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INTEGRATED APPROACH TO THE DIAGNOSTIC CONDITION OF PIPELINE SYSTEMS WITH USE OF SPACE DATA

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In recent years dramatically increased the relevance of monitoring of gas pipeline and gas distribution systems. This is primarily due to the need to minimize the costs of reconstruction and repair of pipelines, which are one of the major expenditure items in their care. At the same time ensuring the reliability of the elements of these systems is essential.

On the operated pipeline systems, there are many sites with complicated geological conditions. This landslide, tectonically active areas, areas subject to flooding, etc. With the passage of such a pipeline is subjected to non-project area loads, which are periodic, seasonal in nature. The result may occur emergency situation up to the destruction of the pipeline.

According to a statistics, more than half (80%) of all accidents pipelines falls on the intersection of tectonic active zones, with frequent recurrence of accidents at the same sites. Typically, the real reasons for repeated breaches and destruction of gas pipelines are the factors that lead to a reduction of technological fatigue properties of steel pipe and reinforced concrete structures. By results of in research oil and gas pipelines, it was determined that approximately 70% of all defects are classified as "loss of metal, which includes cracks, cavities, etc.

Stress-strain state of pipelines correlated with fluctuations in the earth's surface directly in contact with the pipeline system. By increments (changes coordinates) of control points on the section of pipeline can be dynamic movement of parts in time, and thus take into account the stresses that lead to the reduction of technological fatigue properties of steel pipes. Traditionally used for these purposes leveling and construction of special geodetic networks or polygons.

With the advent of space geodesy system GLONASS, GPS, quickly solved the problem of obtaining information about the dynamics of moving parts in time, and hence the offset coordinate axis of the pipeline under the influence of tectonic movements of the crust.

Combining the results of preliminary in-line fault detection, diagnosis and outdoor interpretation of satellite imagery it allows to select parts of pipelines with a high density of defects.

Existing pipelines are a geotechnical system, composed of natural and engineering facilities located within the corridor laying pipelines (ICC). Objects of the system interact with each other. However, some impact on the pipelines are negative, which may lead to the formation of defects.

The processes occurring in the geotechnical system, are typical manifestations of the Earth's surface and are recognized based on aerospace monitoring. Figure 1 shows a satellite image with a fragment of the main section of the Baku-Tbilisi-Ceyhan oil pipeline passes through the Kazakh region of Azerbaijan.

As a result, satellite image interpretation was found a few places with high humidity, which may further accumulate water. Existing methods of aerospace diagnosis ICC, a separate level, along with in-line and surface diagnostics [4].

With the aging pipeline systems ecological conditions in the man-made environment leads to increased corrosion, which significantly reduces the actual time of their life compared with the project, which is characteristic of wet soils with a sufficient content of sulfur compounds and areas with high water cut. For the purpose of planning preventive maintenance for the ICC compiled maps of the corrosion activity of the soil on the basis of space data (Fig. 2).

Fig.1. Fragment of outer high-resolution images on the route proleganiya main oil pipeline Baku-Tbilisi-Ceyhan

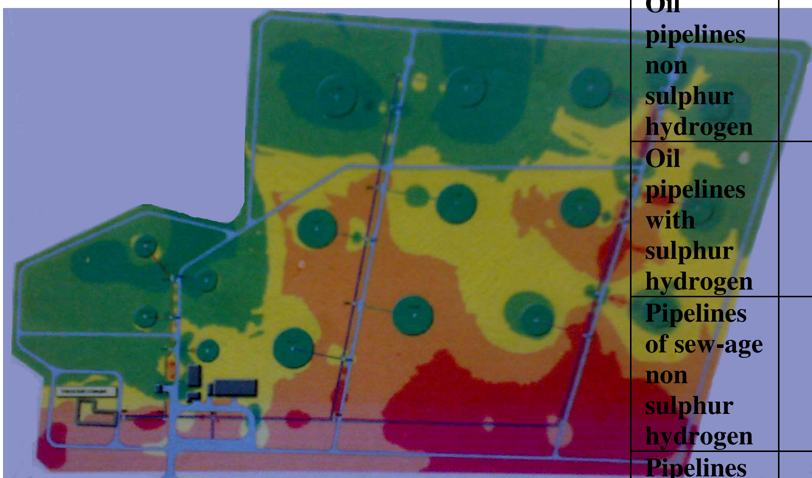

Fig.2. Schematic map of corrosion activity of soil constructed by interpolation of ground measurements with the use of space data

Maps of erosion hazard lands are the basis for solving problems for the protection of infrastructures, in particular, technological corridors, laying oil and gas pipelines that are on these sites, and they should give an objective view on the distribution and extent of the risk of erosion of land and meet several requirements, depending on the stage of the project and survey work. The first condition is achieved by quantification of the main factors of erosion and the use of mathematical relationships between processes and their determinants.

To assess the risk of erosion can be used various models of erosion, which should be created under the reference and data base, covering the investigated area of the region. Mapping of soil erosion using GIS makes it possible to identify potential risk areas of intensive soil erosion and allows to quantify soil loss in different parts of laying the technical corridor for the MT.

Also, when transporting sulphur hydrogen liquids, such as oil and gas technical deterioration of steel pipes reached much earlier statutory deadlines (see table) [5]

Table
Actual and normative terms of service piping systems oil and gas industry

Pipelines	**Time of exploitation, years**		
	Real		**standard**
	Ural and Урал и Поволжье	**West Siberian**	
Gas pipelines	**4-6**	**10-12**	**non setup**
Oil pipelines non sulphur hydrogen	**10-15**	**10-15**	**21**
Oil pipelines with sulphur hydrogen	**5-8**	**5-8**	**non setup**
Pipelines of sew-age non sulphur hydrogen	**5-7**	**6-8**	**21**
Pipelines of sew-age with sulphur hydrogen	**2-3**	**4-6**	**non setup**

In recent years among the main causes of accidents pipelines transporting oil and natural gas specified by the local corrosion damage (in-line or external underfilm corrosion) and corrosion cracking under the stress of deformation or stress corrosion. This is due primarily to the natural aging pipeline network.

At present, different countries have developed and manufactured measuring control systems, devices and equipment that are designed for process control transportation of oil, gas and process gas distribution, to monitor and predict changes in the technical condition of various pipelines. However, the integrated measurement system designed for process control transportation of products, and for monitoring the technical condition of distribution networks of gas pipelines do not exist.

[5] presented the requirements for information-measuring systems (IMS), the technical condition of steel pipelines and gas distribution systems, which offered conditional classification of gas pipeline systems: land, underground pipelines and having the intersection with road, rail and water barriers.

In general, the measured parameters determined during the monitoring can be divided into a number of indicators.

• Technical condition to which the thickness of the pipeline, the size of corrosion damage, the presence and characteristics of defects connections (welded, flanged, threaded), the quality of anti-corrosion coating (insulation), the state supports (for ground gas pipelines)

• Operating conditions, characterizing the external negative effects on the pipeline: the degree of aggressiveness of soils, the efficiency of cathodic protection, temperature drop, the rate of flow of groundwater, etc.

However, it does not take into account the stress-strain state of pipelines, which occurs when the Earth's surface vibrations that lead to the reduction of technological properties of steel pipelines, the appearance of cracks.

All parameters on the state complexity of an extended object should act in a common information base and monitoring should be conducted on the basis of information technologies in real time.

Thus, for effective monitoring and control of technical condition of steel pipelines and gas distribution systems perspective is the introduction of IMS, which can be easily integrated into automated process control systems (DCS) gas transmission and distribution. Outline of this RIS is shown in Figure 3.

At present, the principles and model solutions are already available hardware for all parts of the structure of the IMS, as shown in the figure, except for the lower level. This level determines the composition of the parameters for determining the technical condition of the pipeline and a set of sensors for their control. Consider the options and gauges lower level IMS, which allow, for example, to determine the location of leakage of oil or gas pipelines.

A measurement system that uses the velocity of the acoustic signal in the pumped medium, which occurs as a result of rupture in the pipeline, and, accordingly, the registration time difference of pressure drop in the related pumping stations, based on which product is calculated leak in a pipeline [6,7].

Known [8] system of laser diagnostics of technical condition of gas pipeline, which allows to detect leaks of methane. Laser gas analyzers operate in reflection mode radiation from a topographic target, clouds of methane.

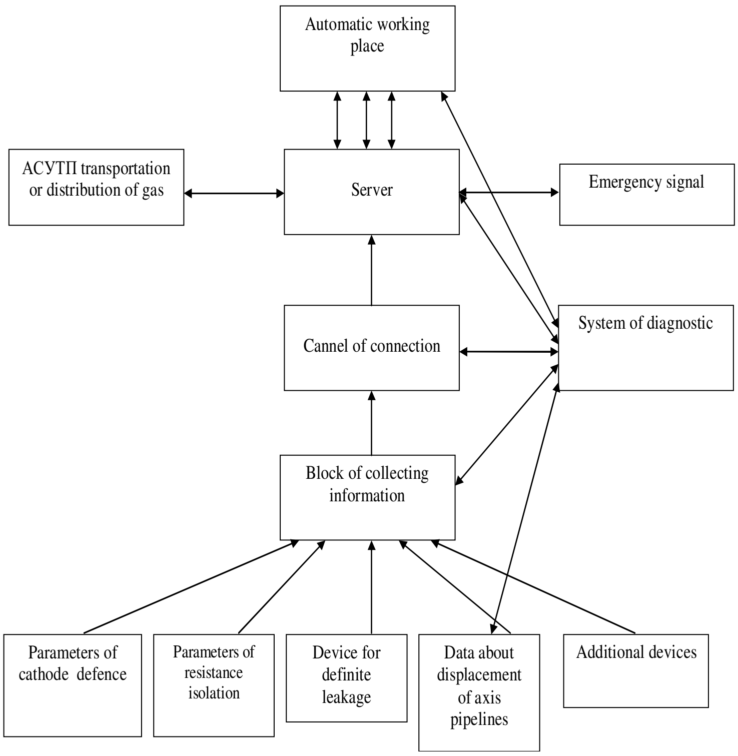

Fig.3. Blocks of data collection. IMS scheme for monitoring the technical condition of pipelines and gas distribution systems

Remote optical path laser gas analyzer tlg-01 is based on optical parametric oscillator with a wavelength tunable in the spectral range of 2,7-3,6 mm and is designed for the detection and measurement in the atmosphere, the pipeline corridor, the concentration of gases in the atmosphere, including methane, propane and other light hydrocarbons. Laser Gas Analyzer tlg-01 was used in the automotive version (available on the ZIL-131) and combined with GPS-receiver, which allows you to position the leak in the pipeline.

However, ground-based laser inspection of gas pipelines inferior version of the aircraft, for example, the use of laser sounding drones, which are equipped with laser sights and navigation systems with GPS. This increases the speed control of the pipeline, and ensuring the independence of the conditions of his pads (ravines, swamps, etc.).

In addition, unmanned spy planes with laser sights, can be successfully used, and when detecting forest fires by sensing laser beams clouds of carbon monoxide CO. [9] describe a method and system fault detection in pipelines by generating pulses of high frequency acoustic signals that are distributed through the pipes of the system and reflected from the fault location. In each of the pipe system, the sensors are recorded as passing through the medium of transmitted signals and reflected. Time for the signal to the consumer and back-calibrated time, and time for the signal to back injuries and describes the place of damage. Each pipe has its own number and their length, which is determined and the distance to the injury in a pipe or group of pipes.

Obviously, the reliability of the pipelines to a great extent depends on the state potivokorrozionnoy protection and, in particular, on the condition of the insulating coating. With the aging of pipeline systems and operating time in the technological environment, increasing internal and external corrosion, which significantly reduces the actual length of service pipelines compared with the project. There is a change in the structure of metal and having a zone of longitudinal and transverse stresses.

Currently under development methods and devices of diagnosing the real technical condition of pipeline systems, in particular, in-line inspection.

For example, a pilot device "MI-03", which allows one to record the magnetic field of the pipeline in three orthogonal directions with simultaneous recording of multiple parameters of sensor units with a step of measuring 1-15cm and automatic recording. The resulting database allows you to pinpoint the location of sites deviation of the stress-strain state of metal in the areas of defects. As a result of lengthy sections of the pipeline revealed dangerous defects, and estimate the residual thickness of the pipe wall method of contact inspection.

However, this device allows you to monitor the state of the pipeline overhead sensors only on the available sites. The most suitable for solving problems of securing the pipelines ultrasonic principle of control, which allows not only an assessment of pipe wall defects, but also the qualitative characteristics of modern types of insulating coatings. The ultrasonic flaw detection method has the highest sensitivity and resolution in relation to various types of defects [10].

Firm Payptroniks "developed In-line inspection" Ultraskan-SD, designed for the detection of longitudinal cracks pipe corrosion cracking under stress [11]. The device is highly sensitive and can detect cracks in the metal length of 30mm and a depth of more than 1 mm at a rate of passage of the projectile inside the tube up to 1 m / sec. The structure of in-pipe system "Ultraskan-SD" is a shell designed to measure the degree of corrosion or residual wall thickness of the pipe. In addition, based on analysis of the amplitude distribution of multiple reflected echoes are the main features informative defectoscopical delamination of polymer coatings on metal pipes. However, this device is not designed to detect cross-In-cracks.

Thus, to ensure effective control of technical condition of pipeline systems must be the introduction of continuous monitoring. Currently, there is a necessary element base and experience in implementing information-measuring systems. A priority for the implementation of IMS include:

- Integration of process control energy transportation elements of technical inspection of pipelines;
- Economic evaluation of the introduction of IMS in the individual pipe sections

In our opinion, in existing process control system of transportations of oil & gas is necessary to build in elements of measuring systems of detection of a place of arising ruptures of the main pipelines which are already developed, and then consistently to introduce all set of elements of technical diagnostics of a technical condition of the main pipelines. It will allow to prolong terms of operation and to avoid infringement of ecology of environment.

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THE IMPACT OF DIESEL FUELS' COMBUSTION IN CARS ON THE URBAN AIR SO_2 POLLUTION IN TIRANA, ALBANIA

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ABSTRACT

Albanian vehicle fleet is composed of 80 % Diesel vehicles, which operate on Diesel with very high sulfur content and are relatively "old". This article addresses an important aspect: comparison of sulfur concentrations in Diesels traded in Albania with the ones in Diesels traded in an EU country, and the impact of the Diesels' combustion in cars on the urban air SO_2 pollution in Albania.

While fuel companies pretend to sell high quality Diesel, this research showed that Diesel D2 resulted with an average S concentration of 1020 ppm S for the imported fuel, and 1600 ppm S for the Diesel D2 produced in the country. Diesel D1, while being a relatively higher quality fuel regarding the S content in it, shows great differences regarding S content: the average S concentration for Diesel D1 imported in Albania was 210 ppm S, whereas the average S concentration in the Diesel D1 in use by the vehicles in an EU country [Greece] resulted 27 ppm S. Labels on fuel stations do not always match the quality of Diesel offered to drivers.

On the other hand, although the SO_2 concentrations in the air of Albanian cities continue to respect the Albanian norm of 60 $\mu g/m^3$, there is noticed a significant increase of SO_2 concentrations in the urban air. SO_2 higher concentrations and trends of annual increase are very well correlated with the annual increase in the number of cars and most of all with the traffic density in certain cross-roads in Tirana city.

Keywords: diesel, sulfur content, SO_2 air pollution.

1. INTRODUCTION

1.1 Vehicle Fleet in Albania

The Albanian vehicle fleet is composed of about 80 % of Diesel cars which are mostly second hand vehicles imported from neighbor countries after the 90s. In particular, the number of private cars, has significantly increased during the last 16 years (Figure 1), comprising slightly more than 70 % of the total number of registered vehicles in 2009. The number of "0 km" cars at the moment of purchase is very small. The cars produced in the period 2006-2009, which are registered as brand new cars purchased in these years is less than 5 % of the total number of vehicles (MTTPW, 2010)

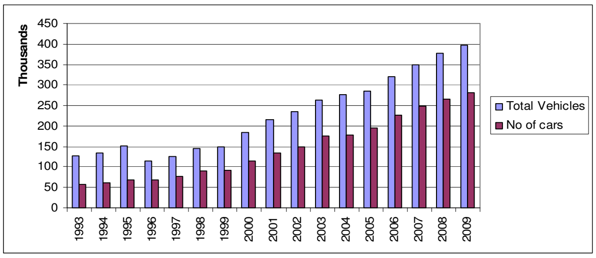

Figure 1. The progress of the number of cars compared to the total number of registered vehicles in Albania in the last 16 years. **Source:** (MTTPW, 2010).

Due to the better living conditions and the higher standard of living in Tirana compared to other Districts, the number of cars per 1000 inhabitants has been almost double in the capital compared to this figure for the whole country in the last decade. The trends show a significant and constant annual increase, as presented in Figure 2.

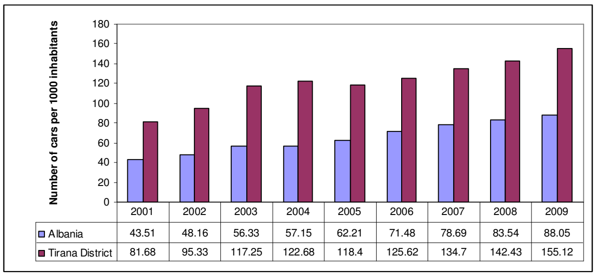

Figure 2: Number of cars per 1000 inhabitants in the Republic of Albania and in Tirana District for the period 2001–2009. (Source: MTTPW, 2010; INSTAT, 2010).

Table 1: Number of vehicles and cars / 1000 inhabitants for the year 1990

Population of Albania	Total no. of vehicles	No. of cars	vehicles / 1000 inhabitants	cars / 1000 inhabitants
3,273,131	20200	2400	6.171	0.733

The number of cars per 1000 inhabitants presented in Figure 2 above shows an even more dramatic increase of this parameter compared to the year 1990, as illustrated from data given in Table 1 (MTTPW, 2010; INSTAT, 2010), keeping in mind that till 1991, the private ownership of any vehicle was not permitted by the Socialist Government in power up to that year.

1.2 Diesels consumed in Albania

The several reports on the State of Environment published every 2 years by the Ministry of Environment in the period 1997-2009 (SoE 1999; SoE 2001; SoE 2003; SoE 2005; SoE 2008; SoE 2009) quote that the "bad urban air quality" is due to the fact that the vehicles in Albania are "very old" and that the fuel they use is not of a good quality . While this is true, it was noticed that these reports do not give figures to illustrate the "bad quality" of fuels that these vehicles use.

Although there is a State Institution that is responsible for the fuel analysis, The Central Technical Inspectorate, up to now, there are not published any official Reports regarding the fuel quality in the country by them. Therefore it was necessary for the authors of this paper to undertake this research in 2008-2009 in order to observe the Diesel quality regarding sulfur content in Diesels traded in Albania and their impact on the SO_2 urban air pollution. Tirana was chosen as the City on which to observe the SO_2 air concentrations because in Tirana District circulate over 36 % of the total vehicles that Albania has (MTTPW, 2010) and lives 23 % of the population of the country (INSTAT, 2010) and also because SO_2 is one of the indicators of the urban air quality.

In Albania up to 2009, the Diesel vehicles used Diesel D2 which contained sulfur in the range of 0.05 – 0.2 % in mass and Diesel D1, otherwise named "Eurodiesel", which contained less than 0.05 % (in mass) sulfur in it, according to the customs' classification. The Diesel produced in Albania up to 2008 was of the type D2 due to its high sulfur content and the lack of a desulphurization plant in the country. The quantity of diesels consumed by the Albanian market has annually increased in the last decade, as the Figure 3 shows. However, there was an exception of this trend in the year 2009, due to the banning of the import of the Diesel D2 type by the Government, and also due to the effects of the world financial crisis on fuel consumption in Albania.

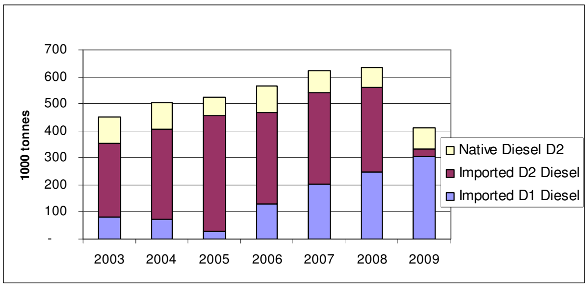

Figure 3: The progress of the quantity of diesels consumed by the Albanian vehicle fleet in the last 6 years. (Source: METE, 2010; NICC, 2010).

In general, in the last decade, 85–90 % of fuels in Albania come from import, mainly from Greece and Russia which have contributed respectively with 61 % and 32 %, of the whole fuel quantity imported in Albania for the year 2008 (NICC, 2010). In average in the last decade only about 10-15 % of the fuel market in Albania is being supplied by the ARMO, the Albanian Oil Refining company [Figure 4] (METE, 2010).

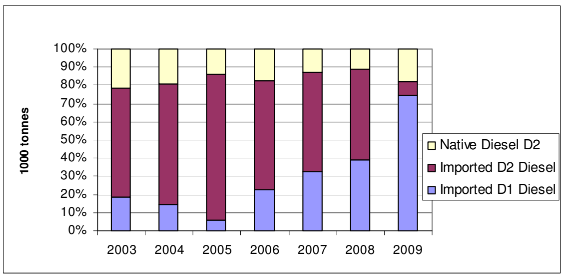

Figure 4. Percentage of the Albanian D2, imported D2 diesel and imported D1 Eurodiesel in the last 6 years in the Albanian fuel consumption market. (Source: METE, 2010; NICC, 2010).

1.3 Sulfur dioxide concentrations in Tirana

By comparing consecutive Air Quality Monitoring Reports by the Institute of Public Health [IPH] which carries out annual measurements of several air pollutants with Monitoring results of the Agency of Environment and Forests (AEF) Figure 5 was produced with annual average SO_2 concentrations in 5 monitoring stations in Tirana (MEFAW, 2009; IPH 2010).

