the ideal

case the transformer does not modify the electrical power from entrance to exit; this means that:

$$P_e = V_e * I_e = V_u * I_u = P_u \qquad (4.9)$$

Where:

Ie and *Iu* are respectively the values of current in entrance and in exit.

But in the real case the electrical power in entrance is always higher than in exit; the main reasons of this energy dissipation are:

- Winding resistance: current flowing through the windings of the transformers causes a resistive heating of the conductors which represents a dissipative conversion of energy (Joule effect in the windings).
- Eddy currents: Induced eddy currents circulate within the core of the transformer, causing resistive heating (Joule effect in the core of the transformer).
- Hysteresis losses: These kinds of losses are connected with the magnetic field generated inside of the transformer.

In order to face this kind of problems the common utilized measures used are:

- Windings with low number of turns and with circular section in order to minimize the total length of the wire and, consequently, the Joule effect.
- The material used for the wire is copper which is very useful because of its electrical property. In fact , it is characterized by a low electrical resistance which minimizes the Joule effect and a high coercive force which minimizes the hysteresis losses
- The core is not compact but it is built with different layers in order to minimize the dissipation inducted by eddy current.

In order to maximize the performance of the transformer it should be better to choose a big one, but some problems connected with the refreshment of the machine can occur in this case.

The low voltage electrical power which abandons the transformer, reaches the main panel control which is the distribution centre for the building and from here it is switched to:

- Different lighting panels in each apartment through feeders.
- Different electrical motors through sub-feeders.

The electrical motors are used for converting electrical energy to mechanical energy and they are typically used in a building to drive machines. Driven machines can serve a myriad of purposes in a building including moving air (HVAC system), moving liquids (pumps) or moving people (elevators). To choose energy efficient electrical motors is suggestible in order to minimize the electrical consumption connected with the use of electrical motors.
The electrical power available to different domestic uses arrives from the lighting panel. In an alternating current system both voltage and current are vectors and for this reason the electrical power is a vector too, since it is the result of the product between the voltage and the current as written in the Eq (4.9). The two components of the electrical power (Pt) are the real power (Pr) and the reactive power (Px); as it is showed in the figure below, the angle between the components is called Φ and it is possible to demonstrate that it is the phase lag between the current and the voltage.

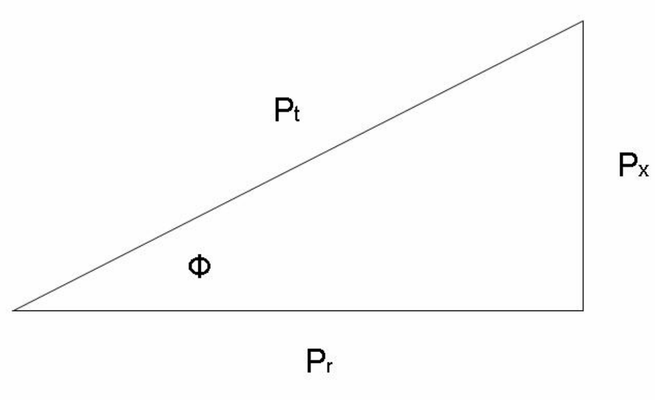

Figure 28: The power triangle for an electrical system

The user of the electrical system consumes only the real power and the reactive power and even if the latter is made available by the electrical provider it is stored and then released by the electrical system and for this reason it is not utilized. In the previous figure it is clear that the ratio between the real power and the total power represents the cosine of the phase lag. This ratio is widely known as the power factor (pf) of the electrical system:

$$pf = \frac{P_r}{P_t} = \cos\Phi \leq 1 \tag{4.10}$$

In order to minimize the electrical power dissipated, the real power should be as close to total power as possible and this means that the power factor should be close to the unit which represents the maximum value of the factor. As it is showed by the Eq.(4.8), the way for maximizing the power factor is to decrease the phase lag between the current and the voltage and this is possible with the addiction of a capacitor in parallel to the electrical system. (Krarty 2005)