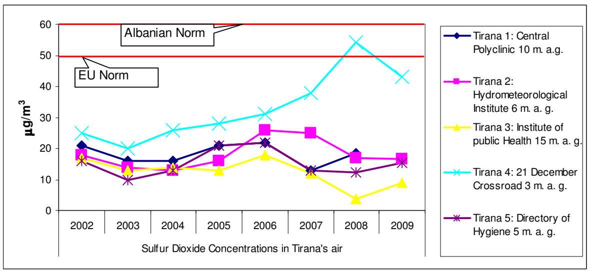

Figure 5: Average SO_2 <u>annual</u> air concentrations in Tirana in 5 monitoring stations carried out by IPH for the period 2001 – 2009. (Source: MEFAW, 2009; ISHP, 2010).

The EU annual arithmetic average standard for the SO_2 air concentrations is 50 □g / m^3 whereas the Albanian standard is 60 □g / m^3 (AEF, 2009). Concentrations of SO_2 measured in Tirana respect the Albanian standard in all monitoring stations, nevertheless they show an annual increase especially in the "heavy traffic" cross road named "21 December", which for the year 2008 passed the EU norm for this air pollutant.

The relationship between the number of vehicles passing by a road and the SO_2 concentrations is shown by comparing Figure 5 above with the Figure 6 below. The much higher SO_2 concentrations in the Tirana 4 monitoring point are explained by the much higher number of vehicles passing daily in this monitoring site, based on the traffic numbering in Tirana's roads in the morning rush hour in 2007 (MT, 2008).

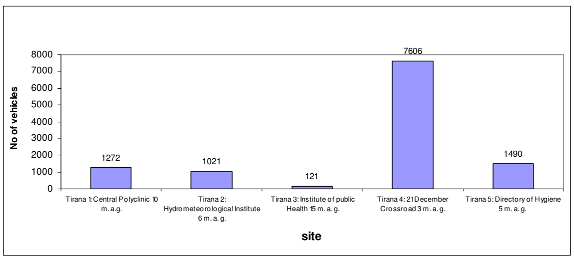

Figure 6: Total number of vehicles passing by each Air Quality Monitoring Site in Tirana, in the year 2007. (Source: MT, 2008).

For the period April 2008 – June 2009, in Tirana's heavy traffic section of the crossroad "21 December", the average <u>monthly</u> SO_2 concentration resulted 20.8 □g / m^3 (AEF, 2009), as presented in Figure 7.

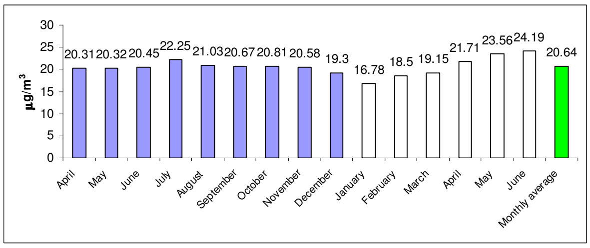

Figure 7: SO_2 air concentrations in Tirana for the period April 2008 – June 2009. (Source: AEF, 2009).

2. MATERIAL AND METHODS

Because there are not many published data on the Fuels' quality in Albania, in order to complete this research, information was obtained from various Governmental Institutions, such as Ministries of the line, Agencies and Directorates, as presented in the References and Source of data for each case that the data was used by itself or when it was combined with data from several Institutions to compile certain graphs.

For the experimental part, Diesel samples of one liter were taken in sterile plastic bottles from various fuel stations along Tirana- Durres and Korça – Kapshtica highways. For a reference of the fuel used in an EU country, diesel brought from Greek fuel stations was analyzed regarding its sulfur content at the same time and with the same equipment that the other diesel samples were analyzed.

The equipment used to analyze the sulfur content in Diesel fuels is Multi EA 3100 Analytik Jena. Pyrolysis is used for the breakdown of the substances in the Multi EA 3100, with subsequent thermal oxidation of the pyrolysis products. The apparatus was operated in the vertical mode for the analysis of our Diesel samples.

With a syringe of a capacity 50 □l, there was taken exactly 20 □l of diesel sample and it was injected manually directly into the evaporation zone of the combustion tube. There the sample is subjected to pyrolysis in the stream of argon. After this, the gases from the pyrolysis are completely oxidized in the stream of oxygen. Reaction taking place can be summarized as below:

$$R\text{-}S + O_2 \rightarrow SO_2 + CO_2 + H_2O \qquad (1)$$

R – represents the organic substances containing carbon in the Diesel to be analyzed.

A calibration function that has been determined before hand then automatically calculates the amount of total sulfur in the fuel sample. The average S concentration is displayed on the screen on the computer linked to the Multi EA 3100 Analytic Jena apparatus for each analysis. The result gives the total sulfur content in the Diesel sample analyzed (CL, 2009).

For Diesels containing 0–50 mg/l sulfur the linear calibration curve was used. For the ones containing 51-500 mg/l sulfur the quadratic calibration curve was used. For the Diesels that contain much more than 500 mg/l sulfur, dilution takes place with the solvent iso-octane. Iso-octane is used as a diluent because it is used to “zero” the apparatus and it does not contain sulfur in it, thus not interfering with the results.

The proportion of dilution depends on the result of the first trial experiment: if it resulted in 1 g/l sulfur, the dilution is 1 part in volume fuel : 3 parts in volume iso-octane. If the result was 1.5 g/l the dilution is made in the proportion 1:4 and if it resulted in 2 g/l the dilution was made in the proportion 1:5 respectively. Dilution is made in order for the S concentrations to be within the boundary of 51-500 mg/l calibration curve, thus resulting in more accurate measurements. For each sample one trial measurement and three other measurements were carried out in order to define an average value of the total sulfur content in the Diesels analyzed.

3. RESULTS & DISCUSSION

Samples of Diesel were collected in the period August – December 2008. Their analysis were carried out at the Laboratory of Petrochemicals in the Customs Directory of Laboratories by the first author of this article, in the period March - April 2009. The summary of analysis’ results is presented in the Tables 2-6 below according to the Diesel types analyzed and it is grouped by the place where the Diesel samples are taken.

Even in previous research regarding the sulfur content in Albanian fuels in 1996 (Mulla and Dhimitri, 2002) and 2003 (Mulla and Norbeck, 2005), it is noticed that the Diesels’ quality in Albania in 2008 has improved significantly compared to their quality in 1996 when the S content in them did not even respect the Albanian standard of less than 0.2 % S for both the native and the imported Diesel (Mulla and Dhimitri, 2002). In 2003 most of the Diesel used in Albania was D2 with more than 500 ppm Sulfur in it, but all of the imported Diesel samples met the Albanian Standard, whereas the Albanian Diesel D2 [Ballshi Naphta] passed this standard significantly (Mulla and Norbeck, 2005). Five years latter, in 2008, we notice a diversification of the types of Diesels used in the country, and all the samples meet the Albanian standard, even the Diesel produced in Ballshi Refinery.

Depending on their quality and their sulfur content the prices of Diesels vary. Native Diesel is cheaper and Eurodiesel is the most expensive in the market. The economic situation of the people determines the type of car (new or old), the frequency of service that they will do to their cars and, most importantly, the type of fuel (the expensive or the cheap one) they will use on daily basis.

Table 2: Results for the sulfur content in the Diesel D2 samples.

Place taken	Korca – Kapshtica highway fuel stations				Tirana fuel stations		Diesel D2 from Ballshi, native fuel		
Sample name	diesel 1	diesel 5	diesel 7	diesel 8	diesel 9	diesel 19	diesel 25	diesel 26	diesel 27
S concentration average (mg /l)	865	1257	981.9	866.6	552.7	622.5	1325.1	1349. 2	1408.9
Standard deviation (mg / l)	5.2	5.78	8.56	25.11	4.97	9.15	24.7	16.6	32
Variation coefficient (%)	0.6	0.46	0.87	2.9	0.9	1.47	1.89	1.24	2.04
Quadratic regression [□g]	$C = (k_2 \cdot I^2_{net} + k_1 \cdot I_{net} + k_o) / V$ $k_0 = -0.055513 \quad k_1 = 7.651E-6 \quad k_2 = 1.115 E-12$								
Density at 15 oC	0.8454	0.8384	0.8335	0.8401	0.8325	0.8504	0.8549	0.8539	0.8539
S content calculated **in ppm** = Csulfur average (mg/l) / d15oC (kg/l)	1023	1499.28	1178.04	1031.5	663.90	732.01	1550	1580	1650
S content **in mass %** = Sppm : 10000	0.1023	0.1499	0.1178	0.1032	0.0664	0.0732	0.155	0.158	0.165

Table 3: Results for the sulfur content in the Diesel D1 samples with S concentration more than 50 mg/l and less than 500 mg/l.

Place taken	Korca – Kapshtica highway		Tirana	brought from Greece	Tirana – Durres fuel stations					
Sample name	diesel 2	diesel 3	diesel 10	diesel 11	diesel 12	diesel 13	diesel 14	diesel 16	diesel 20	diesel 21
S concentration average (mg/l)	156.8	353.5	298.8	54.33	218.9	386.2	463.6	81.68	46.12	54.93
Standard deviation (mg/l)	1.1	2.02	946.4	0.8327	1.07	2.65	5.62	1.92	1.24	1.09
Variation coefficient (%)	0.7	0.57	0.32	1.53	0.49	0.69	1.21	2.35	2.69	1.98
Quadratic regression [□g]	$C = (k_2 \cdot I^2_{net} + k_1 \cdot I_{net} + k_o) / V$ $k_0 = - 0.055513$ $k_1 = 7.651E – 6$ $k_2 = 1.115\ E – 12$									
Density at 15 oC	0.8318	0.8371	0.8222	0.8404	0.8394	0.8405	0.8241	0.8255	0.8355	0.8359
S content calculated **in ppm** = Csulfur (mg/l) / d15oC (kg/l)	188.5	422.29	363.42	64.65	260.78	459.49	562.55	98.95	55.20	65.71
S content **in mass %** = Sppm : 10000	0.0189	0.0422	0.0363	0.0065	0.0261	0.0459	0.0563	0.0099	0.0055	0.0066

Table 4: Results for the sulfur content in the Diesel D1 samples with S concentration less than 50 mg /l.

Place taken	Tirana	Brought from Greece		Tirana – Durres highway		Brought from Greece		
Sample name	diesel 4	diesel 6	diesel 15	diesel 17	diesel 18	diesel 22	diesel 23	diesel 24
S concentration average (mg /l)	24.45	30.85	2.75	4.02	8.25	22.92	22.85	2.3
Standard deviation (mg / l)	6.06	0.12	0.05216	0.06712	0.08621	0.191	0.084	0.0641
Variation coefficient (%)	24.78	0.39	1.9	1.67	1.05	0.83	0.37	2.79
Linear regression [□g]	$C = (k_1 \cdot I_{net} + k_0) / V$ $k_0 = - 0.052299$ $k_1 = 8.182\ E - 6$							
Density at 15 oC	0.8324	0.8424	0.8351	0.8355	0.8365	0.8335	0.8335	0.8351
S content calculated **in ppm** = Csulfur (mg/l) / d15oC (kg/l)	29.37	36.62	3.29	4.81	9.86	27.50	27.41	2.75
S content **in mass %** = Sppm : 10000	0.0029	0.0037	0.0003	0.0005	0.0010	0.0027	0.0027	0.0003

Table 5: Summary of the average sulfur content (in mass percentage) of the fuels traded in Albania in 2008, according to their categories.

Diesel D1 imported	12 samples	0.021
Diesel D2 imported	6 samples	0.102
Albanian D2 diesel	3 samples	0.16
Diesel brought from Greece	6 samples	0.0027

Table 6: Average amount of S and SO_2 per inhabitant in Albania in 2008.

	S mass %	Diesel quantity in kg in 2008	Total S in Diesels in kg
Diesel D1 imported	0.021	246000000	51660
Diesel D2 imported	0.102	316000000	322320
Albanian D2 diesel	0.16	71000000	113600
Total amount of Sulfur in Diesels in kg			487580
Average amount of SO_2, supposing that S is oxidized 100 % in SO_2 M_{SO2} = 64 g/mol whereas A_S = 32 g/mol			975160
Number of inhabitants in 2008			3170048
Average amount of S per inhabitant / year 2008 in kg			0.154
Average amount of SO_2 per inhabitant / year 2008 in kg			0.308

Source: Table 6 calculations are based on data received from NICC, 2010; METE, 2010; INSTAT, 2010

Based on data from Table 6, the pie charts on Figures 8 and 9 are compiled in order to give a more visual representation of different types of Diesels' contribution in the SO_2 quantity in the air of Albania in the year 2008. The proportions for S content in the fuels and SO_2 released in the urban air are the same because the molar mass of SO_2 is double than the atomic mass of sulfur.

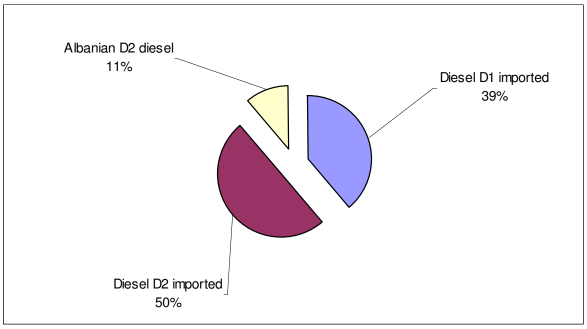

Figure 8: The mass percentage different types of Diesels traded in Albania in the year 2008. (Source: NICC, 2010).

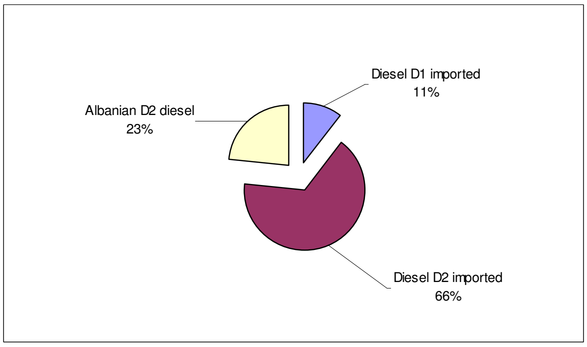

Figure 9: The mass percentage of the total amount of Sulfur contained in different types of Diesels traded in Albania in the year 2008.

From the graphs in Figure 8 and 9 it is easily noticeable that in the year 2008, although the Albanian D2 Diesel contributed with only 11 % of the total fuel quantity, due to its very high S content, it contributed with 23 % of the total S contained in the Diesels used, and consequently with 23 % of the total SO_2 released in the urban air, due to the Diesels combustion in vehicles' engines. On the other hand, the imported Diesel D1, or the EuroDiesel, contributed with 39 % of the total quantity of fuels, but only with 11 % of the total S in the fuels, and the 11 % of the total SO_2 released in the urban air due to its combustion.

In this research it was found that the Diesels D2 used in Tirana District contained less S than the ones used in Korça District. As expected, and as it is illustrated in Figure 10, the samples of Diesel D2 from Ballshi Refinery contained much more S than all the samples of Diesel D2 imported in Albania.

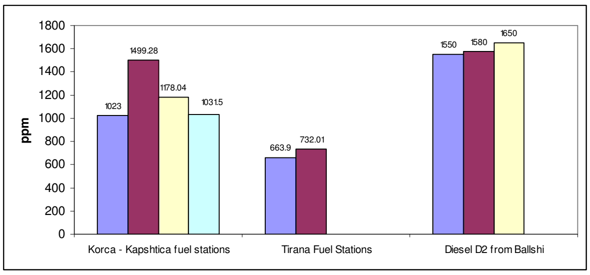

Figure 10: Sulfur content in Diesel D2 samples.

By comparing the S content in the Diesel samples taken in Albania with the ones taken in an EU country, Greece, it is noticeable that the average S content in Diesel D1 used in Albania is nearly 8 times more than the average S content in the Diesels used in Greece as demonstrated by the Graph in Figure 12 below:

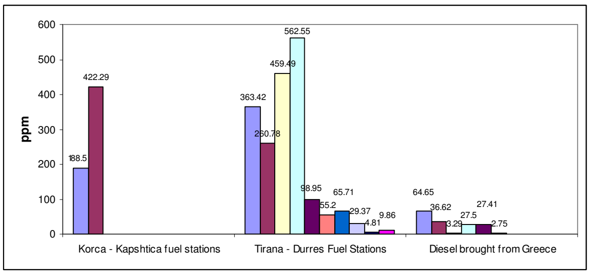

Figure 11: Sulfur content in Diesel D1 samples.

The variation of S content in the Diesel D1 samples taken in Albania is great, from 4.81 ppm to 562.55 ppm, whereas for the samples taken from Greece, the variation of S content is much smaller, from 2.75 to 64.65 ppm.

It is worth mentioning that some of the Diesel samples were not matching the labels under which they were traded. F. ex. The diesel samples indexed “diesel 7” and “diesel 9” were purchased for “Eurodiesel” and D1 type, but after the analysis they resulted to contain 1178.04 ppm S and 663.9 ppm S respectively, thus being both of them, Diesel D2 type.

For many years, meeting the fuel standards has been a challenge, especially regarding their extremely high sulfur content. Up to early 2009, the Albanian Standard of sulfur content was the same as the one of 1987 (STASH, 1987) providing in this way a very good “climate” for the import of fuels with less than 0.2 % (in mass) of sulfur in them, when in all the EU countries these fuels are not allowed to be used in cars. By the Decision of the Council of Ministers No. 52 dt. 14 January 2009 (DCM, 2009) the Diesel produced in the Refinery of Ballshi would be allowed to be in the fuel market up to the end of 2009 and after that date the ARMO fuel company is obliged to produce and sell Diesel which will respect the EURO standards on this schedule:

From 1 Jan. 2010, the Diesel not to contain more than 350 ppm S in it.

From 1 Jan. 2011, the Diesel not to contain more then 150 ppm S in it.

From 1 Jan. 2012, the Diesel not to contain more than 10 ppm S in it.

By the percentage of the fuels consumed (Figure 4), it is noticed that in the last seven years the quantity of Eurodiesel consumed in Albania has increased annually, comprising 74 % of the total quantity of the Diesel consumed in 2009, compared to the 18.5 % of the total quantity of Diesel consumed in 2003. This is a good indication of the pressure by the Government to the fuel importers to provide a good quality Diesel for the Albanian drivers, the majority of whom cannot afford to purchase a brand new car for themselves. Even in the D1 category of Diesel we do have fuel stations which provide Euro 5 Diesel with less than 10 ppm of sulfur in it, thus providing a market for the drivers who care not only about their cars but about their environment as well.

4. CONCLUSIONS & RECOMMENDATIONS

In conclusion, the Diesel samples analysed were found to meet the Albanian Standard regarding the sulfur content, but in general they failed to meet the EU standards of Euro 5 type of Diesel. There were a few fuel stations that provided good quality Diesel comparable to the Diesel that was currently traded in Greece.

Also the air quality in Tirana generally does respect the Albanian standard and the EU standard regarding the SO_2 concentrations in the 5 monitoring points, but the trends of these concentrations being increased annually in heavy traffic sections show that the respect of these standards will not last indefinitely. With the significant reduction of Diesel D2 consumption in 2009, there is noticed a slight decrease of the SO_2 air concentrations measured at the Tirana 4 station as the monitoring results of 2009 show.

As a recommendation, out of this research, the Government needs to refresh the Standard regarding the sulfur content. At least, the import of only Euro 5 Diesel (with less than 10 ppm S) must be the first amendment of the Revised standard, in order to provide not only meeting for a very long time the SO_2 air concentrations standard, but also the SPM (Suspended Particulate Matter) and the PM_{10} (particulate matter) standard.

The SPM and PM_{10} concentrations in the urban air in Albania continue to be much higher even than the present Albanian PM_{10} standard in all the monitoring points not only in Tirana, but in all the monitored cities in Albania (SoE, 2009). An explanation for this is based on research findings from other Universities, that although sulfur is oxidized mostly to SO_2 on combustion in Diesel car engines, sometimes, besides in SO_2, it is oxidized in sulfate ions, SO_4^{2-}, which can assist in the nucleation of particles (Colvile et. al. 2001; Placentino et al., 2008; Bader, 2007; Wahlin et al., 2001; Sterner, 2003; Elsom, 1996) and therefore give rise to SPM and PM_{10} air concentrations which for Tirana also correlate very well with the total number of cars passing by the 5 monitoring points there (Mulla E. 2008; Mulla E. 2009).

In order to provide space for the native Diesel which has resulted always in very high S content, it is recommended that in the near future the Government finds the proper economical and legal mechanism that the private company that runs the Oil Refinery of Ballshi provides only Euro 5 Diesel for the Albanian car drivers and becomes a good competitor in the Diesel market in Albania.

The present situation with the fuels' quality foresees a great challenge not only for the Government in setting standards and meeting them, in the law enforcement against those fuel stations which do not comply with the Standard, but also for the people who must be aware enough that using good quality Diesel for their cars is a necessity, most of all for ensuring a good quality of life in their own country for themselves today and for their own children tomorrow.

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The Generation of Domestic Electricity Load Profiles through Markov Chain Modelling

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Abstract

Micro-generation technologies such as photovoltaics and micro-wind power are becoming increasing popular among homeowners, mainly a result of policy support mechanisms helping to improve cost competiveness as compared to traditional fossil fuel generation. National government strategies to reduce electricity demand generated from fossil fuels and to meet European Union 20/20 targets is driving this change. However, the real performance of these technologies in a domestic setting is not often known as high time resolution models for domestic electricity load profiles are not readily available. As a result, projections in terms of reducing electricity demand and financial paybacks for these micro-generation technologies are not always realistic.

Domestic electricity load profiles are often highly stochastic, influenced by many different independent variables such as environmental, dwelling and occupant characteristics that shape individual customer's load across a single day. This paper presents a stochastic method for generating electricity load profiles based on the application of a Markov chain process. Electricity consumption was recorded at half hourly intervals over a six month period for five individual Irish dwelling types and used to generate synthetic electricity load profiles. The purpose of this paper is to determine whether Markov chain modelling is an effective way of re-generating electricity load profiles for domestic dwellings and identify shortcomings with this particular technique. The results show that the magnitude component of the load profile can be reproduced effectively whilst the temporal distribution needs to be addressed further.

Keywords: Markov chain, electricity

Introduction

Domestic electricity use in most European countries accounts for a major proportion of overall demand. In Ireland, 32% of final electricity was consumed in the residential sector in 2008 (SEAI, 2009). This is the second largest electricity consuming sector in the economy, exceeded only by commercial and public services sectors. The EU has set stringent targets for 2020 based on a 2005 emissions baseline: a reduction of 21% in greenhouse gas emissions for the emission trading sector across the EU-27 countries and a 10% reduction for the non-trading sector across the EU. The 10% reduction across the EU-27 countries for the non-trading sector is broken up collectively for the different member states. Ireland has been assigned a target of 20% reduction in greenhouse gas emissions by 2020.

In order to effectively respond to the EU 20/20 targets, national governments will need to accurately assess the cost and emissions effects of any energy policy decisions up to 2020. In Ireland, the National Energy Efficiency Action Plan published in 2009 makes recommendations to fully investigate the role of micro-generation, such as photovoltaics and micro-wind turbines, as an alternative to traditional power generation (DCENR, 2009).

Support mechanisms for mico-generation exist across the EU to encourage the up-take of technologies in an attempt to make them more cost competitive with conventional generation. In Ireland, the level of support for micro-generation is quite small compared to other European countries like Spain and Germany where a Renewable Energy Feed in Tariff (REFIT) price of 34cent/kWh and 39cent/kWh respectively is offered for micro-generation installations (EPIA, 2010). In February 2009, the Minister for Communications and Natural Resources offered 19cent/kWh to support micro-generation but only applies to the first 4000 installations over the next three years (DCENR, 2009).

Photovoltaics and micro-wind are highly site-specific technologies. Depending upon the available resources at a particular site, energy yield will vary considerably. Furthermore, depending on site demand characteristics and the REFIT price, payback periods and greenhouse gas marginal abatement costs will vary. Manufactures and retailers usually supply the customer with payback periods for their products based on local environmental conditions and electricity price and support mechanisms. These calculations are usually based on an average load profile, usually daily or monthly, for a typical dwelling type. However, the actual load profile for a particular dwelling rarely resembles the average, with large fluctuations between peaks and troughs throughout the course of a day.

Historically, electricity metering at a domestic level has been carried out at a low time resolution, usually on a monthly or bi-monthly basis. However, with improvements in technology, time of use metering is now becoming more prevalent, with large energy utilities throughout Europe trialling the technology. In this paper the first stage of a Markov chain model is presented to generate high time resolution load profiles for five individual dwelling types in Ireland. Markov chain is a type of Monte Carlo analysis where probability distributions determine the likelihood of a dwelling consuming a particular load. It is suited to modelling stochastic processes such as that relating to the generation of domestic electricity load profiles.

Methodology

Domestic electricity load profiles are usually cyclical with typically a morning and evening peak and a small base load over the night time period. The load profile is shaped by switching on/off individual electrical appliances which is influenced by various environmental, dwelling and occupant characteristics. Although some appliances are cyclical, other appliances may appear to be switched on and off at random. Firth et al. (2008) looked at groups of electrical appliances (continuous and standby, cold appliances and active appliances) and examined periods of the day with which they are likely to be switched on. Continuous and standby appliances tend to form a base load with the switching in and out of cold appliances across a 24 hour period. Electricity consumption from active appliances such as kettles and electric showers are more random and typically have high power requirements.

Wood and Newborough (2003) used three characteristic groups to explain electricity consumption patterns in the home: "predictable", "moderately predictable" and "unpredictable". "Predictable loads" consisted of small cyclic loads occurring when a dwelling is unoccupied or all the occupants are asleep. "Moderately predictable" related to the habitual behaviour of the occupants and "unpredictable" described the vast majority of electricity consumption within a dwelling. The "predictable" component could be classed as a deterministic process, the "unpredictable" component as a stochastic process and the "moderately predictable" somewhere between the two.

An electricity load profile can therefore be described as a combination of deterministic and stochastic processes. For example a cold appliance such as a fridge is usually left on 24 hours a day, would be a deterministic process. This could be approximated as a function of internal dwelling temperature. The use of other appliances such as kettles are more random and difficult to model and may be a function of various independent variables relating to a dwelling occupant. This introduces a stochastic component to a typical electricity load profile and can be difficult to model.

Markov chain modelling is an autoregressive process that can be used to generate synthetic sequences for modelling stochastic domestic load profiles. This technique has been used in the past to model various applications such as rainfall (Srikanthan, 1985) and wind speed at particular locations (Shamshad et al. 2005). In particular it is suited to modelling systems where the current state of a sequence is highly correlated to the state immediately preceding it and where a large sample size of data exists.

Markov chain modelling is based on the construction of a transitional probability matrix where the transition from one discrete state to another discrete state is represented in terms of its probability. A first order Markov chain model looks at the current state and the one immediately preceding it to calculate the probability of going to the next state. A second order Markov chain model looks at the two previous states and compares with the current state to determine the next state. For a first order Markov chain model, the transitional probability matrix, P, can be defined with $p_{k,k}$ probabilities for k states as follows:

$$P = \begin{bmatrix} p_{1,1} & p_{1,2} & \cdots & p_{1,k} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,k} \\ \vdots & \vdots & \vdots & \vdots \\ p_{k,1} & p_{k,2} & \cdots & p_{k,k} \end{bmatrix}$$

The state probabilities are calculated by the relative frequencies for each state changing from one to the next. A cumulative probability matrix is calculated by summing the number of frequencies of a particular state, $n_{i,j}$, where i and j represent different states, and dividing by the total number per state:

$$P_{cum} = \frac{n_{i,j}}{\sum_j n_{i,j}}$$

For each group of states (i.e. each row) the cumulative probability equals one. This represents the relative probability of changing from the current state to every other state including the current state.

A first order Markov chain model using a 24x24 probability matrix was chosen to model individual domestic load profiles based on the distribution of household loads in Ireland. Bin sizes for sampling were chosen based on standard deviation (0.0837) and mean electricity consumption (0.5525kW) for a sample of 4,500 Irish dwellings. Synthetically generated output values were calculated using a uniformly distributed random number generator choosing a value between each bin width.

The first state of the Markov chain sequence is generated by a random number generator with values between 0 and 1. After the initial state is chosen the transitional probability matrix is used to select every consecutive state after this. The state with the highest probability, which is usually the same state, will be selected most often but will depend upon the probability matrix. This is reflected in the matrix where the largest probabilities are usually located along the diagonal.

Five different dwelling types were modelled by generating transitional probability matrices for detached, semi-detached, bungalow, terraced and apartment dwellings. Six months electricity consumption data, metered at half hourly intervals between 1st July 2009 and 31st December 2009 was used to calculate the probability matrices.

Results and Discussion

A Markov chain approach to modelling domestic load profiles was discussed above. A program was coded in Matlab to calculate probability transitional matrices and generate synthetic load profiles for five individual dwelling types based on metered data. Table 1 compares statistical properties between metered and synthetic sequences such as mean, standard deviation (std), maximum and minimum values over a six month period. For each dwelling type the difference between mean and standard deviation for each sequence is less than 6%. However, the synthetic sequence continually over-estimated the mean and standard deviation for each dwelling over the period shown. This is most likely a result of sampling error and could be resolved by further increasing the number of bins at the lower end of a customer load at the expense of higher values. Maximum and minimum values of dwellings load are also shown in the Table 1 below.

	Detached	*Semi-detached*	*Bungalow*	*Terraced*	*Apartment*
Mean (metered)	0.4901	0.5834	0.7460	0.6510	0.1397
Mean (synthetic)	0.5073	0.5917	0.7661	0.6583	0.1436
STD (metered)	0.5969	0.7265	0.7578	0.7023	0.1976
STD (synthetic)	0.6300	0.7477	0.7930	0.7198	0.2021
Max (metered)	5.9820	5.4400	6.6060	5.5980	3.6980
Max (synthetic)	5.7638	5.3840	7.3146	6.4895	3.4000
Min (metered)	0.0800	0	0	0	0
Min (synthetic)	0.0503	0.0002	0.0110	0.0504	0.0001

Table 1 – Statistical properties for each dwelling type for metered and synthetic profiles (kW)

Table 2 shows total kWh for each dwelling type for metered and synthetically generated profiles over a one year period. Six months data (July – December 2009) was mirrored to extend to a full years data. This can be compared with national and international benchmarks such as that published by Sustainable Energy Authority of Ireland where it is estimated that an ‘average’ dwelling in Ireland consumed 5,591kWh in 2006 (SEAI, 2008). The error between metered and synthetic profiles is shown with terraced dwelling showing the largest deviation from the real data.

	Detached	*Semi-detached*	*Bungalow*	*Terraced*	*Apartment*
Metered	4305	5125	6553	5718	1227
Synthetic	4456	5170	6922	6094	1261
Error	3.4%	0.9%	5.3%	6.2%	2.7%

Table 2 – Electricity consumption per dwelling type for metered and synthetic profiles (kWh)

Synthetic sequences were generated for each dwelling type with similar results. Due to space requirements within this paper only figures for a single detached dwelling are shown with results in table form for all dwelling types where appropriate. Figure 1 shows metered and synthetic sequences over a six month period for a detached dwelling. A simple visual inspection of the sequences indicates that they both compare reasonably well in the time domain and further comparative tests are carried out to determine whether this is the case.

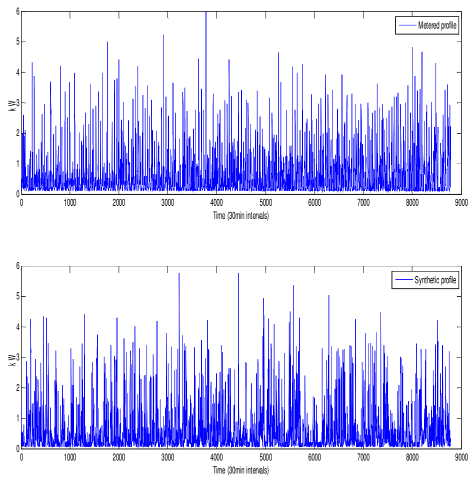

Figure 1 – Detached Dwelling
Six Month Profile

Figure 2 shows the frequency distribution for both sequences. A three parameter log-normal distribution is fitted to the data and location, scale and threshold statistical properties are shown in Table 3. Marginal differences exist between the log normal distribution parameters for metered and synthetic generated sequences.

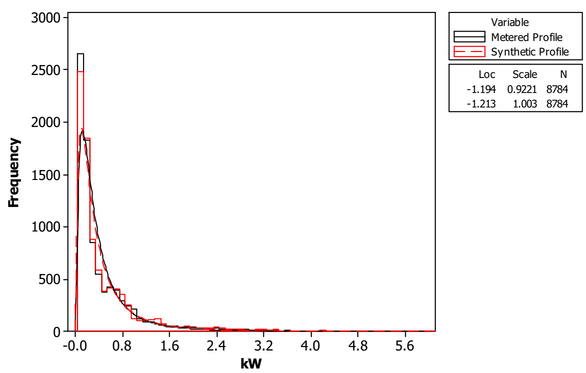

Figure 2 – Detached dwelling histogram for metered and synthetic profiles over six months

	Detached	*Semi-detached*	*Bungalow*	*Terraced*	*Apartment*
Location (metered)	-1.752	-1.215	-0.7807	-0.8834	-2.316
Location (synthetic)	-1.523	-1.233	-0.7896	-1.003	-2.203
Scale (metered)	1.37	1.162	1.024	0.9482	0.7286
Scale (synthetic)	1.299	1.21	1.073	1.105	0.7696
Threshold (metered)	0.07889	-0.00027	-0.00097	-0.00442	-0.00121
Threshold (synthetic)	0.04463	-0.00056	0.009584	0.03553	-0.012

Table 3 – Three parameter lognormal for metered and synthetic distribution over 6 month period

Figures 3 and 4 show autocorrelation functions for the same detached dwelling for metered and synthetic profiles over a weekly period. A period of one week is shown with lag of half hourly intervals. There is a clear cyclical pattern to the metered data over a 24 hour period showing the high correlation between electricity consumed at the same time interval each day. For the synthetic sequence the autocorrelation function decays to zero almost instantly indicating that the same daily cyclical pattern is not present in the synthetic sequence.

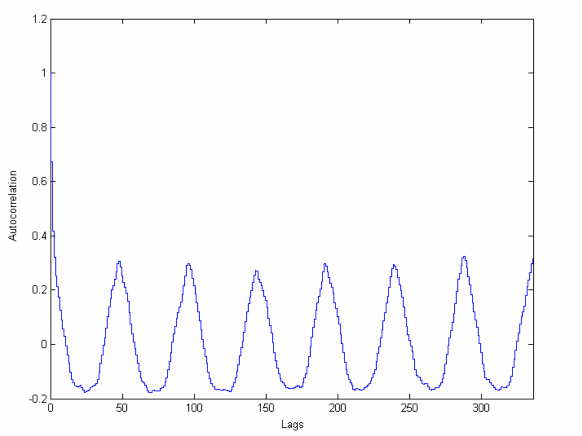

Figure 3 – Autocorrelation function for metered profile of a detached dwelling

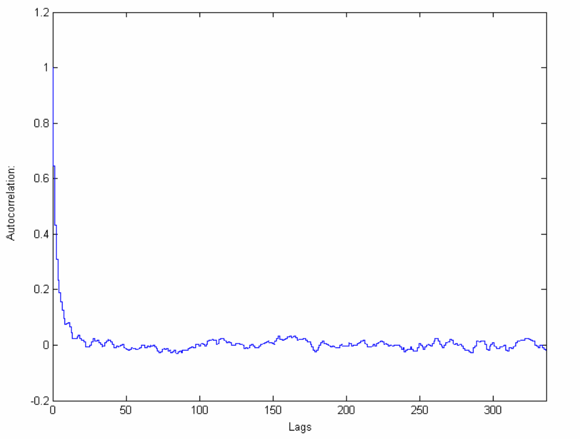

Figure 4 – Autocorrelation function for synthetic profile of a detached dwelling

Spectral density functions are also shown for metered and synthetic sequences in Figures 5 and 6 with frequency period in hours. The metered profile shows large frequency components around twelve and twenty-four hour periods which was also reflected in the autocorrelation function. This is in stark contrast to the synthetic sequence where multiple frequency components are shown which don't appear to indicate any clear pattern.

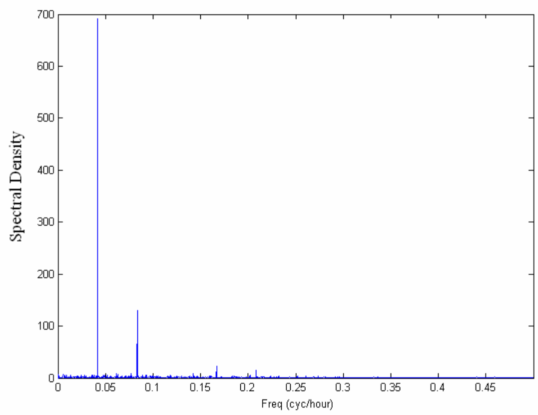

Figure 5 – Spectral periodgram for detached dwelling for metered profile over a six month period

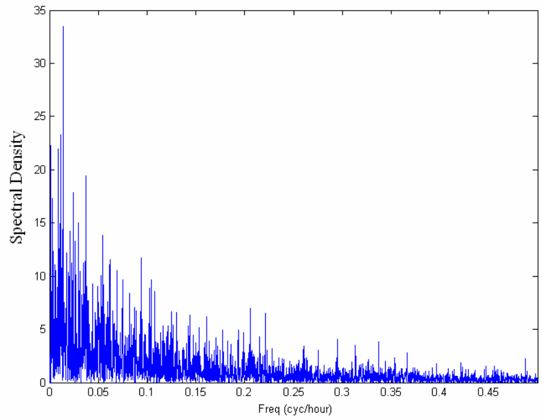

Figure 6 – Spectral periodgram for detached dwelling for synthetic profile over a six month period

Figure 7 shows metered and synthetic sequences for the same detached dwelling on the 1st July 2009. It is apparent from Figure 7 that the daily peaks for each profile do not coincide on a time basis. The synthetic profile predicted a daily peak in the early hours of the morning around 1.30am where as the metered profile showed a daily peak at 5.30pm over a daily period.

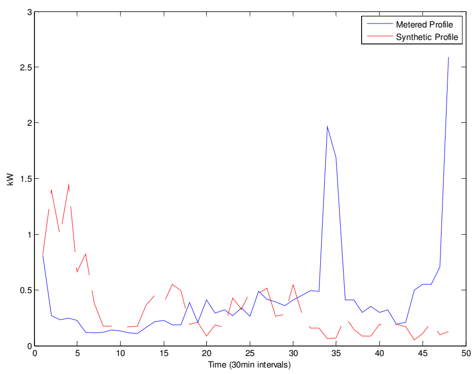

Figure 7 – Detached dwelling daily profile for 01st July 2009

The Markov chain process shown above was unable to model the effect of time of day on electricity consumption patterns. This is an obvious flaw to the model where time of day is a major determinant for electricity consumption. Hence daily peaks did not occur at the same time interval. A time component needs to be included as part of the transitional probability matrices.

Figure 8 shows the daily distribution of electricity consumption for the detached dwelling. A two parameter log normal distribution is fitted to the data showing location and scale parameters. The synthetic profile slightly under estimated the load in this particular instance with the difference between metered and synthetic generated electricity consumption 10.3kWh compared to 8.2kWh respectively for the 1st July 2009.

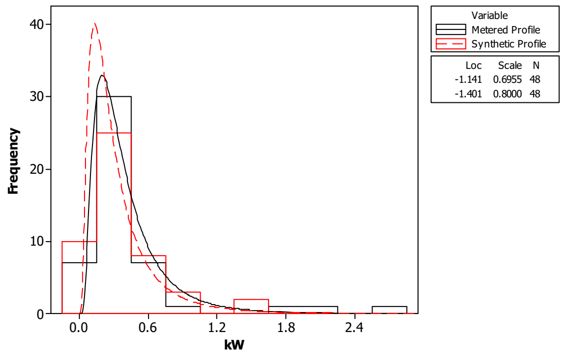

Figure 8 – Detached dwelling daily histogram for 01st July 2009

When averaged over time, a clear pattern of a small peak in the morning with a larger peak in the evening and a small baseload over the night time period is apparent. This can be seen in Figure 9 where mean and 95% confidence intervals are shown over a daily period for six months. The synthetic sequence shown in Figure 10 did not reproduce this characteristic profile shape with an almost flat response across the entire day reflecting a mean value for electricity consumption across a random day. It is clear that Figures 9 and 10 represent two distinctly different profiles for the same detached dwelling when compared over the same time intervals.

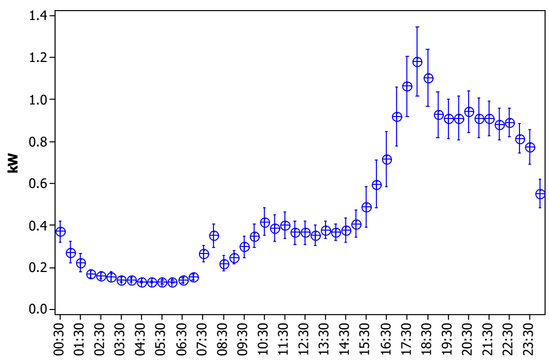

Figure 9 – Mean and 95% Confidence Intervals for detached dwelling over a six month period – metered profile

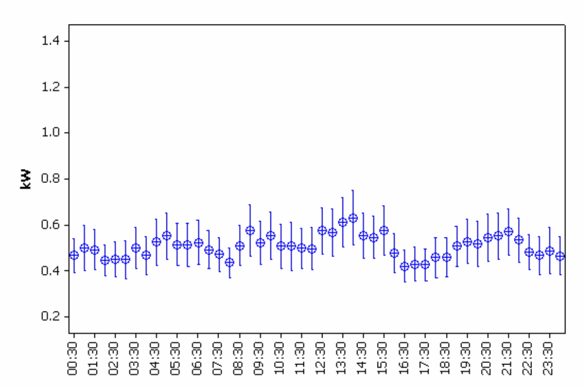

Figure 10 – Mean and 95% Confidence Intervals for detached dwelling over a six month period – synthetic profile

A large number of independent variables influence the magnitude and time component of electricity consumption. However, time is a major factor in determining the amount of electricity consumed with a dwelling even though the profile may appear to be highly stochastic. In its current form the model is unable to characterise load profiles for individual dwellings as the generated synthetic sequence is independent of time. However, the synthetic sequence generates a good approximation of the total electricity consumed within dwellings as one would expect from an empirical model.

Conclusions

A Markov chain model was used to model domestic electricity load profiles using a 24x24 probability matrix. Five different dwelling types were modelled over half hourly intervals and results compared to the original data. Certain key statistical properties such as mean, standard deviation, maximum and minimum values were satisfactory transferred between metered and synthetically generated load profiles. The temporal properties of the synthetic sequence compared poorly with the original data. The autocorrelation function was not reproduced in the synthetic profile and there was little correlation shown between spectral density plots.

Time of day is a major factor in determining electricity consumption. The Markov chain process was unable to successfully model the time component. The results showed uncharacteristic peak loads occurring at times of the day and night uncommon to typical domestic load profiles.

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Structure of Electricity Balance of Romania for the year 2020, Established Based on Optimal Primary Energy Resources Using the Multi-criteria Analysis Model

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Abstract: The main objective of carrying out this work was the creation of a multi-criteria model analysis of optimal electricity balance of Romania in terms of primary energy mix used for electricity generation. The paper is part of a comprehensive thesis named "Contributions to the Elaboration of Strategies Regarding the Sustainable Development of the Romanian Energy Sector”. The motivation for choosing this theme comprises two main elements: first the need for substantiation of the energy sector development strategies using dynamic methods sensitive to legislative changes and secondly the need, that conception and implementation of a sustainable development strategies for the energy sector for medium and long term, to take into account technical, economic and environmental factors. The program "Eclipse" (based on the Java platform), is used to achieve a multi-criteria analysis of optimal electricity balance for Romania in 2020. The program has a large database for the environment (fuel life-cycle analysis for each life-cycle stage), technical and economic points of view. It allows numerous changes of parameters and the results can be viewed in real time. The program also allows the user to realize many simulations and interpretations of data that can be used in establishing the energy sector development strategy.