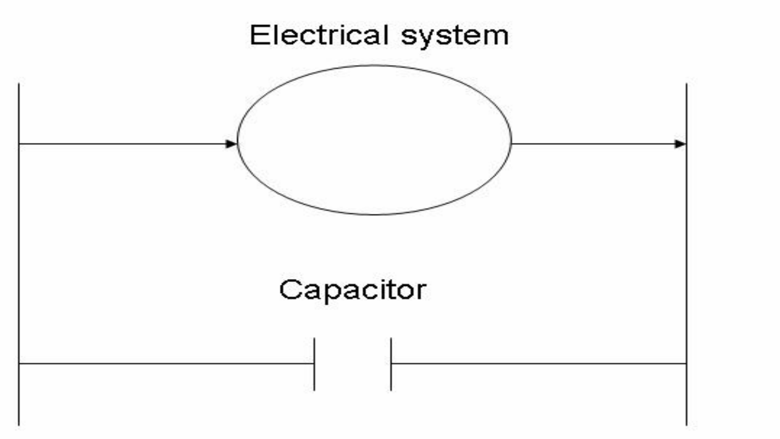

Figure 29: A capacitor in parallel with the electrical system

4.2.2 Water Services

Energy costs connected with the use of water represent an important fraction of the entire energy bill for a residential building.
Water is distributed thought a plumbing system within the building and it is used for two main purposes:

- Domestic uses such as hand washing, showering and toilet flushing.
- Space heating and hot water through the District Heating System, mentioned in the second chapter, that covers 48 per cent of share in the Finnish market of heat produced for residential buildings.

As regards the domestic use, the most important energy saving measure is to repair the leaks in water fixtures even if these leaks consist of few water drips per minute. Over long periods of time, the amount of water wasted from these drips, even if they come from a small leak, can be significant as indicated in the table below which belongs to a study about water management led in Finland by the Ministry of Trade and Industry[6]. The daily, monthly and annual water wasted due to leaks is estimated counting the number of drips in one minute from the leaky fixture.

Number of Drips per Minute	**Water wasted pre day (l/day)**	**Water Wasted per Month (l/month)**	**Water Wasted per Year (l/year)**
1	0.53	16.28	199.1
5	2.73	81.76	991.8
10	5.45	163.53	1987.3
20	10.9	327.12	3978.5
50	27.25	817.64	9948.0
100	54.51	1635.30	19896.1
200	109.01	3270.60	39792.2

Table 4: Volumes of water wasted from small leaks

As regards the hot water used for domestic applications and for heating spaces, the saving measures are based on the reduction of the transferred heat from the water flow inside the building water pipes. The mechanisms for the heat transfer are conduction and convection.

In order to decrease the conduction dissipation, the commonly applied measure is to adopt pipes opportunely covered in order to increase the thermal resistance.

As regard the convection, it depends on the turbulent flows in the pipe that favour the heating transfer between the different parts of the fluid. The growth of turbulent flows is

[6]Water management: OPPORTUNITIES TO INVEST IN INNOVATIVE ENVIRONMENTAL TECHNOLOGY,2006

connected with characteristics of the fluid and with the geometrical features of the pipe; the saving measures aim to decrease these losses acting on geometrical features, for example increasing the diameter of the pipe as much as it is possible and adopting pipes with a material which guarantees low roughness.

Moreover, during the designing of the water distribution system, it is also important to consider the flow resistances of the entire system from which the power consumption of the pumps depends. A good distribution system allows to minimize the flow resistances, for this reason, the power required by the pumps and the energy consumed by them. Flow resistances could be:

1. Localized in a particular point of the distribution system because of the presence of mechanisms such as valves or pipe's connections that deviate the direction of the flow. It is suggestible to design a water distribution system using the less number of these mechanisms as possible.
2. Continue along the rectilinear parts of the system. In order to minimize these resistances the main measures consist in the choice of a pipe made by a low roughness material. (Krarty 2005)

4.2.3 Heating Ventilation and Air Conditioning System

The Heating Ventilation and Air Conditioning (HVAC) system maintains and controls temperature and humidity levels in order to provide an adequate indoor environment in the residential building. The functions of heating, ventilation and air condition are grouped in the same centralized system, because in the modern building design they are considered closely interrelated, as they control the temperature and humidity of the air within a building.

The energy saving measures, are connected with the three different services offered by HVAC system.

The function of heating is provided by a central boiler (in the case there is not a District Heating System) to heat the fluid, piping to distribute the heated fluid, and radiators to transfer this heat to the inner air. It is important to focus the attention on the energy saving measures regarding the boilers, as the distribution system of heated fluid has already been treated. The saving measures connected with the boilers aim at reduce the fuel consumptions which are necessary for the combustion. They are:

- To use of modular boilers. Almost all the heating systems are more efficient when they operate at the full capacity. However, the reduction in the fuel use is not necessarily proportional to the improvements in the heating system efficiency. Indeed, peaks of loads occur rarely in the most of heating installations and boilers are often operating under part-load conditions. Some boilers may be forced to operate in an on-off cycling mode but this causes loss heat through the piping when the cycle is off; the water in the distribution system cools down and a part of energy provided by the fuel is dissipated. If the boiler capacity is much higher than the load, the cycling can be frequent, reducing the efficiency of the heating system. In order to avoid cycling the most effective measure consists in adopting modular boilers. In a modular heating plant, a boiler first operates to meet small heating loads; then, as the heating loads increase, new boilers are switched on and enter on-line to increase gradually the capacity of the heating system. Similarly, as the heating loads decrease, the boilers are taken off-line one by one. The modular boilers can increase the efficiency of the heating system of 15-30 per cent.
- To increase the boiler thermal efficiency. In the boiler, the fuel combustion involves a chemical reaction of carbon and oxygen atoms to produce heat; for this reason a specific amount of air, from which the oxygen comes from, is needed for ideally completing the combustion of fuel. This amount of air is typically referred to as the stoichiometric air. However, in actual reaction, more air than the stoichiometric amount is necessary to totally complete the combustion of fuel. The main challenge to ensure the optimal operating condition for boilers is to provide the proper excess air (about 10 per cent of excess of air) for the fuel combustion. In fact too much excess of air causes higher stack losses and requires more fuel to heat the ambient air. On the other hand, if insufficient air is supplied, incomplete combustion occurs and the flame temperature is reduced. The improvement of the boiler thermal efficiency consists in improving the combustion efficiency providing the optimal fuel/air ratio for completing the combustion.

The function of ventilation consists in changing the air in any space in order to remove moisture, odours, smoke, heat, and airborne bacteria. Ventilation includes both the exchange of air to the outside as well as circulation of air within the building and it is one of the most important factors for maintaining healthy indoor air quality in a building. The function is provided by the following basic components:

- Dampers to control the amount of air to be distributed by the ventilation system.
- Filters to clear any dirty from air.
- A distribution system (i.e. ducts) where the air is channelled to various locations and spaces.

The most important saving measures connected with this function are related to the control of the amount of ventilation air that flows into the system. An excess of volume of fresh air, compared to the estimated needed amount, can lead to increase of thermal loads inside the building, which represents a source of thermal dissipation, as it has already been mentioned. The auditor should first estimate the existing level of ventilation air for each ambient of the building reached by the ventilation system and after compare it with level of required level of ventilation air.

The required level of ventilation is determinable consulting standardized tables in which is written the acceptable value according to the typology of ambient (such as kitchen or bathroom or parking garage) and the dimension of the ambient express in cubic meters. If excess of ventilation is found it is necessary to decrease the air flowing trough the adjustment of the damper set up.

As regards the function of air conditioning, on the contrary of office or public building, in the residential building it is not usually connected with a central provider. This kind of services is provided by specific plants that each resident can adopt; but, in order to maximize the effects of each air condition system, decreasing consequently the relative energy consumption, the chosen measures are those one connected with the thermal insulation of the building treated in the previous study about the building envelope. (Porges 2001)

4.3 Energy uses saving measures

As it has already been mentioned, in this paragraph those saving measures which are closely connected with the energy uses in the residential building will be analyzed.

The identification of these measures presents big difficulties essentially because of the nature of energy consumption sources that are linked to this kind of services; in fact, even if the consumption sources are known, it is difficult to quantify the amount of energy that is related to each source and consequently to choose the measures that, acting to these sources, are able to decrease sensibly energy consumptions.

The saving measure belonging to this field aims at solve this problem, creating inside the building a system capable of monitoring each energy consumption during the running phase of the building. The system is called Energy Management Control System (EMCS) and its development is mostly related to the introduction of computerized and integrated automatic technologies in the residential building sector.

These technologies form a complex control system suitable to:

- Catch the information about the time trend of the different consumptions of energy sources connected with the use of different building services.
- Operate through programmed actions which, basing on the collected information, aim at decreasing the monitored energy consumption.