Keywords: sustainable development, life cycle analysis, multi-criteria model

1. Introduction

In this article the authors explains how to build a multi-criteria model and the results of using it as a model for analysing the optimal electricity balance in Romania up to 2020, from the point of view of primary energy mix used to produce electricity.
The model has gone from setting the electricity needs for a particular year and then settled its coverage by alternative scenarios. For each primary energy source analyzed (natural gas, coal, uranium, biomass, wind, large hydro, small hydro), for environmental component it was applied the life cycle analysis method (LCA). We carried out an inventory, which identified the main pollutants for each primary energy source. It was developed, also, an environment impact assessment by which indicators were calculated for each impact class.
In order to perform the technical and economic analysis, we started to determine the installed power required to produce a certain quantity of electricity for each primary energy source considered. It was calculated the costs of investment, the cost of operating, the cost of fuel and finally, calculate the total expenditure. To select the optimal scenario, the economic recovery cost was used as main criterion.
Through this model the user can identify the optimal scenario for covering the electricity demand (balance)

as from environment and technical/economic point of view.

2. How to create a multi-criteria model

The multi-criteria model was first developed using Excel. This allowed designing the multi-criteria model in simple manner. The steps performed in model design and the obtained result are presented in the following sections.

2.1. Defining objectives and the field of study

2.1.1. Defining objectives:

The main objective of the analysis was to develop a multi-criteria model that might to optimal load the electricity balance of Romania (in terms of primary resources used for electricity generation) in 2020, in terms of environmental, technical and economic criteria.

2.1.2. Coverage of electricity demand in 2020:

– The way for establishing the electricity demand:

The program allows setting the electricity demand every year. For this particular case, we will determine the particular needs of electricity in 2020. It has been defined taking into account the primary and final energy scenarios realized in other work using the MAED model (model analysis of energy demand). The MAED model, as it was built realized six possible scenarios for primary energy and final energy. Of the scenarios made, for further development we chose the scenario under which the final electricity consumption in 2020 will be 6.3 million toe (73.3 TWh). The total electricity demand was calculated as the sum of the final electricity consumption, ancillary services consumption in networks and was obtained (taking into account specific documents for each parameter) value of 85 TWh in 2020 perspective.

– How to cover of electricity demand (the preparation of scenarios):

To meet demand the electricity (85 TWh) we have established different scenarios that would achieve the electricity balance of different loading. In this article presents eight scenarios that coverage 85 TWh. The program enables by the user creating and other scenarios. In making these scenarios we considered technological restrictions (conditions imposed) the various international engagement assumed by Romania, and some programs being implemented with government support.

Thus, as regards the nuclear chain it was considered that alongside the two groups in operation at Cernavoda will be completed two other groups with similar characteristics. In the period 2010 - 2020 we will install an additional gross power of 1,400 MW in nuclear groups and a total energy production of 11 TWh gross.

Energy delivered into the system (net production) in these two groups will then be about 10.1 TWh. The total net production of nuclear energy of all four groups will be 20.2 TWh.

The Energy Strategy aims to build a fifth nuclear power, but this will be done in an unspecified future. Putting it into operation will take place with certainty beyond 2020. Under these conditions it has not been established to develop a nuclear scenario electricity generation. It was considered that developing nuclear energy is the same in all scenarios.

In achieving scenarios we considered retirement program groups of the National Power Generation System established.

Nuclear groups and small hydro power will not be retirement.

Another restriction relates to compliance the engagement governmental to achieving an production of 38% of gross electricity consumption from renewable sources.

According to the above gross electricity consumption in 2020 was estimated at 81 TWh.

We have thus achieved an output of 30.8 TWh of electricity from renewable sources. Thermal energy is obtained by difference.

Under these conditions the imposed structure of electricity generation is as follows:

Table 1 – The structure imposed on electricity production

Total production, including:	**85 TWh**
- **nuclear**	20.2 TWh
- **renewables**	30.8 TWh
- **thermo**	34 TWh

Renewable energy sources considered are: large hydro, small hydro, energy from biomass and wind energy. The program enables the user to use other renewable sources. Thermo energy is studied for coal and natural gas. The program enables also the use fuel oil.

By combining the ways of producing electricity from renewable sources and thermo resulted eight scenarios and the quantities of electricity made by each chains within each scenario are presented in Table 2.

Table 2 – The amount of electricity carried by chains in the scenarios (TWh)

Energy chains	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Uranium	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
Large hidro	25	25	25	25	25	25	15.4	15.4
Small hidro	0	0	1.2	1.2	0.5	0.5	0	0
Biomass	5.8	5.8	4.6	4.6	0	0	15.4	15.4
Energy wind	0	0	0	0	5.3	5.3	0	0
Coal	17	25.5	17	25.5	17	25.5	17	25.5
Natural Gas	17	8.5	17	8.5	17	8.5	17	8.5

– The technological solutions and life cycle stages:
From the variety of technological solutions from the literature we retained the following for the production of electricity taking into account the different primary energy sources:

- For natural gas (an inferior caloric power of 50,000 [kJ/kg]) as a technical solution gas-steam combined cycle without postcombustion with an efficiency of 55% was chosen.
- For coal (coal with an inferior calorific power of 27,000 [kJ/kg]) a technical solution was chosen circulating fluidized bed combustion with supercritical parameters, with an efficiency of 45%.
- For uranium nuclear power generation technology is considered that is based on the concept of CANDU reactor, which operating with indigenous natural uranium. The efficiency for production of electricity through this chain is 35.5%.
- For biomass (an inferior calorific power 12,300 [kJ/kg]) we chose as a technical solution for the stationary fluidized bed combustion, with an efficiency of 30%.
- For the production of hydro energy in large plants using the Pelton turbine and hydropower production in small plants using the Kaplan turbine.
- Propeller-type turbines are used horizontal shaft mounted in "wind farms" to produce electricity from wind.

For each life cycle stage related to energy chain we established the efficiency and were calculated masses of fuel needed at every stage. For the stages of construction and demolition for the power plant we did not considered the efficiency. These values are approximate. The program enables the user to change the values for the stages effiency and fuels with different compositions, which lead to other inferior calorific powers.

2.1.3. Defining the field of study:

First we established the field of study of each energy chains that will be part of the energy scenarios achieved. Then, field study was realized for each scenario separately. Given that the functional unit is defined on the basis of three units: the function, time and product is considered as the functional unit: Romania's electricity needs in 2020 (85 TWh).
All scenarios are compared to this year's level. In conclusion, it will select the energy scenario which will cover energy needs with minimal environmental impact and minimum cost of production.
For each scenario, electricity demand coverage in 2020 (85 TWh), we have made detailed study fields. For example the diagram shows the results for scenario 5 (results from the analysis, Figure 1).

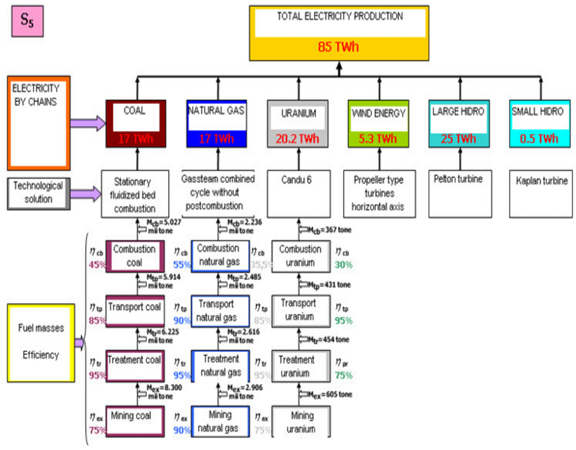

Figure 1 – The field of study for scenario 5

2.2. *Inventory Analysis*

First the calculation of emission was achieved for each life cycle stage of each energy chains, and ultimately obtained the emissions for each scenario. After establishing the functional unit at one TWh and efficiency for stages, starting from the inferior calorific power of each fuel we calculated mass of fuel required at each stage relative to the functional unit (FU). Reference Unit (RU) in this study represented the amount of fuel required at each stage to produce a TWh of electricity.
Inventory of emissions to air was realised on ecosystems air, water and soil on each stage for each chain separately. Were taken from literature reference emissions for each chain. The unit is g/kWh.
The stages of construction and demolition power plant chains of natural gas, coal, uranium and biomass were considered equal in terms of emissions.
Each scenario is designed to produce 85 TWh of electricity.
The inventory analysis was performed for each scenario, the emissions are reported according to the contribution of each chain to produce electricity. The total emissions in each scenario are presented in Table 3.

Table 3 – The pollutants for each scenario (thousand t/scenario)

Emissions	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
CO_2	28,363	32,939	28,828	32,831	28,358	32,361	29,692	33,695
CO	16.473	14.610	16.263	14.401	15.408	13.546	18.053	16.191
NO	0.721	0.363	0.721	0.363	0.721	0.363	0.721	0.363
NH_3	2.224	2.883	2.182	2.841	2.020	2.679	2.562	3.221
CH_4	90.687	64.898	90.661	64.872	90.061	64.272	89.977	64.188
NO_2	82.082	102.867	81.096	101.881	77.149	97.934	89.682	110.467
Dust	162.971	239.166	162.931	239.127	162.649	238.844	163.044	239.240
Formaldehyde (CH_2O)	0.145	0.073	0.145	0.073	0.145	0.073	0.145	0.073
COD	1.209	0.641	1.208	0.640	1.203	0.636	1.217	0.650
SO_2	123.727	177.447	123.346	177.065	121.775	175.495	126.587	180.306
N_2O	0.780	0.634	0.756	0.610	0.664	0.518	0.968	0.822
Lead	0.058	0.031	0.058	0.031	0.058	0.031	0.059	0.031
Arsenic	0.003	0.004	0.003	0.005	0.003	0.005	0.003	0.005
Barium	0.008	0.011	0.008	0.011	0.008	0.011	0.008	0.011
Chromium	0.005	0.007	0.005	0.007	0.005	0.007	0.005	0.007
Cobalt	0	0.001	0	0.001	0	0.001	0	0.001
Copper	0.002	0.004	0.002	0.004	0.002	0.004	0.002	0.004
Molybdenum	0.001	0	0	0	0	0	0	0
Nickel	0.004	0.006	0.004	0.006	0.004	0.006	0.004	0.006
Selenium	0.007	0.011	0.008	0.011	0.007	0.011	0.007	0.011
Vanadium	0.007	0.010	0.007	0.010	0.005	0.010	0.007	0.010
NH_4	0.399	0.597	0.399	0.597	0.399	0.597	0.399	0.597
Hydrogen Chloride (HCl)	1.229	1.229	0.984	0.984	0.039	0.039	3.183	3.183
Hydrogen Fluoride (HF)	0.004	0.004	0.004	0.004	0.004	0.004	2.413	2.413
Nitric acid	0.002	0.002	0.002	0.002	0	0	0.006	0.006
Isopren	123.172	123.172	97.732	97.732	0	0	326.692	326.692

In quantitative terms, the emissions to air are much higher than those generated in water and soil ecosystems. The main pollutants in the scenarios are: CO_2, dust, SO_2, NO_2, CH_4, CO, NH_3 and N_20. Although the values for other pollutants are insignificant, however, impact assessment should be realize to determine their influence on the environment. Regarding the maximum values of the main pollutants in each scenario the following aspects are distinguished:

- In terms of carbon dioxide, dust particles, sulphur dioxide, nitrogen dioxide, scenario 8 (biomass-coal scenario) has the largest quantity of emissions.
- For carbon monoxide, methane the maximum values are recorded in the scenario 1 (large hydro-gas scenario, 90.7 thousand t/scenario) and scenario 7 (biomass-gas scenario, 16.2 thousand t/scenario).

2.3. *Impact Analysis*

Table 4. shows a comparison between the calculated impact indicators for each scenario.

Table 4 – The impact indicators for each scenario

Impact indicators	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
ADP[t equivalent Sb]	272,738	300,524	250,785	278,572	167,510	195,297	448,360	476,147
GWP [thou. t equivalent CO_2]	31,083	35,516	30,968	35,401	30,457	34,890	31,883	36,316
AP [t equivalent SO_2]	193,074	271,128	192,055	270,110	187,938	265,993	200,846	278,900
POCP [t equivalent ethylene]	143,316	146,533	115,534	118,751	8,792	12,009	365,544	368,761
EP [t equivalent PO_4^{3-}]	11,760	15,044	11,617	14,901	11,047	14,331	12,867	16,151
HTP [thou. t equivalent 1,4-dichlorobenzene]	817.495	997.400	816.181	996.087	810.817	990.722	827.372	1.007
FAETP [t equivalent 1,4-dichlorobenzene]	13,171	18,141	13,171	18,141	13,175	18,145	13,165	18,135
MAETP [t equivalent 1,4-dichlorobenzene]	837,555	590,985	875,604	590,989	837,580	591,009	837,480	590,910
TETP [t equivalent 1,4-dichlorobenzene]	5,744	6,601	5,744	6,601	5,744	6,602	5,744	6,601

According to available data we can make some observations:

- ✓ In terms of the impact indicator "Abiotic Depletion Potential" (ADP), scenario 8 presents the highest value (equivalent to 476,147 t Sb) versus the lowest value recorded for the scenario 5 (equivalent to 167,510 t Sb).
- ✓ In terms of the impact indicator "Global Warming Potential" (GWP), the highest value scenario is also found in scenario 8 (36,316,272 tonnes CO_2 equivalent), and the lowest in scenario 5 (30,456,539 tonnes CO_2 equivalent).
- ✓ Regarding the indicator "Acidification Potential" (AP), maximum and minimum values obtained in this study are equivalent to 278,900 tons SO_2 (in scenario 8) and 187,938 tons SO_2. (in scenario five).
- ✓ Regarding the indicator "Photochemical Ozone Creation Potential" (POCP), the values obtained in this study vary greatly. The minimum recorded in scenario 5 (8,892 tons are equivalent ethylene), and the maximum scenario 8 (equivalent to 368,761 tons ethylene).
- ✓ In terms of the impact indicator "Eutrophication" (EP) the scenario 8 presents the highest value (equivalent to 16,151 tons phosphate), while the minimum value is found in the scenario 5 (equivalent to 11,047 tons of phosphate).
- ✓ Analyzing the impact indicator "Human Toxicity Potential" (HTP), we conclude that the EP as the indicator, the maximum value presents in the scenario 8 (approximately equivalent to 1,007 kt 1,4 DCB) and the minimum value in the scenario 5 (equivalent to 811 kt 1,4 DCB).
- ✓ The "Freshwater Aquatic Ecotoxicity Potential" (FAETP) shows the maximum (equivalent to 18,135 t 1,4 DCB) in scenario 8, and the minimum value in scenario 7 (equivalent to 13,165 t 1,4 DCB).
- ✓ The "Marine Aquatic Ecotoxicity Potential" (MAETP) has maximum value equivalent to 875,604 t DCB 1,4 in scenario 3 and the minimum value is recorded in the scenario 8 (equivalent to 590 910 t 1,4 DCB).
- ✓ For indicator "Terrestrial Ecotoxicity Potential" (TETP) scenarios 1, 3, 5 and 7 presents the minimum value of about 6 kt 1,4 DCB equivalent and scenarios two, four, six and eight presents the maximum to about 7 kt DCB 1,4 equivalent.

2.4. *Technical and economic analysis*

Starting from the amount of electricity produced for each scenario we determined for each chain the power installed in each scenario for 2020. Taking into account the duration of the investment, the duration of exploitation and the duration of the study, were determined the investment costs, operating costs, fuel costs, resulting the total expenses. We used three cost scenarios eco-taxes. The table below shows the total expenditure eco-tax. It is noted that the scenario that requires the highest total expenditure is the scenario 7. The program allows the user to modify the values considered for eco-taxes.

Table 5 – The total expenditure with eco-taxes for the energy chains and for the scenarios [million Euro]

Total expenditure without/with ecotax	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Total expenditure without ecotax	4,397	4,305	4,005	3,913	2,500	2,408	7,531	7,439
Total expenditure with minimumecotax	4,658	4,629	4,264	4,235	2,753	2,723	7,804	7,774
Total expenditure with mediumecotax	5,389	5,525	4,996	5,132	3,450	3,586	8,559	8,695
Total expenditure with maximum ecotax	7,745	8,616	7,335	8,206	5,720	6,592	11,044	11,915

The economic cost recovery (Table 6) was chosen as the criterion of selection the technical and economic scenarios. This indicator is appropriate for these types of scenarios created, each producing the same amount of electricity.

This indicator represents the minimum price at which electricity can be sold so as to cover all economic costs over the lifetime.

Table 6 – The economic cost recovery for the scenarios [Euro/MWh]

Economic cost recovery (ECR)	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
ECR without ecotax	65.7	65.4	61.3	60.9	43.8	43.4	101.4	101.1
ECR with minimum ecotax	69.2	64.3	64.8	46.7	46.7	47.2	104.7	105.1
ECR with medium ecotax	79.9	73.0	75.3	55.2	55.2	57.6	113.6	116.0
ECR with maximum ecotax	116.4	100.7	111.7	82.1	82.1	93.1	143.0	154.0

Note that the minimum value for the cost of recovery scenarios are recorded in scenario 5 (43.8 Euro/MWh) and scenario 6 (43.4 Euro/MWh) which has very similar values.
Program allows the changing the values for the duration of study and for the discount rate.

2.5. *Multi-criteria Analysis*

The previous performed steps allowed us to obtain information about energy chains used to create scenarios. Further, we will achieve global comparison between scenarios.
Evaluations were normalized after each criterion and were established in the class memberships good/low.
We obtained the normalized matrix (Table 7), based on which energy scenarios were evaluated by each set of criteria to finally obtain a global evaluation of energy scenarios.

Table 7 - The normalized matrix

CRITERIA	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Ecological								
ADP[t equivalent Sb]	0.573	0.631	0.527	0.585	0.352	0.410	0.942	1.000
GWP [thou. t equivalent CO_2]	0.856	0.978	0.853	0.975	0.839	0.961	0.878	1.000
AP [t equivalent SO_2]	0.692	0.972	0.689	0.968	0.674	0.954	0.720	1.000
POCP [t equivalent ethylene]	0.389	0.397	0.313	0.322	0.024	0.033	0.991	1.000
EP [t equivalent PO_4^{3-}]	0.728	0.931	0.719	0.923	0.684	0.887	0.797	1.000
HTP [thou. t equivalent 1,4-dichlorobenzene]	0.812	0.990	0.810	0.989	0.805	0.984	0.821	1.000
FAETP [t equivalent 1,4-dichlorobenzene]	0.726	1.000	0.726	1.000	0.726	1.000	0.726	0.999
MAETP [t equivalent 1,4-dichlorobenzene]	0.957	0.675	1.000	0.675	0.957	0.675	0.956	0.675
TETP [t equivalent 1,4-dichlorobenzene]	0.870	1.000	0.870	1.000	0.870	1.000	0.870	1.000
Technical and economic								
Investment expenses (thou. Euro)	0.928	0.979	0.937	0.988	0.949	1.000	0.854	0.905
Operating expenses (thou. Euro)	0.942	0.972	0.938	0.969	0.925	0.956	0.970	1.000
Fuel expenditure (thou. Euro)	0.563	0.548	0.508	0.494	0.299	0.284	1.000	0.985
Economic recovery cost without cost to emissions of CO_2. SO_2 and NOx (Euro/ MWh) (at "a"=discount rate=8%)	0.856	0.886	0.842	0.871	0.771	0.801	0.971	1.000

Normalization was performed for each value of this criterion in relation to the maximum value of that criterion.
Referring to the environmental criteria, scenario 5 presents the highest value and is considered the best scenario, and scenario 8 is the worst scenario (Figure 2).

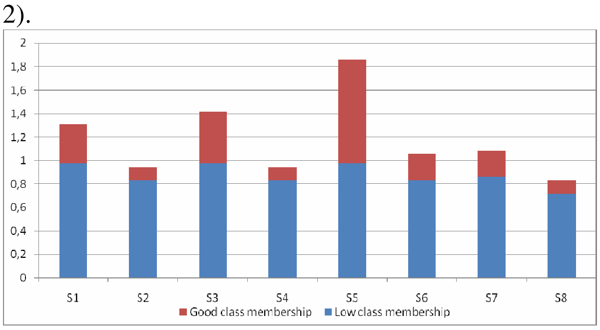

Figure 2 – The evaluation of energy scenarios using environmental criteria

Regarding the technical and economic criteria, scenario 5 presents the highest value and is, therefore, the best scenario. The program also selects other two scenarios as the best scenario (scenario 6, with a value close to that of Scenario 5 and Scenario 7 with a lower value) (Figure 3).

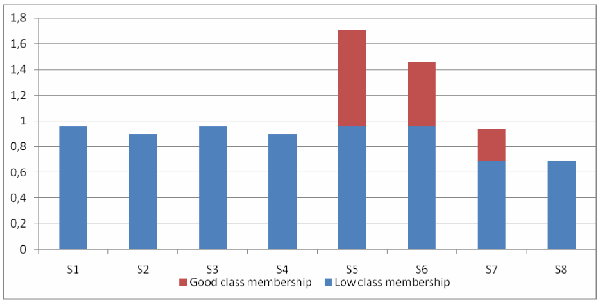

Figure 3 – The evaluation of energy scenarios using economic and technical criteria

The evaluation results were represented by families of criteria set by a radar chart (Figure 4).