A typical EMCS includes four elements as briefly described below:

1. The controlled variable is the characteristic of the system to be controlled; for instance, the indoor temperature is often the controlled variable in the HVAC system
2. Sensors which measure the controlled variable; for instance thermocouple can be used to measure indoor temperature.
3. Controllers that determinate the needed actions to achieve the proper setting for the controlled variable; for instance the position of a damper belonging to a HVAC system can be modulated to increase the air supply, regulating the indoor ventilation and temperature.
4. Actuators are the controlled devices which need to be activated in order to complete the actions set by the controllers, varying, for instance, the position of the damper.

Two main categories of control system can be distinguished including closed loop and open loop system.

Generally in the residential building, it is preferable that the interconnections between the different elements of control system form a closed loop system.

In a closed loop system, also known as a feedback control system, the different elements are interconnected in such a way that the information coming from a sensor directly affects the controller. This kind of system has the advantage that to act on the controlled variable is always possible and this leads to a more consistent saving level. In the picture below the scheme of closed loop control system is showed.

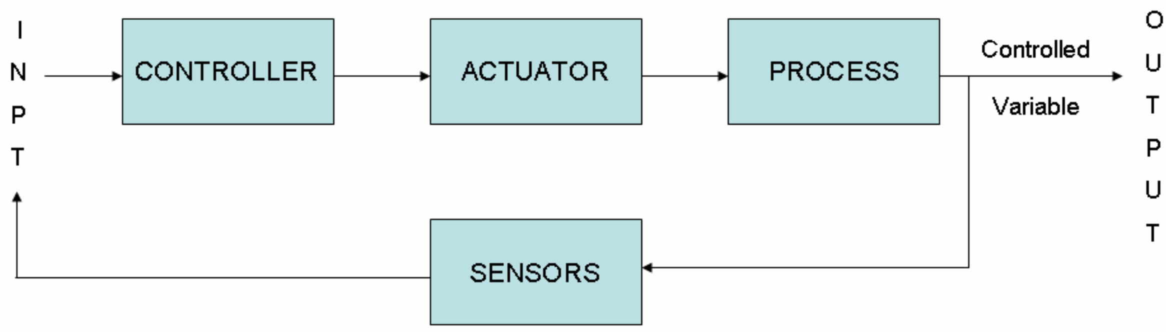

Figure 30: Closed loop control system

An example of closed loop system is the lighting system that switches off the light after that some sensors have relieved no person in a specific space. Only an automatic light switching system can respond in real-time to change in occupancy in order to optimize the electrical consumption. Two type of motion sensing technologies are currently available in the market:

1. Infrared sensors which register the infrared radiations emitted by various surfaces in the spaces including the human body. When the controller connected to the infrared sensor receives a sustained change in the thermal signature of the environment, as in the case when an occupant moves, it turns the light off.
2. Ultrasound sensors which operate on a sonar principle. This system is able to perceive the movements of a person through the variation of the emitted sound wave, and consequently lights are switched on. Lights remain on until no movement is detected for a specific time period (typically five minutes).

Others applications of a closed control loop in the residential building are represented by the self-closing faucets and the boiler thermal efficiency control system.

The self-closing faucets can detect through a sensor placed on the faucet when a user moves away from the bathroom sink, avoiding the waste of water.

The boiler thermal efficiency control system is used for regulating the amount of air in the boiler that influences the efficiency of the thermal application. This is possible thanks to some sensors that detect the temperature of the stack gas which is directly related to the amount of air that participates in the combustion process.
But the closed loop is not always feasible because of practical features that characterize the use of some services. For example in the case of the centralized heating system, it is not possible to provide the heat on the basis of the value of the inner temperature because it is different in the various apartments. In these cases, the EMCS consists in an open control loop.
The open control loop has no means for comparing the output with the input of the system for control purposes. The control is activated independently from the information coming from the sensors which detect the output of the controller (not the output of the system) in order to regulate it; this means that the system does not observe the output of the processes that it is controlling. In the picture below the scheme of open loop control system is showed.

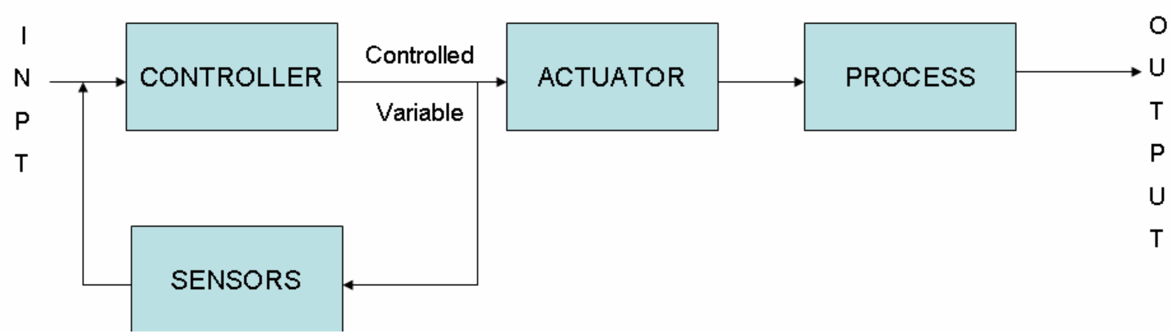

Figure 31: Open loop control system

The control of open loop systems, at the contrary of the closed one, often requires human interventions for activating the controller; the activation is not direct but it happens through a programmable timer.
A typical example of an energy management control system based on an open loop is the one applied for managing the centralized heating system. In this case the service is regulated by the instructions that come from a timer which is previously programmed, fixing the operation time range and the temperature.

In this case, the saving performance are connected with the capability of the programmer in setting the timer options that regulate the time and the intensity of the services; for this reason it is necessary for a good scheduling, to know the real need of use of the services. This kind of control loop is applied in a big variety of electrical appliance such as computers, dishwashing machines and other household appliances, whose consumption heavily influences the total energy consumption during the running phase of a residential building.

Other saving measures which decrease the energy consumption during the running phase aim at optimizing from the energy point of view the building furniture. The furniture that belongs to this category is:

- Fluorescent Lamps or Compact Halogen Lamps. They are more energy efficient and have a longer life than incandescent lamps. These lamps are heavily promoted as energy saving alternatives even though they may have some drawbacks connected with their high cost.
- Water efficient appliances. All the appliances that aim at reducing the consumption of water during their use belong to this category, such as Water-Saving Showerheads and Water-Saving Toilets.

Moreover, it is important to remark that the amount of energy consumption during the running phase of the building is mostly connected with the energy behaviour of the building occupants. From this viewpoint, all those actions which aim at improving the energy education of the residents are considered important saving measures.

In Finland, Motiva Oy has the responsibility for the information dissemination project called “Education for Energy Efficiency” which aims at influencing people’s attitudes in favour of energy conservation, permanently changing their habits of using energy in the residential building. (Butterworth and Heinemann 2000)

4.4 Evaluation of Energy Saving Measures

As it has already been mentioned, the research of energy saving measures represents the final stage of the energy auditing process, and for this reason the efficiency of energy saving measures is strongly connected with the quality of the previous work made by the auditor. For example, an underestimation during the data collecting phase (see Chapter 5, p.57) of the thermal loss caused by not well insolated building envelope components, can lead to a not significant improvement of the total energy performance of the building, because the adopted saving measures do not consider the building envelope. This means that the process of evaluation of the saving measures takes into account not only the efficacy of the measures from a strictly technical point of view, but also the reasons that has supported the choice of the measures

It is important to point out that the evaluation should consider the interconnections of the effects that a saving measure can produce. For example, even if the reduction of the number of windows leads to a significant decrease of the thermal loss (the windows are the most important thermal bridges in the building envelope), it also leads to a sensible decrease of the natural light and for this reason to an increase of the electrical consumption connected with the intensive use of the lighting system. For the mentioned reason, the process of evaluation of the energy saving measures requires a huge knowledge; it is usually made by a team of experts specialized in different energy fields in order to understand all the energy effects related to any specific measures.

Finally, economic aspects have an important role during the evaluation of the energy saving measures. In this point of view, it is important to say that the economic effects of most of the saving measures have long time duration and for this reason the economic analysis should be extended to a time period (Pay Back Period) not inferior to 10 years. Even if the economic analysis in this field has a big disadvantage connected to the difficulties in the future estimation of the economic benefit, the savings solutions that interest the energy sources are very expensive and characterized by an unpredictable trend of the price, for instance fuel, should be preferred because, in most cases, it guarantees a major economic efficiency.

5 Conclusions

This research is a study about the energy management in Finnish residential building sector. The objective is, beginning from a general overview of the Finnish energy scenario, to identify the methods used by the different operators belonging to the sectors for increasing the energy performance of a residential building, taking into count the different points of view of each operator.