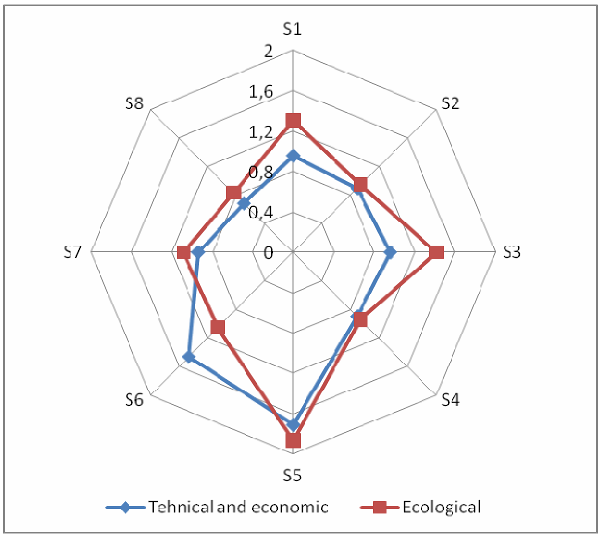

Figure 4 – The global assessment of energy scenarios

Observe the diagram above that scenario 5 is the scenario that the highest values recorded in terms of family environmental criteria in terms of family economic and technical criteria, so scenario 5 is the optimal scenario. The overall assessment the technical and economic evaluation. We require that the solution always chosen to have maximum value for environmental criteria, an environmental criterion is decisive criterion in choosing the optimal scenario.

2.6. *Sensitivity analysis and robustness analysis*

The sensitivity analysis was performed taking into account both the change in the objective indicators (share of families of criteria etc.) and subjective indicators of change (fuel prices, introduction eco-taxes, the discount rate).

The robustness analysis revealed that the chosen solution (scenario 5) remains the best because the optimal loading scenarios depending types of primary sources of energy is achieved at about the same proportion.

3. The structure and the results obtained with multi-criteria model using "Eclipse"

In the previous chapter has presented the multi-criteria model as was done in Excel. Transposition was done in the "Eclipse" program (using Java) in order to quickly select an optimal energy scenario in detail using other values, where modification is done in a long time and with lower performance. Eclipse program offers an attractive graphical interfaces and database created multi-criteria model can be enriched by providing greater opportunities for simulation and interpretation of different data loads.

The multi-criteria model developed consists of five modules, named after the steps necessary to achieve the program (and have been detailed in part 2 of article in the creation phase of the model), as follows:

1. Establishment of electricity demand;
2. Scenarios;
3. Life Cycle Analysis;
4. Powers, technical and economic calculations;
5. Evaluation scenarios.

These modules are added to a home page, from which the user has direct access to the modules listed above.

View the Module 1 "Establishment of electricity demand" is possible in Figure 5.

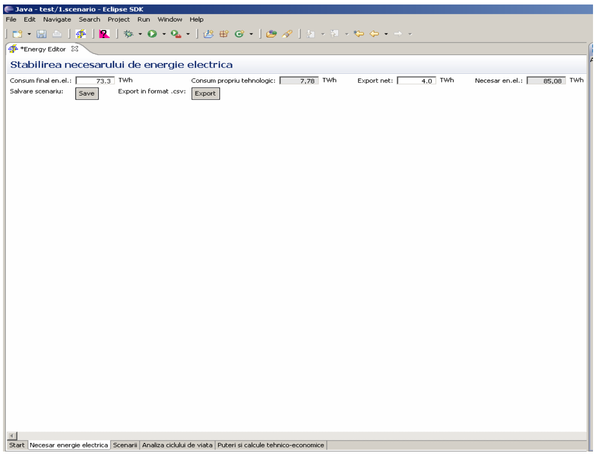

Figure 5 - Module 1 "Establishment of electricity demand"

Module 2 "Scenarios" makes covering different amounts for each scenario with electricity of each scenario with power produced from primary energy sources to 2020 (year of study in the article), but also for any desired year. The program developed allows the user to use for simulation other scenarios, which it creates.

Viewing this module is done in Figure 6.

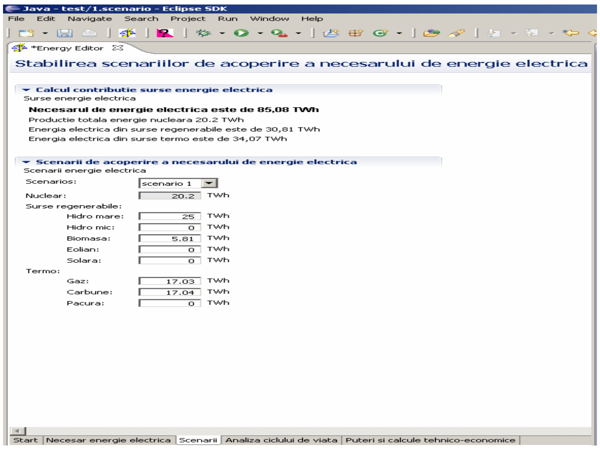

Figure 6 - Module 2 "Scenarios"

Module 3 "Life cycle analysis" is very detailed and contains all the analysis done by applying the methodology LCA.

In the next window we present the inventory analysis and the impact assessment on all scenarios (Figure 7).

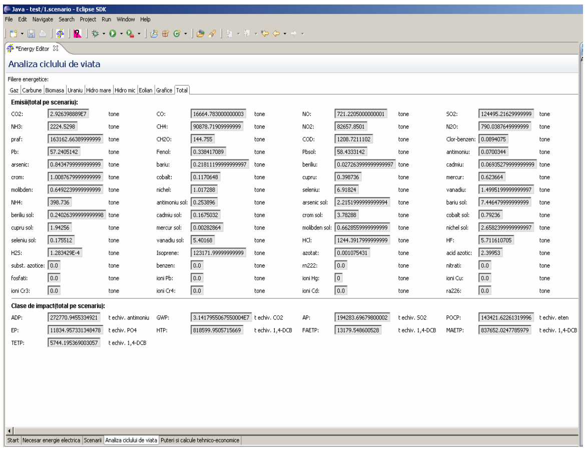

Figure 7 – The inventory analysis and the impact assessment on all scenarios

The program allows the user to choose different fuel composition and other specific efficiency for each stage of the respective chains, but also using other reference values for emissions. Graphic comparisons can be made in terms of chains (total emissions of CO_2, CO_2 emissions without, figure 8), comparisons in terms of an impact indicator, but comparisons between chains (from the point of view of all indicators, except the "Global Warming Potential, in Figure 9).

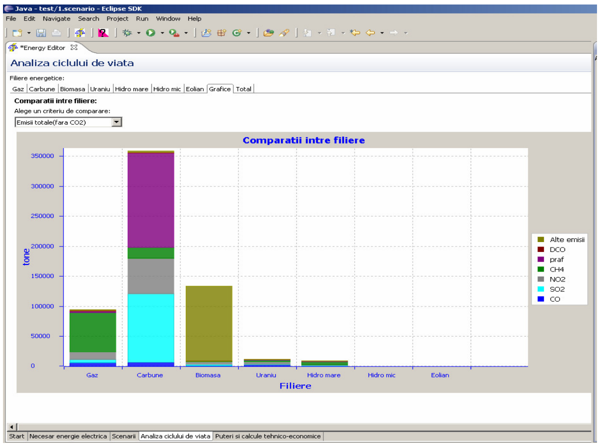

Figure 8 - Comparison between the chains in terms of total non-CO_2 emissions

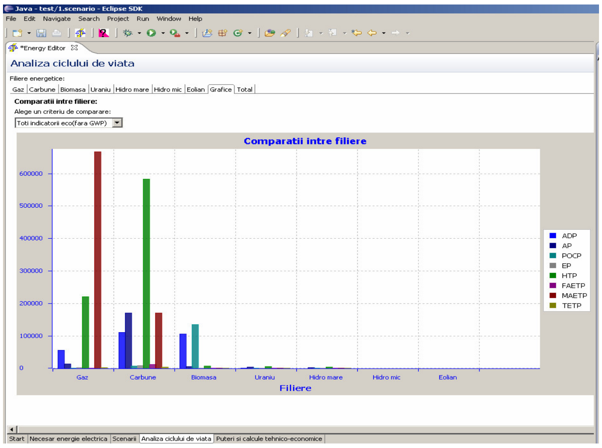

Figure 9 - Comparison between the chains in terms of impact classes, less GWP

Module 4 "Powers, technical and economic calculations" is detailed (Fig. 10), and was described in part 2 of the article.

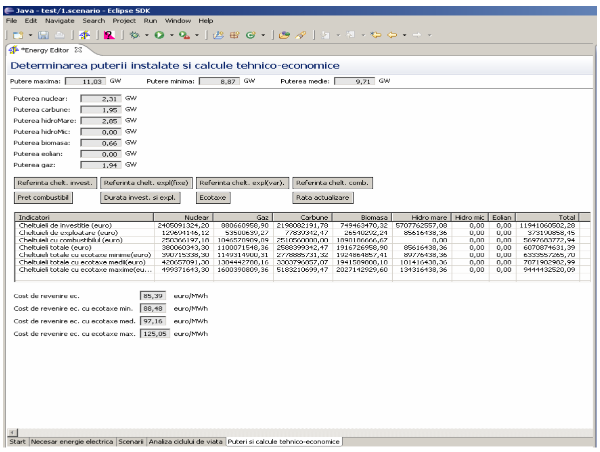

Figure 10 – The installed capacity and technical and economic calculations

Module 5 "Evaluation scenarios" made global comparison (ecological, technical and economic) for the scenarios achieved. You can compare any scenarios between them.

This module is based on the evaluation matrix that includes ecological and techno-economic indicators for each scenario. Matrix is then made to normalize the values of the evaluation matrix (figure 11). We calculated the class membership of good/low on environmental criteria categories, namely technical and economic (fig.12, fig.13).

In the final I realized the global evaluation of scenarios both families of criteria, ecological and techno-economic. Evaluation is possible in the form of graphic (Fig. 14).

We representation can make comparisons between scenarios (graph) in terms of emission recorded and in terms of impact of each indicator assigned to a scenario. (Fig.15).

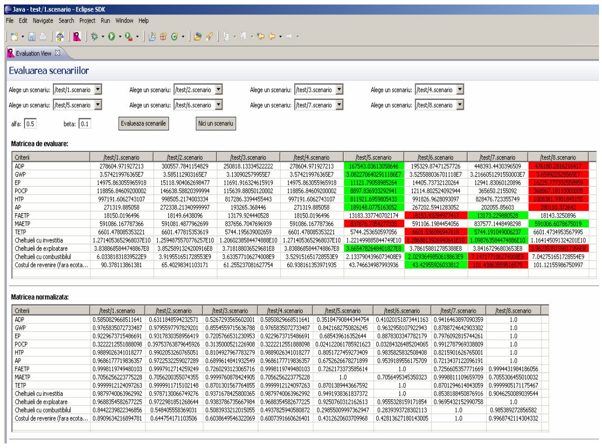

Figure 11 - Assessment scenarios (matrices evaluation and normalization)

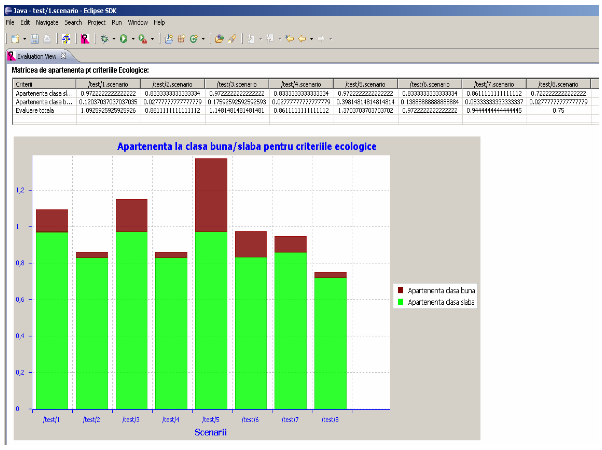

Figure 12 - Assessment scenarios (class membership good/low as ecological criteria)

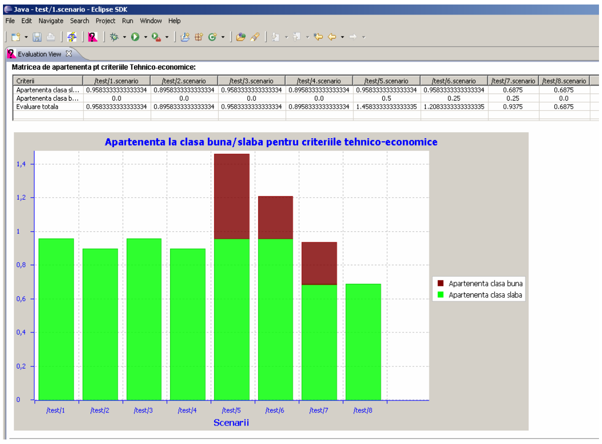

Figure 13 - Assessment scenarios (class membership good/low as economic and technical criteria)

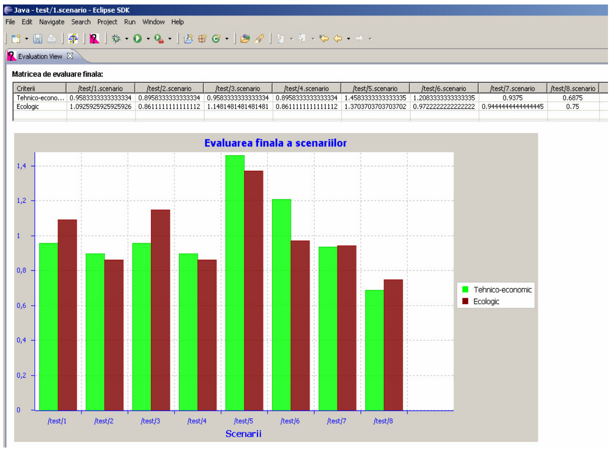

Figure 14 - Global assessment of scenarios

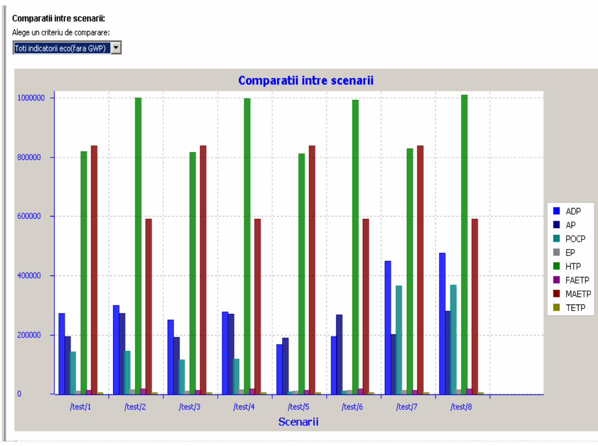

Figure 15 - Comparison between scenarios in terms of impact classes, less GWP

4. Conclusions

- ❖ The implementation of this model enabled the identification of the optimal scenario to cover the balance of electricity in terms of environmental criteria and in terms of technical and economic criteria.
- ❖ Following analysis, scenario 5 is the optimal scenario to cover the electricity needs of 85 TWh in 2020. It was called "Wind – Natural gas Scenario. The loading of this scenario is as follows:
  - four nuclear groups, provide 20.2 TWh;
  - wind energy provides 5.3 TWh;
  - large hydro provides 25 TWh;
  - small hydro provides 0.5 TWh;
  - thermo energy is achieved in equal proportion of coal and gas, each making one 17 TWh.
- ❖ Since the program supports changes to many parameters, it allows the user achieve many simulations and data interpretation (in a very short time) that can be used in determining strategies for energy sector development.
- ❖ The program also addressed to less initiated persons into multi-criteria model, encompassing a part of graphics makes it possible to interpret the data in an easier manner. It presents a tool that allows exporting data in Excel format.

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Creating a hotel building stock model focused on energy consumption

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Abstract: Policies and strategies that aim to reduce CO_2 emissions of the hotel building stock should be supported by efficient and rational implementation of comprehensive models. Those models should have the ability to estimate the baseline energy demand of hotels and to explore the technical and economic effects of proposed interventions. In order to create such a model two data bases have been created for the Greek hotel sector. The first one includes the characteristics from all the hotels sited at the third climatic Greek zone and the other carries data from in situ energy audits in that climatic zone.
This papers aims are threefold: (a) an analysis of the existing characteristics of the hotel data of the third Greek climatic zone and evolution comparison of the hotel building stock the last 5 years, (b) to analyse and compare the results of the hotel characteristics gathered from in-situ audits, (c) exploring the barriers of promoting energy conservation measures and the lack of available detailed energy consumption data of the hotel sector.

Keywords: Hotels, building data models

1. Introduction

Buildings have become one of the fastest growing energy consuming sectors, especially in the European Union (EU). EU's building stock contributes around 160 million buildings with present rate of construction of below 2% (Eurostat, 2010). Those figures push the hope of truly energy-efficient built environment far beyond. For that reason focus to renovation in existing buildings is essential.

But also, requirements for the assurance of the necessary thermal, visual comfort and indoor air-quality are increased by leading to the study, and in several cases to the adoption, of energy efficient measures (Doukas et al., 2009).

In that struggle and due to the rise of energy intensity and energy consumption indexes the last decade, European Commission released the Directive 2002/91 regarding building's energy efficiency (EPBD). This directive foresees an energy certificate for specific building cases by setting a minimum of energy requirements according to its size. A further step has been made by the European Parliament and the Council of the European Union in order to strengthen the energy performance requirements and to clarify and streamline some of the provisions of EPBD with Directive 2010/31/EU. The far-reaching reform of the European policy is a comprehensive package of measures to reduce the EU's contribution to global warming and ensure reliable and sufficient supplies of energy. According to it by December 2020 new buildings in the EU will have to consume "nearly zero" energy and the energy will be "to a very large extent" from renewable sources. Public authorities that own or occupy a new building should set an example building by buying or renting such "nearly zero energy building" as of December 2018. Minimum requirements for components are introduced for all replacements and renovations.

In that rapidly and substantially changing political ambience, it is essential to use models which have the ability to estimate the baseline energy demand of buildings, and in that case lodging services buildings, to determine the technical and economic effects of proposed interventions.

2. Greek legislation

Greece has committed to limit the increase of its GHG emissions to 25% during the period 2008-2012 compared to the base year. Also, efforts have been made to implement the EPBD. EPBD's implementation follows the provisions of the national law N.3661/08 on "Measures for the reduction of energy consumption in buildings and other provisions" that was issued in May 2008 and due to several delays is expected to be enforced in 2010 with the publication of the new "Regulation on the Energy Assessment of Buildings—KENAK". Those two sets a framework of regular inspections requirements in heating, cooling, air conditioning and lighting systems and at the building in general which is compulsory for new constructions and existing buildings over $1000m^2$ that undergo major renovations, and existing buildings with floor area of at least 50 m^2 when they are sold, rented or transferred to other relatives of the owners. However, there is still a gap of know-how at their implementation to the public use buildings, such as hotels.

Also, according to KENAK Greek is re-categorised in climatic zones according to their heating degree days (HDD) (Figure 1, Table 1): Zone A 601-1100 HDD, Zone B 1101-1600 HDD, Zone C 1601-2200 HDD, Zone D 2201-2620 HDD.

Figure 1. The Greek Climatic zones. (Legislation of Energy Efficiency in Buildings,2010).

The only effort that has been made from the Greek government to establish a legislative frame for tourism was with the plan of spatial touristical development at 2007. The spatial developmental plan provides the guidance and set standards and criteria for spatial structure, hotels infrastructure, organization and development of tourism around Greece.

3. The proposed model

The model's general philosophy is presented in figure 2.

- *Database*. This database includes a set of in situ audits carried around Greece. Data such as lightning, heating, cooling and utility appliances energy demand for the whole building accompanied with data for maintenance costs are included.
- *Real data*. It includes data for all Greek hotel units around Greece as they are presented at the Greek Chamber of Hotels for 2010. The gathered data are based on the energy need of the hotels according their features.

Those data will be analysed with bottom-up and top-down approach in order to create a reference building based on existing hotel infrastructure and to evaluate its energy efficiency, to explore technical and economic effects of future interventions.

In the next paragraphs those data bases will be presented in order to verify the problem and the process that should be followed with a view to identify correlations between variables used in the bottom-up and top-down approach.

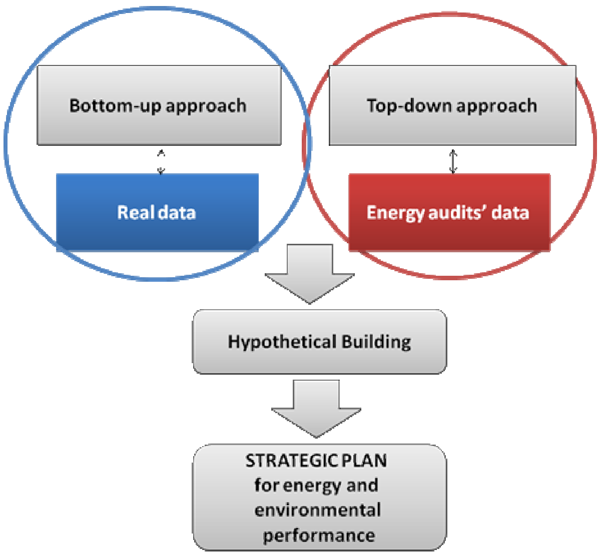

Figure 2. Models general philosophy.

The methodologies and the underlying techniques available for modelling at the hotel sector and generally at the building sector have been a topic of discussion to a plethora of articles (Kavgic et al., 2010). The two fundamental classes of modelling are usually used to predict and analyze various aspects of the overall building stock energy use performance.

4. Hotel industry

Tourism recently described as the world's largest industry by comprising a large number of heterogeneous small to medium-sized business entities (Anastassopoulos et al., 2009). In terms of figures, international tourist arrivals in developing countries have increased about 8% per year in the period 1992–96 to a total of 182.6 million. This number represents a share of 30.7% of all international arrivals in this year. In terms of receipts, tourism earned US$ 129.7 billion for developing countries in 1996 (excluding fares), which is 29.9%of the global total (WTO, 1998).

According "progress and priority report" for 2009-2010 of the World Travel & Tourism Council (WTTC) GDP is expected to rise from 9.2% (US$5,751 bn) in 2010 to 9.6% (US$11,151 bn) by 2020 which means real GDP growth average 4.4% per annum over the coming 10 years. Also, an employment rise of from 8.1% (235,758,000 jobs or 1 in every 12.3 jobs) in 2010, to 9.2% of total employment (303,019,000 jobs, or 1 in every 10.9 jobs) is expected by 2020. Nevertheless, even 2009 and 2010 have been depressed years for touristical activity is expected to boost.

In term of competitiveness, Greece, as is on its way to transform to an upmarket tourism destination, is at the 42th place among 133 countries, behind Spain, Portugal and Cyprus (ITEP, 2009). That position is far from satisfactory especially when the rich cultural heritage which is endowed by history and other natural resources of sun and the sea is considered. This is inherent with the fact that state does not provide the necessary resources for its development disposed towards tourism development.

5. Greek hotel building stock

The developmental policy measures during May 2005 to July 2008 and the Developmental Law 399/04 have failed to turn the interest to no already developed tourist areas. Most of the investments that have been made the last years at the hotels sector focused primarily on the hotel's modernization, the establishment of new and the expansion of the existing ones. The existing hotel stock according to the arrival data shows that the available hotel stock exceed 184.7% of current demand without taking into account the rented rooms.

So, in order to adapt well-tailored energy conservation strategies for hotels requires knowledge of the specific characteristics of the building stock. According to the Hellenic National Statistics Service, there are about 4 million buildings in Greece, with a total floor area of more than 16 million m^2, but only 0.6% of them are hotels with 712.058 m^2 and 685 floors.

In Greece is situated 9.554 hotel units with 726.546 beds (Hellenic Chamber of Hotels, 2010), most of them are classic hotels (65,8%) and specifically 2-star (45,9%) and 3-star (22.6%) hotels that operates seasonally (56,0%). A hotels average size is with 76 beds per units.

Moreover it appears that there is a widespread underemployment of hotel's infrastructure and a hotel over-concentration capacity in only four areas (Crete, north Aegean islands - Cyclades, and Attiki). Specifically, 47% of the total hotel buildings stock is situated at the A climatic zone which include all Aegean islands.

Other data shows that a major percentage (68.2%) of the total hotel building stock is constructed after the application of the first Greek regulation for building's insulation, which means most of the hotels are properly insulated.

If energy demand is analyzed with respect to its time variation, it is obvious that the peak values are recorded in the summer season, due to the use of air-conditioning for space cooling, a fact that is enhanced by the seasonal character of Greek tourism (Figure 4).

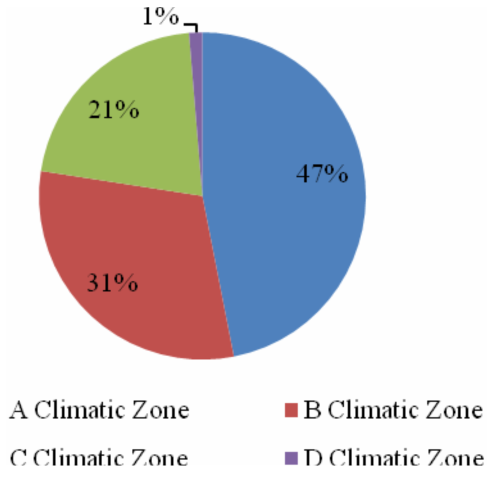

Figure 3. Hotel's distribution in climatic zones (Hellenic chamber of hotels, 2010).

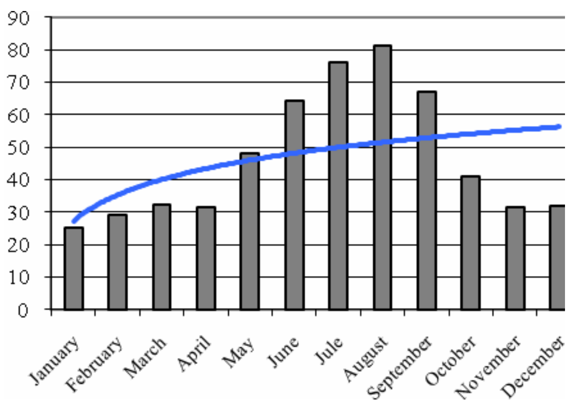

Figure 4. Complement of the Greek hotel sector (ESYE, 2007).

Moreover, in a hotel building various types of energy are required for the operation. Electricity and thermal energy are the main energy carriers used in hotels for necessary services. Electricity is used throughout the tourist accommodations for several tasks, including lightning, water heating, air-conditioning, laundry operations and sometimes for space heating. Finally, the existence of a restaurant, spa, conference center or even the facilities that included into a hotel room affects energy demand.

C climatic zone

The third climatic zone is the second coldest zone in Greece. Hotel building stock in that zone represents about 20,3% (1765 hotels) of the total, a quite small percentage compared to other climatic zones.

On the other hand C Zone includes two of the most popular destinations, Chalkidiki and Pieria. In Macedonia, the northern geographical part of Greece which belongs to the Climatic zone C, is located 16.56% of the total hotel stock, the biggest concentration of all Greek geographical areas.

Moreover, the hotel located in that zone is mostly annual hotels (56% are annually hotels and 44% seasonal) and 2-star hotels (38.4%) with an average value of 31 rooms with 61 beds. Table 1 analyses the features of the hotel building stock at the tired climatic zone.

Table 1. Provisions of the hotel buildings tock of the third climatic zone (Greek hotel chamber, 2010).

Number of Hotels	**1949**
Rooms	61284
Beds	118146
Use of Air-conditioning systems	68,70%
Swimming pool	23,04%
Restaurant	39,05%
Conference center	3,85%
Meeting rooms	14,88%

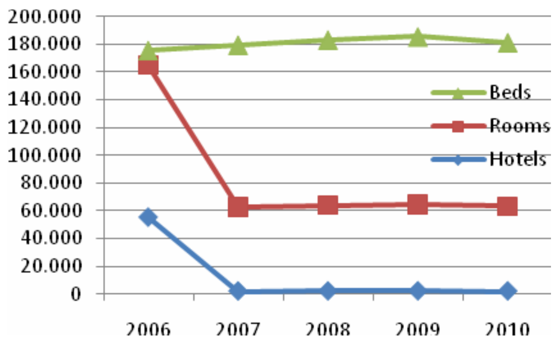

Figure 5. Evolution of the hotel building stock at the third climatic zone over the last 5 years.

Over the last decade and due to the fact that there is in progress an economic crisis there has been a decrease of hotels to that climatic zone (Figure 5). But there has been no variation to the percentage of the hotel's star-categorization. Still 2-star hotels constitute the major percentage.

6. Data Base

Information focused on the general state of the hotel's casing, information relating to hotel operations, energy and water consumption, average monthly occupancy levels in the auditing years, together with information concerning indoor environmental quality was gathered by 55 hotels all over Greece. The collected data was gathered with the help of a questionnaire which is suggested by an under-consultation-regulation about energy management in buildings.

The performed audits were picked out without any designed parameter. Audited hotels are placed in urban areas or close to major cities. Most of the hotels are placed in Central Greece (58% in Thessaloniki and 26% in Chalkidiki) and were: 1% 1-star hotel, 20% are 2-star, 22 are 3-star, 24 are 4-star and 25 are 5-star and LUX hotels. That allocation indicates a balance between hotels' class.

From the fifty five audited hotel 55% were built before the 1980s, 30% were constructed during the 1980s and 1990s and only 15% were built during the 2000s. So it is obvious that more of them need to adopt conservation measures.

Furthermore, all hotel units, seasonal and annual, are renovated after 2000. That fact, which is quite encouraging for the future of the tourist sector, shows that hoteliers are trying to reduce their energy production.

Electricity consumption for the most hotel units fluctuates to 300 kWh/m^2 month for rural hotels and over 400 kWh/m^2 for urban hotels. This first value is equal with the hotel case that is presented above at the literature review. But the hotel total energy value explodes to about 2500 - 3000 kWh/m^{2}month.

Also, the audit showed that in order to support energy saving in the tourism sector effectively isolated promotional activities are not sufficient that happens why you usually meet poor.

Finally, from in situ energy audits results arise the conclusion that the major consumer carrier in a hotel is electricity, then oil and finally gas consumption.

7. Barriers for the promotion of energy conservation measures

There are many ways in a hotel that you can reduce energy consumption. According to the references, retrofitting measures which are designed to conserve energy in areas of space heating, hot water production, cooling systems, artificial lighting, equipment and various other systems of building according to each hotels needs. Those retrofitting assessments have been studied both of the amount of possible energy conservation and cost (Santamouris et al., 1996).

From the other side Barros and Dieke (2008) studied the perspective of improving energy efficiency by adopting appropriate managerial policies.

In general, managing energy use in a hotel may be seen as part of an overall quality and environmental management which may help identify inefficiencies and resources wastage (Boemi and Papadopoulos, 2009).

But even thought efforts have been made from various studies barriers for promoting

The failure of adopting energy conservation measures have to do with (i) the lack of information, (ii) with their organization structure and (iii) with technical and financial reasons that hinder enterprises. That conclusion came up not only after this audit but advocate with the conclusion from Markis and Paravantis audit (2007) and Papadopoulos (2009) survey in the building sector.

8. Conclusions

The hotel sector is of vital importance for the Greek economy, so is its energy performance for the building sector. The purpose of this study is to gather all the needed data in order to create a cost-effective model with a view to reduce energy at the hotel sector. The gather data included characteristics of the hotels of the hotel building stock situated mostly o the C climatic zone.

The best knowledge of the hotel building stock that have been processed and analysis will drive to the form of a hypothetical building. That hypothetical-hotel will be used to the decision-making process of possible energy-saving measures.
The data bases targets primarily to study the manufacture and operation of existing lodgings services and hotels and secondly to propose interventions and improvements leading to the reduction of consumption and the rational use of energy and also to the use of new and innovative technologies in this sector. A detailed energy analysis and performance of the studied hotels is following.

But the lack of data lead us to the adoption of a combination of top-down and bottom-up approach, in order to produce a viable strategic plan for the improvement of the hotels' energy and environmental performance.

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Green transport in island areas

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Abstract

The development of environmental friendlier transportation systems is a leading policy both at European and national level. This paper presents an alternative green transportation system development plan that will take into account the characteristics and growth prospects of the Aegean islands. The data used come from a household survey conducted in the island of Chios, in November 2009 and April 2010 (resulting to approximately 200 questionnaires). The survey emphasized on the understanding of social and behavioural issues, indentifying factors influencing mode choice behaviour and promoting a culture for environmentally friendly mobility as well as increasing overall passenger happiness. The ultimate goal of this paper is to understand the factors affecting GREEN transport choices in islander areas that would lead to increased well-being and the reduction of carbon emissions.

Keywords: Green transport, Lifestyle choices, Mode choice

1. Introduction

In recent years, the concern over climate change and its effect on the global eco-system has drawn the attention of many researchers from different science fields.

According to statistics from the European Commission (2009), the transport sector contributes approximately 13% to the European GDP, occupies more than 19 million individuals; and although it is a key enabler for the free transport of passengers and goods, its activities give rise to environmental impacts, accidents and have harmful effects on human health (Buehler, 2009).

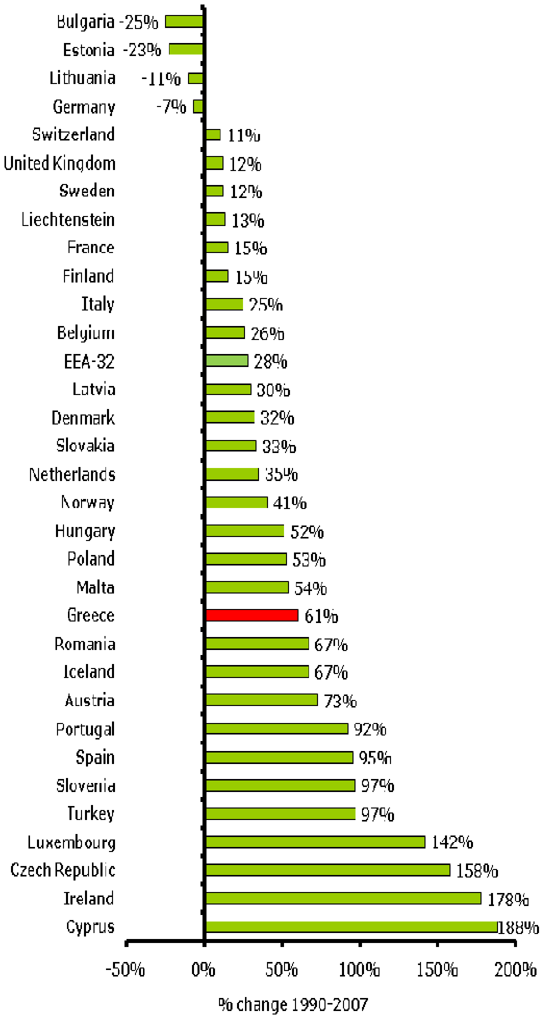
A growing number of research deals with transport greening initiatives in urban areas (Banister et al., 2007; Laffel, 2006; Goncalves, 2007; Rotaris et al., 2010), but up to our knowledge this is one of the few studies that concern an islander area.

A case study was developed for the Chios Island (North Aegean Region, Greece) in 2009. The survey included both revealed and stated preference data, as well as attitudes and perceptions of individuals regarding the environment.

This paper focuses on passengers' road transport, which is one of the most difficult sectors to manage in terms of CO_2 emissions, while it is the major contributor of CO_2

emissions (25% of CO_2). Figure 1 presents the trends in greenhouse emissions by country from 1990-2007. As it can be seen, Greece has increased its greenhouse emissions by 61%, over this past 17 years.

Figure 1: Trends in Greenhouse gas emission per country (1990-2007)



Source: European Environmental Agency (2009)

The aim of this paper is to identify the factors that affect travelers' mode choice (apart from those already known, such as travel time and travel cost), through analysis of revealed and stated preference data, as well as attitudes reflecting the environmental consciousness of travelers and their willingness to help the environment.

The remainder of this paper is organized as follows. Section two presents a brief literature review. Section three presents the behavioral framework. Section four presents the data collection and descriptive analysis. Section five presents the conclusions.

2. Literature Review

From the early 70s, the transport sector had become the principle consumer of non-renewable energy sources, since almost all its needs are being covered by petroleum products (Aranda et al, 2010).

A growing number of studies have been investigating the market penetration rates of hybrid or/and electrical vehicles that would make road transport more independent from crude oil (Clement et al., 2007, 2008; Hadley and Tsvetkova, 2008). The results of these studies indicate a penetration rate that varies from 10 to 30% of the overall road transport fleet by 2030.

Perujo and Ciuffo (2010) studied the impact of electric vehicles' on the environment within the next 20 years (2030). Their analysis revealed that electric vehicles can contribute to the decrease of CO_2 emissions, but without the appropriate regulation, the recharging may have a negative effect on electric supply.

In addition, several studies compared the emissions of electric and conventional vehicles and found that the net reduction due to the use of electric vehicles depends primarily on the source of fuel for electricity generation and secondary from the type and age of the conventional vehicle default (LaveLester et al., 1995; Sgoutas, 1995). A study from Funk and Rabl (1999) regarding the social impact of electric versus conventional vehicles revealed that the cost of air pollution is not enough to give to electric vehicles a clear advantage over the conventional vehicles.

Diana and Mokhtarian (2008) grouped travelers based on the level of use of car and transit. Their analysis showed that in order to maximize modal diversion to transit and non motorized modes (greener transport), policy makers should combine car use reduction targets with alternative modes promotion.

In order to understand the forces that drives travelers behavior (such as mode choice, route choice, etc.), researchers have been extensively studying the role of attitudes, perceptions, values and lifestyle. Shiftan et al (2008), used structural equation modeling and attitudinal market segmentation in order to identify traveler's attitudes, travel behavior and the causal relationship between travelers' attitudes and their socioeconomic characteristics. From the above market segmentation they were able to identify potential transit markets. Anable (2005) revealed that attitudinal segmentation plays a key role on identifying mode switchers, while similar results have been found in other behavioral studies regarding mode choice (Garling et al, 2001; Fuji and Kitamura, 2003; Steg, 2005; Anable and Gatersleben, 2005; Johanson et al., 2006; Duarte et al, 2008,2009).

This paper presents a comprehensive approach for identifying the factors that affect: (a) car ownership (conventional versus a hybrid/electric vehicle) and (b) mode choice.

3. Decision Making Framework

The vision of green transportation requires the development of an integrated system which will be able to compare different policies in three major areas: Economy, Environment and Society, which are the three main pillars of the majority of strategic plans of various organizations, including the United Nations.

Figure 2 presents the decision making framework of individuals. The exogenous variables that affect the decision making process of an individual include the economy, technology, policy and regulations of the society that the decision maker is a member.

In addition the socio-economic profile of the decision maker, encompassing characteristics such as gender, age, income, etc., as well as the travel environment, together with the telecommunication opportunities and the overall spatial structure and organisation, play significant role on the decision making process.

Individuals' choice behaviour initiates from their general culture and values, which lead to the development of perceptions, attitudes and preferences. The decisions that an individual is called to make can be divided into long term and short term. One can argue that long term decisions have a longer effect on individuals life since they include residential location, work place and car ownership, while short term decision involve mostly daily choices, such as the number of activities that need to be implemented, mode and route choice, etc.

In terms of modelling these choices (long term and short term), several studies have been conducted, that have taken into account the attitudinal characteristics of the decision makers (see, for example, Kitrinou et al., 2010 for residential location decisions; Choo and Mokhtarian, 2004, for vehicle type choice; Johansson et al., 2006, Duarte et al, 2008, 2009 for mode choice and Tsirimpa et al., 2007; Tsirimpa et al., 2009 for traffic information acquisition and response to it).

The impact of the above decision making process can be seen in the performance of the transportation system, in the energy consumption and therefore at the environment, as well as in the overall well being of the society.

This paper will explore the decision making process of islanders regarding car ownership decision.

Figure 2: Decision Making Framework

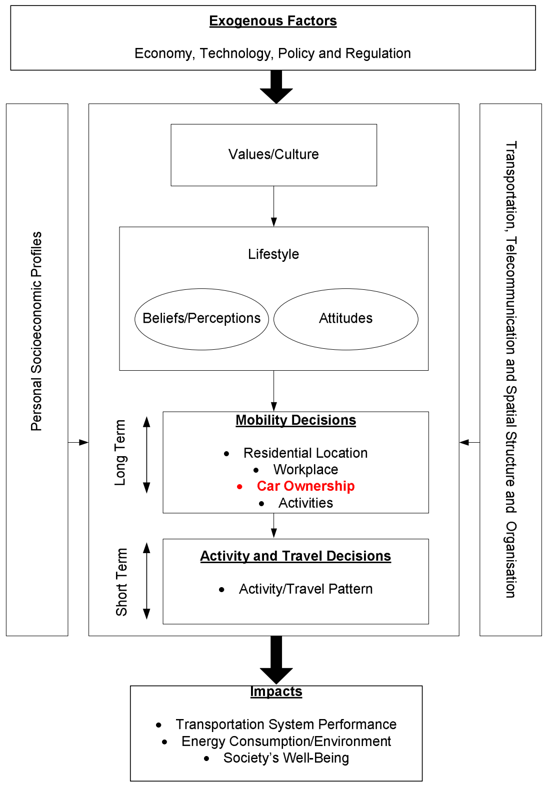
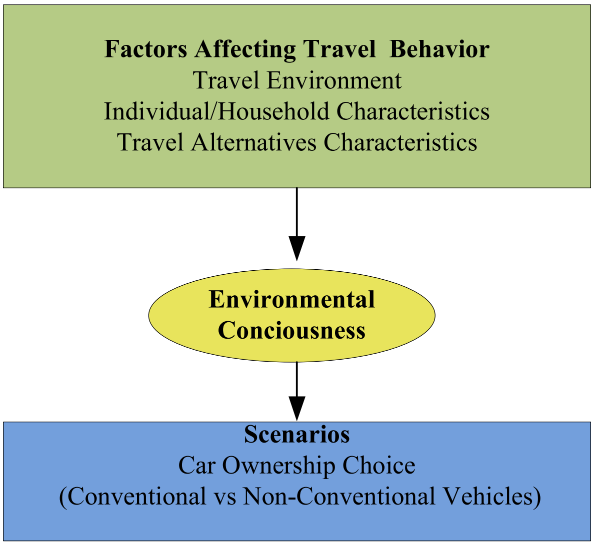


Figure 3 presents the modelling framework of car ownership choice. Travel choices are affected by transport mode characteristics, demographic characteristics of the study area, (unemployment/ employment indicators, quality of life, etc.), travellers' characteristics, such as socio-economic characteristics, attitudes and perceptions (e.g. perceptions about the environment, the sense of security, etc.) and by travel purpose. In this paper we explore the factors that affect car ownership choice.

Travellers' choices will be explored using stated preference scenarios, which were conducted through personal interviews.

Figure 3: Modeling Framework



4. Data Collection and Descriptive Statistics

The objective of this study was to analyse the current transport conditions of Chios transport network and to identify the factors that influence mode choice behaviour by emphasizing on travellers attitudinal characteristics.

The survey was conducted in Chios island (North Aegean Region), through personal interviews to island residents. The survey included 4 sections to gather data on travelers' daily activity pattern (mode choice, route choice, number of activities etc.) and attitudes towards the environment, basic demographic information and stated preferences towards the choice between the use of conventional and non-conventional vehicles (hybrid/electric vehicles).

The stated preference scenarios included the following variables:

- Purchase Cost
- Operational Cost (liters/km)
- Annual Tax
- Insurance Cost
- CO_2 Emissions

Table 1 presents the scenarios structure that was presented to individuals, as well as the levels of each variable presented for each alternative.