The research has also the target of being a starting point for a comparison from the energy viewpoint between the Italian residential building reality and the Finnish one.

In order to offer a complete perspective of analyzed topic, the research has been developed in different levels:

- Strategic level in which the analysis of the national energy strategy and policies, adopted by Finnish Governments in the last ten years to give an answer to environmental targets fixed by the Kyoto protocol, has been led.
- Tactic level in which the study of the methodological approach used for giving an effective relevance in the residential building either to the mentioned strategies and policies or to the European Directive 2002/91/EC about the energy performance of the buildings has been led.
- Operative level in which the analysis of the common techniques and energy saving measures adopted by the Finnish construction companies for improving energy performances of the residential buildings has been led.

The work marks the strong interconnections between the different levels; as a matter of fact, each treated point has been studied trying to develop a homogeneous and consequential discourse in accordance to the adopted bottom-up research method. This feature allows to understand the topic better, presenting it from various angles in order to enlighten its main characteristics. The mentioned feature denotes also a structural cohesion of the Finnish energy management system which is the result of the strong interactions between the actors who operate in it. In this viewpoint, the Finnish residential building sector appears such as a strategic sector for gaining the fixed national energy performances; for this reason it is managed by a strong hierarchy, characterized by defined roles and responsibilities, which guarantees the coherence of the energy results obtained in the sector with the national energy targets.

The research focuses the attention also on the tools, methods and procedures which are used for supporting the energy management in the residential building sector. The Energy Audit has the most important role because of its characteristics of good applicability in different cases; it gives a methodological perspective which led to the improvement of the energy performances of the residential building. Its efficacy is proved by the fact that it is considered in all the building sector the inescapable means that leads to the most consistent energy saving. Its general but not unpractical structure consents to adapt the Energy Audit System to existent organisational systems, favouring its divulgation trough different realities. As it appears from the research, Finnish Governments have invested a lot in the field of Energy Audit conceding resources which aim either at the research or at the divulgation of the Energy Audit through the companies which operate in the sector; this is a clear sign that demonstrates the high consideration of the Energy Audit in Finnish energy policies.

Even if the Energy Audit is already largely applied, it is object of study and research in order to increase is effectiveness through more accurate procedures and models.

The main techniques and the best practices for the energy saving adopted by building companies represent the last stage of the research. Each measure is supported by well-established engineering principles that help to recognize its effectiveness; moreover, this method allows to understand the energy feature on which the saving measure operates, getting the work free by a pure technical viewpoint which is more time-relative because it is dependent on the technological level.

5.1 On data collection

The data and information necessary for elaborating the research come from three types of sources:

1. Books and reviews.
2. Documents and interviews given by members of Finnish organizations, whose work deals with the energy management in the residential building sector.

The reliability of the data and information can be considered good and the subjective interpretation of the interviews is minimized, trying to examine carefully and to compare the contents of the interviews with official sources.

The difficulties faced during the data collection phase are mostly connected with the features of the field of knowledge from which they come from.

Especially the field of the energy audit is considerable a high-dynamic field, characterized by researches which lead to the transformation and the innovation in methods, procedures and models. Anyway, the collected data are selected on the basis of their present solidity, which is on their recognized utility and common applicability in the energy management of the residential building sector.

5.2 Utility of the present research and suggestion for future researches

The research tries to be a tool for understanding the potentiality of the Energy Audit as an energy management method for increasing the energy performance of residential buildings. It explains the energy audit method, focusing on its main features, and it offers models and procedures for implementing the Energy Audit System inside companies operating in the residential building sector. Moreover, through the Energy Audit, the research tries to give an answer to the request about the common method for estimating the energy performance of a residential building mentioned in the European Directive 2002/91/EC which is going to come into forces in the immediate future in all the nations belonging to the European Community.

As it has already been mentioned, the research aims also at being a starting point for comparing from the energy management point of view the Italian reality and the Finnish one; for this reason the topic is fitted into a national dimension and is presented from different angles.

The energy management in the residential building is a huge topic, characterized by continuous developments in methods and techniques and, for this reason it is open to new researches about other energy management tools which are different from the Energy Audit one.

As regards the Energy Audit, a research about the economic and financial tools for supporting the choice of energy saving measures (i.e. Pay Back Period or Life Cycle Cost Analysis) can be significant in order to understand the economic impacts of the investments that building companies make for decreasing the energy consumption of their products.

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