	Conventional	Hybrid	Electric
Purchase Cost	14,000 €	26,000 €	14,000 €
	16,000 €	20,000 €	10,000 €
	36,000 €	42,000 €	16,000 €
Emissions	130 gr. CO2 / km	104 gr. CO2 / km	-
	143 gr. CO2 / km	90 gr. CO2 / km	-
	245 gr. CO2 / km	70 gr. CO2 / km	-
Annual Tax	250 €	Free	Free
	90€	Free	Free
	400€	Free	Free
Insurance Cost	€350 / year	300 € / year	300 € / year
	€450 / year	400 € / year	400 € / year
	€600 / year	500 € / year	500 € / year
Operational Cost (consumption)	7 lt / 100 km	5 lt / 100 km	1 lt / 100 km
	8,5 lt / 100 km	6 lt / 100 km	2 lt / 100 km
	10 lt / 100 km	10 lt / 100 km	3 lt / 100 km

A total of 200 individuals participated in the survey. The majority of the sample is between 21-30 years old (43%) and more than fifty percent are male. Almost two thirds of the respondents use for their daily trips their car and approximately 14% travel actively (walking and/or bicycling). It should be also noted that car users claim to use their car because of its comfort and usefulness, while those that travel active do it for physical activity and for the environmental reasons.

The primary purpose of respondents' trips during morning hours is work or work related activities, while the majority of the sample didn't report any activities that involved travel during the afternoon.

Table 2 presents traveler's attitudes towards mode choice. A 7-point likert scale is used where 1=highly unlikely and 7=extremely likely. As it can be seen most of the respondents believe that they would be healthier and would help the environment if they use less their car.

Table 2: Mode Choice Attitudes

Statement	Mean	Standard Deviation
I believe that by using public transport or by walking I could save some money	4.78	1.464
I believe that if I use public transport I would be constrained	4.43	2.068
I believe that if I use public transport or/ and walking I would be healthier	5.49	1.554
I believe that if I use public transport or/ and walking I would help the environment	5.47	1.628

Figure 4 presents the concern of the respondents regarding the emissions from road transport in Chios (in a scale from 1 to 7, where 1=not at all concerned and 7=extremely concerned). The majority of the sample is quite concerned about the emissions; however 10% of the sample declares that is not concerned at all.

Figure 4: Emissions Concern

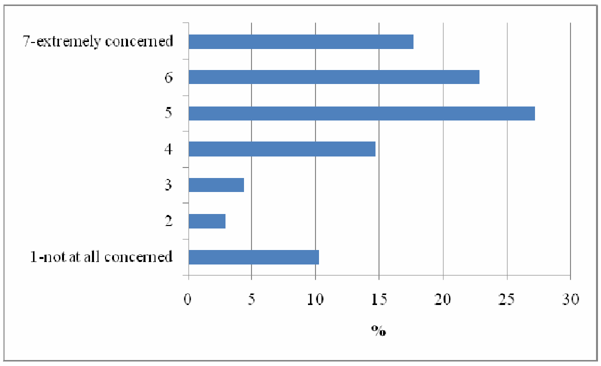


Table 3 presents the indicators of the environmental consciousness factor, which was extracted through factor analysis. A 7-point likert scale is used where 1=completely disagree and 7=completely agree. The total variance explained by the environmental consciousness factor is 52.11%.

Table 3: Environmental Consciousness

Indicators of Environmental Consciousness	Component	Mean	Standard Deviation
I'm willing to pay more in order to use an environmental friendlier mode	0.797	3.52	1.65
I would change travel mode for the environment	0.802	4.39	1.64
I'm willing to accept longer travel time if that would benefit the environment	0.441	3.83	1.75
I choose transport mode based on each environmental footprint	0.781	3.61	1.75

Figure 5 presents the car ownership choice model structure. The upper level choice is between conventional and non-conventional vehicle. If an individual choose to purchase a non-conventional vehicle the decision is between hybrid versus electric.

Figure 5: Car Ownership Model Structure

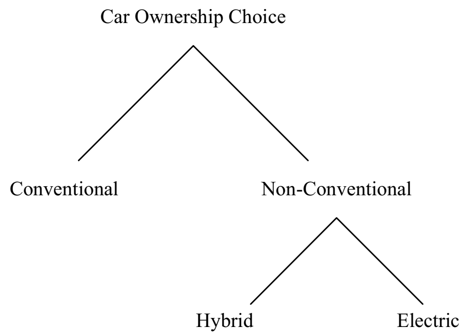
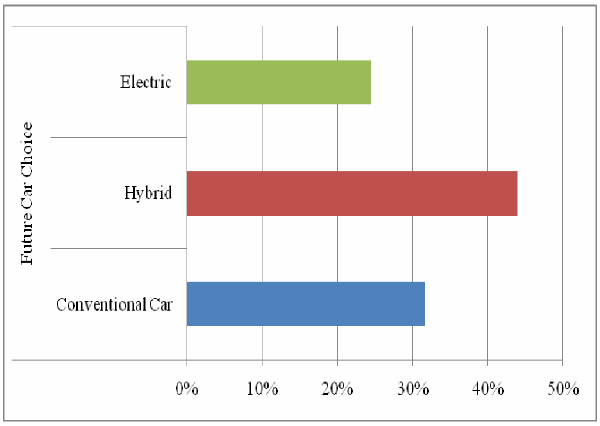


Figure 6 presents the future choice of car based on the scenarios that were presented to the respondents. As it can be seen the majority declared that they would choose to buy a hybrid vehicle, while fewer would choose to buy an electric vehicle.

Figure 6: Car Ownership Choice



5. Conclusions and Further Research

This paper presented a comprehensive approach for understanding and modelling the decision making process of individuals, by taking into account various attitudinal characteristics. Special attention was given to individuals' attitudes and perceptions regarding the environment and mode choice.

The analysis of the case study showed that although individuals are concerned about the emission produced from road transport in the island of Chios, their environmental consciousness is relatively low, as indicated from the corresponding factor.

According to the analysis of the stated preference experiments, the majority of the sample is willing to switch from a conventional vehicle to a hybrid one, but are less willing to switch to an electric vehicle.

The results obtained from this paper, were not fully explored, considering the various analyses that can yet be done. A mode choice model (conventional versus non conventional vehicles) is currently being estimated.

Further research should focus on identifying different market segments through attitudinal market segmentation techniques. Additional data collection should also be pursued in order to study more travel related choices that have an immediate environmental effect.

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Web-based Energy Management Systems, a Necessary Tool for Energy Efficiency and Smart Metering

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Abstract: Renewable Energy Sources and Energy Efficiency seem to be the only way to reduce harmful greenhouse gases like CO_2. Cutting-edge technologies could be a driving force in the energy sector, covering issues that are vital for energy production, consumption and management. With rising energy costs and the move toward more sustainable buildings, increasing energy use in buildings has both financial and environmental consequences. So it is critical for building owners and facility executives to determine if their buildings, companies and industries are operating as efficiently as they can and if not, having the ability and control to do so. The solution is to focus on energy monitoring. The visualization of energy brings the revolution in energy management. Energy Monitoring & Targeting helps organizations integrate, measure, manage and reduce their energy. The debriefing measurements of the past seem to be an inefficient way of energy monitoring in comparison with the real time display of a variety of electrical values. The existence of a system which collects, processes and analyzes energy data is necessary in the era of excessive energy consumption. Our MAIE method (Measure, Analyze, Improve, Evaluate) consists of Data Collection, Analysis, Energy Efficiency Solutions and Results Evaluation. Real-time integration platforms and automation infrastructures enable users to deploy optimal energy and environmental management strategies, allowing notification of events before they occur and finally constructing an individual energy profile. All these, are integrated into energy consulting services through energy analytics modules, the sophisticated and most efficient way of energy management.

Keywords: Energy Monitoring & Targeting, Automated Metering Infrastructure, Energy Analytics, Energy Consulting Services

1. Introduction

The vast majority of energy management activities are based on the financial impact they will have on the company. Today's rapidly evolving energy markets are forcing organizations to consider new ways to centrally manage the energy portfolio of the company. These two real-world conditions are causing building owners and energy managers to search for solutions to integrate and coexist with the rest of the enterprise building information network [1]. Energy managers are looking for an Internet friendly, smart platform that manages the "X" factor of energy.

Build-IT, having the technological know-how resulting from a 3-year Research and Development program, provides modern, reliable solutions in the field of energy Monitoring and Targeting (M&T). Incorporating the global energy trends, Build-IT creates innovative systems for M&T, smart homes, focusing on the energy management of large buildings and industries.

The cost of energy has to be incorporated in the operating cost of any company and should not be assumed as a fixed cost. This is especially critical in times of economic instability, where reduced energy costs can be considered as a profitable investment. With adoption of energy efficiency practices, total country energy consumption increases with lower rates or even remains the same. As a result, energy efficiency and saving comes hand in hand with a plethora of benefits (environmental, commercial, financial), becoming a really vital process. The following figure presents the integrated solutions of Build-IT. This paper focuses on Smart Metering Systems and Energy Management [2].

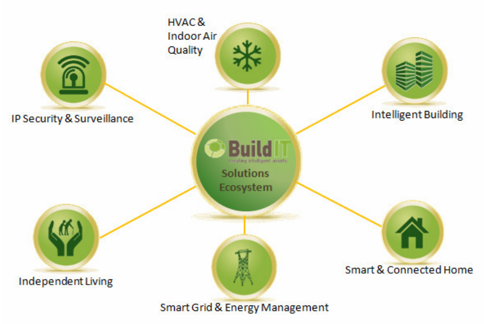

Figure 1. Integrated solutions of Build-IT

2. Advanced Metering Infrastructure (AMI)

In partnership with E-sight Energy (UK), Build-IT provides the AMIplus solution, a fully integrated solution for energy metering, monitoring, targeting and management. As a real-time integration platform and automation infrastructure, it enables users to deploy optimal energy and environmental management strategies, allowing notification of events before they occur.

The technology also enables users to collect information and benchmark buildings so as to expose operational inefficiencies. From a green building perspective, AMIplus allows users to capitalize on accurate and concise intelligence relating to the energy performance of a building in order to achieve lower energy consumption and enhanced efficiencies.

The whole AMI system, as shown in figure 2, combines telecommunication technologies, data base principles, web based programmable logic controllers (Tridium), smart meters and sensors. The users are able to login the system from anywhere, just by using an internet connection.

Figure 2. AMIplus system architecture

2.1 System architecture

Focusing on the system's architecture, the metering system consists of smart meters, autonomous sensors (temperature, lux meters, humidity sensors, occupancy sensors etc) and programmable controllers – data collectors. The following figure presents the energy management installation for a typical large building [3] [4].

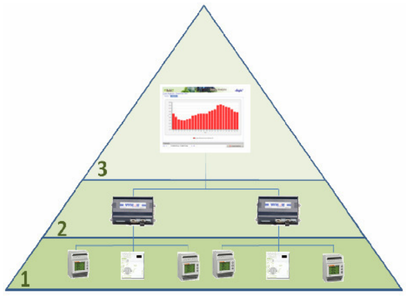

Figure 3. Build-IT AMI system

The *first level* on the above figure consists of smart meters and sensors. It is crucial to collect plenty of values which constitute the input data that will be considered in further energy analysis. Smart meters are divided into two categories. The first category includes the energy meters, whereas the second one the power analyzers. Energy meters record only energy values but they are considerable in special load metering and sub-metering. Power analyzers are complicated and have the ability to record power quality values such as Power, Current, Voltage, Total Harmonic Distortion (THD), Harmonics, Frequency, Energy (Real, Apparent) and Power Factor (cosφ). They are usually applied in the main installation to depict the whole energy profile.

The *second level* consists of the data collector. These powerful controllers, with a web based communication philosophy, are the most important components of the whole automated procedure. They use the internet as a gateway for data transport, using a new, secure, fully automated protocol oBiX (Open Building Information eXchange). oBix leads the new era of Machine to Machine (M2M) communications in buildings.

The *third level* of the above figure is the tool of energy monitoring and analysis. It is a software platform which is developed with sources of E-sight Energy (UK) and Build-IT. The use and benefits of this software are analyzed in paragraph 4.

2.2 Open Building Information eXchange (OBIX)

Standards in the device network industry have attempted to define "models" for every potential type of known device. This exercise continues to produce brittle models which do not capture the reality of smart devices. Devices have an extremely variability between manufacturers. oBIX embraces this reality by using a model based on a simple, flexible type system backed by real computer science. oBIX focuses on a couple of key problems. First of all, defines a "kernel" model based on a few key primitive types such as integers, strings, etc. Secondly, defines an open ended type system for both standards organizations and individual vendors or integrators to build up their own custom models. This is not much different from how a programming language like Java allows people to build up their own class libraries. Furthermore, oBIX sets a simple, elegant mechanism to combine the models from different organizations into one system based on prototype inheritance. This is the critical missing piece in most alternatives to oBIX. Finally, identifies all information using URIs, making it ideal for developing the Web of Things.

2.3 Networking of Things

Although vertical industries have been networking smart devices for decades; they implement their own solid solutions [5]. The following figure illustrates a small sampling of the solutions in use today:

Residential				Commercial		Lighting	Industrial				Automotive	Metering	Verticals
X10	Zigbee	Z-Wave	Konnex	BACnet	Lonworks	DALI	Modbus	ProfieBus	DeviceNet	ControlNet	CAN-Bus	M-Bus	Proprietary

Figure 4. The variety of protocols and their usage

Each industry tends to have hundreds of protocols, most of them proprietary to the manufacturers. Despite the fact that many things are networked today, very few of them are IP networked.

2.4 Internet of Things

Over the past two decades, there has been an explosion of standardization around the Internet Protocol (IP) [5]. The elegance of IP is that it defines a common interface between application protocols and the heterogeneous networking technologies used to transmit those protocols. As new networking technologies become available such as Wifi, all our old protocols continue to work.
Telemetry applications such as energy or fleet management have been using cellular communications for years. The value-chain required to build cellular solutions is quite complicated, typically involving many vendors including modem suppliers, carriers, and aggregators just to obtain basic connectivity. But as the industry matures, it is becoming simpler and more cost effective to create cellular enabled devices. This has huge implications for the Internet of Things – manufacturers can ship devices to the field with automatic, built-in connectivity. The cellular enabled device simply finds the network and reports itself when powered up. As new protocols are invented, they can be carried over existing networks. The following figure depicts this procedure.

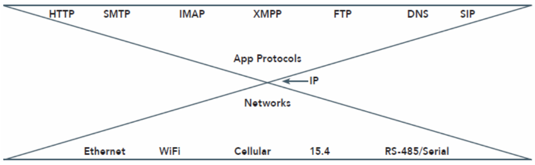

Figure 5. New protocols are carried over existing networks

The only real problem today for using IP to network devices is lack of a standard for running IP over lost cost wired media.
For the foreseeable future, many categories of smart devices will lack an Ethernet port. Wifi will continue to drop in cost and will see its way into more devices. But the explosive growth in the Internet of Things will likely come from IP over cellular, 6LoWPAN, and wired serial communications. The Internet of Things is still in its infancy (today a very small percentage of microprocessors are IP enabled).

3 Energy Monitoring & Targeting

Energy Monitoring & Targeting helps both small and large organizations integrate, measure, manage and reduce their energy [4]. AMIplus solution based on the MAIE methodology (Measure, Analyze, Improve, Evaluate) is a cyclic recurring process that should be repeated continually in the company, in order to allow continuous rational use of energy [6]. Figure 6 shows the four interrelated steps of MAIE method:

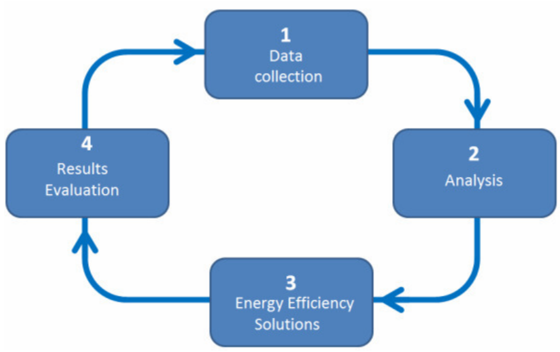

Figure 6. Energy efficiency methodology

These four steps analyzed in the following paragraphs:

Data collection
The first step of the MAIE method applies to the automated collection of energy data (such as energy, temperature, lighting, production etc.). Measurements are made from special digital meters and sensors at regular intervals e.g. per half hour or at smaller intervals (if necessary). The data generated from the meters and sensors are collected wirelessly or wired to a central controller which formats and sends them via the Internet to, a secure database for further processing. The uninterruptible transfer of large data volumes with accuracy and security is a strong feature of the AMIplus solution.

Analysis

The data analysis starts with the conversion of large data volumes into tangible and useful information for the user. The graphical representation of the energy data is able to display potential problems in the energy function of a building. Such problems may be caused by bad planning and bad energy behavior of the personnel, as well as problems of faulty management and waste of energy.

Energy Efficiency Solutions

When problems arise from the energy profile of the building, improvement solutions for minimizing or avoiding the energy waste are proposed. As a next step, an attainable energy optimization target is applied that should be supported by all employees. In many cases it is not possible to save energy solely by improving energy behavior. In these cases, it is important to apply systems which automate the energy – inefficient procedures like heating, cooling, ventilation, lighting etc. During regularly scheduled meetings, consumption parameters are carefully analyzed in combination with other factors (e.g. external temperature) and various corrective actions are proposed.

Results Evaluation

The fourth step of the methodology is the most important one, since it is dedicated to the calculation of the level of achievement of the energy saving target.

Energy is a value that lacks visualization and therefore the location and the amount consumed cannot be determined absolutely. The solution is to focus on energy monitoring. The visualization of energy brings the revolution in energy management [7]. The debriefing measurements of the past seem to be an inefficient way of energy monitoring in comparison with the live display of a variety of electrical values. The existence of a system which collects, processes and analyzes energy data is necessary in the era of excessive energy consumption.

The following figures show two important ways of energy analysis and monitoring [2]. Raw values are transformed into useful diagrams to give an accurate sense of the energy consumption for each installation.

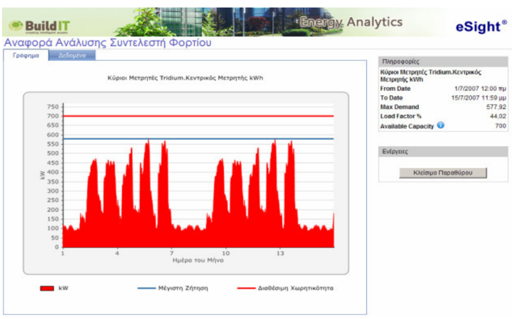

Figure 7. Load factor analysis

Load data analysis depicts the characteristics of the load. This analysis focuses on the average, minimum and maximum load. It represents the consumption of the building, in any time intervals and finds the peaks and the valleys.

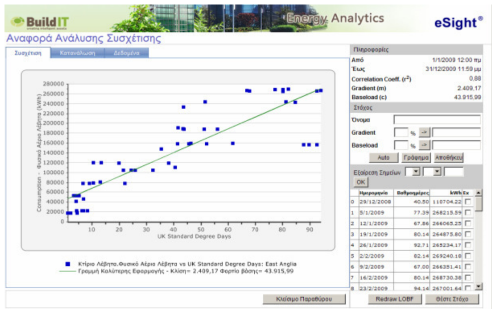

Figure 8. Regression analysis

Regression analysis constitutes an extremely useful tool for the energy manager. It presents the correlation between two values. Regression analysis is known from the diagrams of degree days and energy. Generally, it depicts any value (energy, gas) in regression with a force factor (temperature, degree days).

By managing energy and facilities as investments, companies gain control of energy use and achieve high rates of return in the form of energy savings and better performance with their buildings [8]. Benefits from this investment approach can include double digit energy reductions, as well as improved building performance, lower operating costs and increased environmental responsibility.

4 Energy Benefits from M&T and Energy Management – Case Studies

With a huge portfolio of companies that have applied an AMI system worldwide, monitoring and targeting procedure becomes a new necessary component of energy efficiency in buildings and utilities. The following case studies emphasize the advantages of AMI systems in several types of buildings.

4.1 Industry

The system installed in a food company with 120 employers and a power demand around 600kW. The metering of the energy consumptions took place through many individual meters (lighting, offices, production and heating-cooling) and one power analyzer for the power quality characteristics of the whole installation. CO_2 meters created to export the value of (kg of CO_2)/(kg of product). After weeks, the system detected a critical problem of the power factor of the whole industry, which far exceeded the ideal value. Furthermore, a wrong use of PCs was detected. The office equipment was 24-hours on, as well as the weekends.

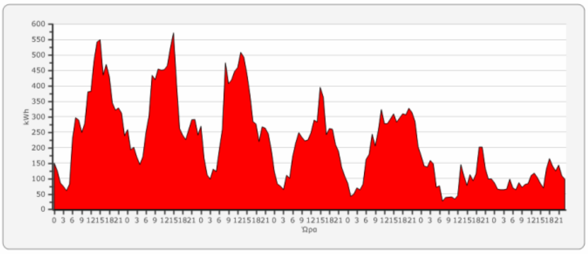

Figure 9. Weekly energy consumption

Through Monitoring & Targeting, the peak demand of the industry presented with its corresponding time. Furthermore, a KPI which calculates the percentages of consumption of the day and night (hours without production) created. This made the technicians to search for unnecessary night consumptions. Specialized alarms for crucial consumptions also created, to prevent peak demands. All the energy errors detected and now, the managers try to build a more "green" consciousness to the personnel.

4.2 Hospital

One of the most different energy profiles appears in the medical sector. In this large hospital with installed power demand of 1,5MW and buildings of 7.500m2 the cost of energy cannot be ignored. Crucial meters installed to measure the most important consumptions such as coolers, lighting, large medical equipment etc. After reasonable weeks of Monitoring & Targeting, some problems surfaced. The main consumption of the building was the coolers which, as a result, need a renewal or a meticulous service. Furthermore, it was recognized that the base load of the hospital (as it is shown in the figure) is a very important percentage of the whole energy consumption. Alarms set to help the technicians of the hospital identify the peak in demand.

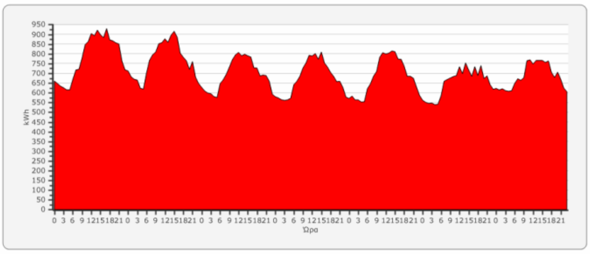

Figure 10. Weekly energy consumption

The whole energy profile changes a little during the week, so week days seem to be almost the same with the weekends. This is a characteristic of hospitals due to their 24/7 operation. Generally, hospitals are an individual installation and took place after serious programming and organizing.

4.3 University

The University is a separate type of energy consumption. In this Greek University, meters for the most important consumptions were installed. Furthermore, a power analyzer gives the whole profile of the building. Heating-cooling and lighting are the most intensive loads of the building.

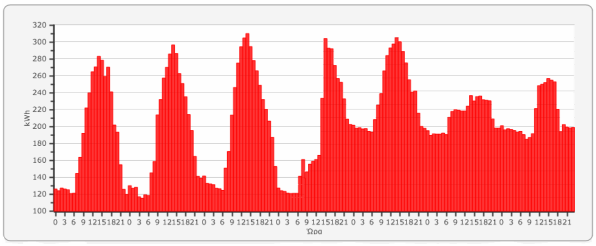

Figure 11. Weekly energy consumption

After weeks of metering, it came clear that the programming and the general use of the lighting have to be improved or change so to avoid aimlessly consumptions in night hours or weekends. As concerns to the heating-cooling, the two most common solutions are: firstly, the service and repair of these systems and secondly, the operation set-point has to change to a higher level in the summer and a lower one in the winter, enough to be tolerated from the typical human.

4.4 House

By installing the AMIplus system to a house, the owners have the ability of live monitoring of the house's consumptions. It is very important to check for possible leakages in the water system or for unexpected consumptions. Specialized alarms report any strange energy behavior and send an email or SMS to the owner. Houses always show undefined energy consumption because of the varied usage from people.

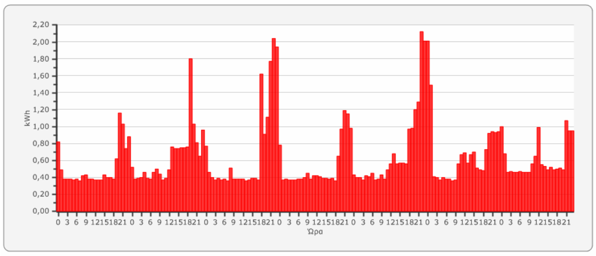

Figure 12. Weekly energy consumption

Generally, houses have a standard base load, as it is showed in the figure, due to the standard consumption of the electric devices and equipment (fridges, TV, Hi-fi etc).

4.5 CDF Suez

GDF SUEZ possesses a broad portfolio of energy supply customers, from manufacturing companies to service providers. With many clients requesting access to energy data on a regular basis, GDF SUEZ identified the need for an energy management suite [9]. Customers would be able to view energy data thus allowing full autonomy of energy management.

Having identified the need for such a system, GDF SUEZ had a number of specific requirements such as Web-based architecture and allowing access across the internet from any PC, at any location for both GDF SUEZ staff and customers. The second need was a scalable system which can be expanded at any time and finally a comprehensive functionality covering a multitude of analyses.

The Solution
GDF SUEZ selected a 100% web enabled energy management suite for the following reasons:

Complete web-based architecture: Using any browser, users are able to log on from any PC, to check the status of their energy data.
Individual profiles can be set up, allowing the personalization of the platform for each independent user regardless of their location.

Scalability: the platform is a fully expandable system and is ideal for any company dealing with growing numbers of metering channels.

Functionality: energy M&T platforms include a wide range of energy analysis techniques enabling the user to perform a multitude of functions; from simple energy graphs to complex calculations, simplifying the sometimes difficult task of managing energy.

Customer Benefits
Utility customers can view energy data from any PC at any location, equipping them with a mean to monitor and manage their own energy consumption. By offering this facility, the supplier empowers the consumer to be responsible for their own energy use, thus increasing customer loyalty and retention.

4.6 Carlsberg

Carlsberg UK Leeds is a Brewing and Packaging Site [10]. Some of its annual operational characteristics are shown in the following table.

Name	Value
Employees	150
Production output	2.6 million Hectoliters beer
Gas energy consumption	57 million kWh
EU ETS Phase II allowance	14,254 tones
Water consumption	900,000 m3
Effluent produced	600,000 m3
Production CO2, N2	8,000 tones

Table 1. Important operational data of Carlsberg

The Solution
For the implementation of an AMI system 6 utilities accounting areas created consisting of Brewery Site KPI centre, Energy Centre plant, Brewing Process plant, Bottling plant, Canning plant, Large Pack Keg and Cask plant.
For purposes of energy monitoring and targeting used 142 meters, 25 calculated meters and 104 energy and performance analysis templates. The energy strategy included:

Weekly Key Performance Indicators (KPIs) which calculated and compared to targets.
Weekly meeting is held with user departments reviewing diagrams for previous 7 days, and any exceptions are discussed.
Hourly dashboards are used at department operator level to monitor usage when the plant is running, stopped, shutdown or during maintenance periods.
Email alarms range and average are used for alerting high usage of specific meters which can have a major impact on utilities costs, environmental compliance, and production output.

Results
The AMI system reduced site overall energy consumption in 2009 by 10% by understanding consumption loads and matching with production periods. Furthermore, utilized CHP plant and the recovered heat by matching to process demands, improved recovered energy from brewing process which uses 60% of site usage and opened a window into shutdown opportunities when production ends.

The whole process reduced site water consumption by 10% and effluent cost by 16%. It used alongside continuous improvement as a measure in root cause analysis and generated automated email systems to all production allowing early reaction and intervention to process losses.

5 Conclusion – Further fields

Build-IT merges automation systems and real-time integration into a single, extensible platform that monitors, manages and controls the power consumption, drives energy efficiency and reduces energy costs. The AMI system is a scalable platform that delivers measurable Return On Investment (ROI) enabling users to capture the benefits of integration, automation and energy control of their buildings and maximize the value of information in real-time contained within them.
An additional field of practice in which Built-IT focuses on is the development of Building Management Systems (BMS). BMS manage all building systems taking into account all critical areas and subsystems that make a building functional, including lighting, heating, ventilation and air-conditioning (HVAC), security, and energy management. It allows devices to share information with each other and streamlines them into a common system where management can control and monitor the buildings' operations [1].
The new era of technology and energy needs a bridge between systems and devices, simplifying the process of connectivity and integration that makes building and facility management easier. In addition to integrating energy consuming devices and systems within a building and getting them to work together to be managed, controlled and operate at optimum levels, Build-IT includes energy measurement and verification tools that allow users to implement the most efficient and sustainable energy strategies in a building today.

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The role of information and communication technology in the implementation of the energy conservation program of the Republic of Uzbekistan

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Abstract
The purpose of this study is to offer evidence-based recommendations for the exchange of information and use of Information and Communication Technologies (ICT) to optimize energy efficiency policy in the electricity sector of Uzbekistan.
An essential solution to the problems of energy efficiency and security of supply in the energy sector is the mutually beneficial exchange of information on the most efficient energy-saving projects. The exchange of information is also beneficial for the determination of the best approaches to meet regional energy needs
However, the impact of information and awareness on the optimization of the basic sectors of the real economy, particularly electricity sector, is virtually unexplored in both theoretical and applied aspects, which confirms the urgency of the problem and determines a direction for future research in developing strategies for energy conservation policies.

Key Words
Information Communication Technologies, energy conservation, policy implementation

1. Introduction

Awareness on the advantages of development and implementation of Information and Communication Technologies (ICT) is growing worldwide. ICT bring revolutionary changes in various aspects of activity of the state institutions and administration, economic and social sphere, science and education, culture and way of life. ICT help people to better realize their potential, and allow achieving mutually complementary objectives for sustainable economic development, increase of public welfare, strengthening of peace, democracy and stability, which have become particularly important in view of the world financial and economic crisis that broke out in 2008. In the era of globalization the ICT play fundamental role and this allows considering it as the 5th factor of production along with labour, natural resources, capital and entrepreneurship.

Uzbekistan is a dynamic player in the global information space and takes increasingly active role in its development. The long term strategy of socio-economic development of Uzbekistan is aimed towards creation of information society, and establishment of appropriate prerequisites and conditions. From the beginning of the independent development process the Republic had chosen the evolutionary way of building of democracy and socially-oriented market economy. This allowed the young state moderating the negative consequences of the global financial crisis and achieving impressive macro-economic indices. The Gross Domestic product of the country in 2009 had increased by 8.1%, industrial production increased by 9.0 % in comparison with the previous year (Allaev, 2009). This is much higher than in other NIS countries, but also in practically all developed industrial countries. The service sector of Uzbekistan had increased by 47%, while ICT demonstrated an increase of 37.4% (Allaev, 2009).

One of the key objectives of the Anti-crisis Programme of the Republic of Uzbekistan for 2009-2014 approved on 13th of April, 2009 by the Cabinet of Ministers of the Republic of Uzbekistan, is implementation of the energy-saving policy, including measures for modernisation of the electric-power industry, decrease of power-intensity of economy and implementation of effective energy saving measures. The competitiveness improvement and increase of population welfare depends to a big extend from our ability to use effectively and wisely existing resources, and primarily electricity along with the other energy resources.

Increase of energy efficiency and safety in the power sector, as well as defining of optimum approaches to covering energy needs can be achieved through the mutually beneficial exchange of information on the most rational energy saving projects. Development of ICT for securing of visibility of the energy saving technologies for internet users is an important factor for overcoming of the negative consequences of the global financial-economic crisis.

At the same time, the impact of the ICT on optimization of development of the real sector of economy, and in particular, electric-power sector is practically not analysed in full depth in Uzbekistan, both in theory and practice. This confirms the topicality of the problem and sets the direction for further research for development of the strategy for energy saving policy.

The objective of this article is to propose the scientifically based recommendations for use of the ICT for optimization of the energy saving policy in electric power sector of the Republic of Uzbekistan.

2. Short Analysis of the Theory Underlying Energy Efficiency Policy and the Role of the ICT in its implementation

Energy has played the decisive role in the development of civilization. Energy consumption and information accumulation have approximately similar variation in time; the relation between energy consumption per capita and industrial production per capita is very close. Energy consumption increase is amazingly high, especially in industrially developed countries (Allaev, 2009). It is due to this increase a human being can spend considerable part of his life on leisure, education, creative activities; additionally the life expectation had considerably increased.

The energy saving policy becomes a strategic direction for the fuel and power sector development. Its growing importance is defined by a number of factors that become increasingly global. These include:

- general increase of primary energy demand;
- energy resources of non-renewable type that will be exhausted in the near future;
- constant increase of costs of production of energy carriers;
- increase of pollution caused by the use of fuel.

Energy saving is a multiplex process and embraces various spheres of human activity. As a matter of fact, it is the way of life of a nation or a community, which cultivates the particular psychological algorithm of behavior.

The main principles for the energy saving policy implementation can be defined as follows. ***The first is to consider energy saving in economic terms***. Thus the strategy of development of the power sector of a country includes increase of volume of production of primary energy resources, energy and heat with simultaneous implementation of measures for efficient use of energy of all types. The rational combination of these two approaches constitutes the important possibility for optimization of proportions between the fuel and power sector and the whole national economy of a country.

The existing and future technology and economic performance capabilities of energy saving, power and primary energy production, make ***the energy saving policy an important factor of balanced development of the energy sector and economy in the long run. This is the second principle*** of energy saving policy.

The third principle is not so much the strict economy of all types of energy, but rather their rational use, including research and development of new non-traditional sources of energy saving, i.e. ***the principle of reasonable sufficiency of consumption***.

It has become apparent, that the specific consumption per unit of production should be one of the most important criteria of scientific and technical progress in technology along with the labour productivity and efficiency of material costs. Industrially developed countries have achieved remarkable results in covering needs of the states in energy resources. According to the USA Department of Energy, energy savings achieved in the USA in 2007 allowed to keep the level of energy consumption of the country almost at the same level as it was in 1973, while during the period that passed since then, the population had increased by 34 million of people, number of houses that should be supplied with electricity, heat and cold, had increased by 20 million, and number of transportation vehicles had increased by 50 million. The annual cost of energy in the USA during the last few years equals approximately 430 billion USD instead of 580 billion USD in 1973 (Rogovskyi, 2008). Furthermore, the energy content of the unit of GDP in Uzbekistan equals 1.16 tons of oil equivalent per 1,000 USD, while in the USA this figure is equal to 0.16 tons of oil equivalent per 1,000 USD, i.e. more than 7 times lower. Consequently, economy of Uzbekistan has huge potential of energy carriers saving (CAREC, 2010).

The following groups of measures, which assure effective use of fuel and power resources, can be distinguished:

- scientific and technical;
- legal;
- technical regulation;
- institutional and economic;
- information.

In ***scientific and technical*** terms, the increase of energy efficiency can be achieved through the following measures:

- introduction of energy efficient production technologies, improvement of production management, decrease of intensity of raw materials used for production,
- enhancement of energy equipment structure, dismantling and refurbishment of obsolete equipment, introduction of energy saving technologies, devices, machines and vehicles in production process;
- decrease of unjustified losses, increase of percentage of use of secondary fuel and energy resources;
- adoption of new combined energy technology processes - gas turbines with consequent utilization of exhaust heat, combined cycle plants.

Legal basis is created by the relevant laws and technical regulations and is necessary for creation of infrastructure for implementation of an energy programme. Implementation of full energy saving potential depends ***also on administrative and economic conditions*** defining the mechanism for energy saving programme implementation, including identification of financing sources and working structures, implementing energy saving tasks;

With regard to ***information and technologies*** related to it, three types of information use can be distinguished in the context of energy saving. *The first* one is the information technologies used within the technological process, *the second* one is the information processing for political and financial decision making, and *the third* is the information dissemination for ensuring good practice dissemination and securing of wider support for energy saving policy in the society.

ICT role within the technological process of energy generation, transmission and distribution is the following:

- increase of metering efficiency,
- optimization of control of electricity generation, transmission and distribution,
- ensuring of quality of electricity,
- ensuring of security of supply,
- reliability and safety of system operation.

However, this is an important issue and deserves to be considered under more technical angle. In this article the administrative, managerial, financial and political aspects of the ICT use in energy saving measures, and in particular in the electricity sector are considered.

Currently, the necessity of data records with respect to the important economy factor, namely energy saving, becomes more and more important when considering various aspects of a country strategy for social and economic development. This is explained mainly by the growing problems with energy supply of a country economy. As it is well known, the investment needed for saving of a unit of fuel is more than two times lower than the investment needed for increase of extraction and production of the same quantity of fuel (Allaev, 2009). Increase of energy efficiency and safety in the power sector, as well as defining of optimum approaches to covering energy needs of the regions can be achieved through the mutually beneficial exchange of information on the most rational energy saving projects.

EU policy with regard to increase of the ICT role in transition to an energy-efficient, low-carbon economy can provide interesting insights and become a source of ideas for the Government of the Republic of Uzbekistan. In line with the Communication COM(2009) 111 and as described in the Communication of the European Commission Brussels COM(2009) 7604 from 9.10.2009, ICT have big potential of improvements of both its own processes and as part of the other sectors in implementation of an EU policy directed at creation of an energy-efficient, low-carbon economy. As noted in the Communication "ICT-enabled improvements in other sectors could save about 15% of total carbon emissions by 2020" (EU, 2009, p. 4). A public consultation, organized in 2009 with regard to ICT role in energy efficiency had indicated that many companies implement different strategies directed at increase of energy efficiency and reduction of green gases emission. As such, the Communication stresses that the integrated policy in that respect would be beneficial both for the ICT sector development and for the overall achievement of objectives set in the energy efficiency field. The main directions for the recommendations, presented in the Communication are related to buildings and construction, transport logistics and energy end-use, since in these sectors ICT can play the biggest role in energy efficiency improvements.

The following recommendations for the Member States were summarised in the Communication (EU, 2009, p. 8):

- To agree by the end of 2010, on a common minimum functional specification for smart metering and by the end of 2012, on a period during which the smart metering is to be implemented.
- To upgrade strategies for the roll-out of a reliable, high-speed, broadband infrastructure to facilitate monitoring and management of consumption, distribution and production of energy including renewables, and the introduction of community-wide systems such as smart metering, smart-grids and smart-cities.
  It is expected that smart metering and smart grids will facilitate penetration of electric vehicles, efficient energy supply and distribution as well as integrating renewable energy sources. Consequently, the new sector of economic activity will grow, involving both the energy and ICT segments.
- To build consensus among all relevant stakeholders on the requirements for the emergence of future ICT-enabled innovations through implementation of large-scale pilots and demonstrations of smart metering and smart grids.
- To adopt the procurement practices that would strengthen the public sector for promoting the dematerialisation of ICT goods and services (i.e. the reduction of equipment that supports the delivery of e-services).
- To facilitate, the use of relevant ICT tools for better understanding of the implication of different policies and avoiding negative results when one policy impedes or slows down the implementation of the other.
- To encourage the use of energy simulation and modelling in the education and training of professionals in critical sectors: architects, builders and installers; energy auditors; logistics and the transport of goods or persons; public services, planning and policy functions.
- To make use of open digital platforms to facilitate an integrated approach to urban planning and public

service delivery and to support knowledge-sharing, catalogues of best practices, and the maintenance of easily accessible information repositories.

- To open up opportunities for creative forms of collaboration and problem-solving at the community level through calls for ideas, competitions, and where possible by providing open access to a wide range of public digital resources and public data.
- To extend the benefits of substituting offline administrative processes with online applications and services, which realize energy efficiency improvements, to all segments of the communities (EU, 2009, p. 8).

Following the short analysis of the theory underlying energy efficiency policy and the role of the ICT in its implementation, the overview of the energy efficiency policy of Uzbekistan is presented.

3. Overview of Energy Efficiency Policy of the Republic Uzbekistan

Further development of the energy sector of Uzbekistan can be considered only as part of general economic and social challenges with due consideration of developments in global economy. For finding optimum solutions the analysis of both existing situation as well as the future trends in the power sector development should be implemented.

One of the key objectives of the **Anti-crisis Programme of the Republic of Uzbekistan for 2009-2014** approved on the 13th of April, 2009 by the Cabinet of Ministers of the Republic of Uzbekistan, is implementation of the energy-saving policy, including measures for modernisation of the electric-power industry, decrease of power-intensity of economy and implementation of effective energy saving measures. The programme also includes the introduction of the first stage of the automated electricity control and assessment system (Baybulatova, 2010).

The **"Electric Power Generation Programme of the Republic of Uzbekistan up to the year 2010"** sets forward ways to develop the use of thermal power and mainly focuses on three essential points: energy pricing, institutional capability development and education and information dissemination (Abdullaev, Nasyrov, 2010).

In 2009 the specific energy content of the Uzbek economy (GDP) had been reduced by 2.8%, the number quite close to the assessments of **Energy Strategy of the Republic of Uzbekistan -2010**, developed in 2001, according to which the energy content should be reduced on average by 2.9% annually (Allaev, 2009). However, this increase of energy efficiency was achieved not due to implementation of energy saving programmes, but rather as a result of higher than planned increase of the GDP. Taking this into account, as well as slowing down of dynamics of reduction of the specific energy content of the Uzbek GDP, related to financial and economic crisis, the measures for improvement of energy efficiency should be implemented.

Along with the energy planning the relevant financial and legal framework is also created in Uzbekistan. The legal basis is created by the **Law of the RoU "On the Rational Use of Energy"** adopted on the 25th of April 1997, which regulates activities of juristic and non-juristic persons in connection with extraction, production, refining, storage, transportation, distribution, and consumption of fuel, thermal and electric energy. (Abdullaev, Nasyrov, 2010). The **Law of the RoU "On power industry"** came into effect on the 30th of September 2009. It outlines clear regulation of legal relationships in the sphere of energy production, transfer, distribution, sale and consumption. The adoption of this law provided the balanced legal management system for the integral electric power system. It also clearly regulates relationships between electric power suppliers and consumers (Baybulatova, 2010).

The new Energy Strategy of the Republic of Uzbekistan will cover period till the year 2025. It is currently developed with participation of all branch ministries and agencies. The cornerstone of this strategy is the fuel and energy balance and the energy saving programme. Additionally, the regional and branch energy saving programmes will be developed for the same period.

The main pillar of the coming energy programme of Uzbekistan, includes **first** of all implementation of the active energy saving policy on the basis of **introduction of advanced technology and techniques in all sectors of the economy**, as well as transfer to market mechanisms of efficient energy use.

The second in importance component of the strategy for efficient use of energy **is an institutional one**, since it ensures coordination and motivation of all players interested in the rational use of energy (producers, designers, constructors, investors, and consumers).

The third component for efficient energy use **is training and information dissemination**. All these components should be supported by the relevant mechanisms for provision of financial and economic incentives. For implementation of the energy saving policy the awareness of all population and end users in particular on the ways and methods of efficient energy use, modern metering systems at all levels of generation, transmission and distribution and end-use of energy is of paramount importance.

Additionally, the main directions for use of the energy saving potential of Uzbekistan, which are under discussion include:

- improvements in technologies in industrial production
- improvements in use and structure of industrial equipment**;**
- use of combined cycle of electricity and heat production on the basis of combined cycle and gas-turbine plants;
- installation of meters on all stages of flow of

resources;

- decrease of losses and improvement of technology of use of fuel and energy;
- improvement of quality of raw materials and use of raw materials types with lower power intensity;
- improvement of structure of fleet of motor vehicles in the country;
- decrease of waste amount in industry and increase of waste utilization level;
- implementation of temperature control in dwellings;
- development of electrified urban transport;
- implementation of more strict standards for energy consumption, etc.

Following the brief outline of the Energy Efficiency policy of the RoU, the analysis of the ICT implementation in all three components of the energy saving strategy is presented in the paragraphs below.

4. The Role of ICT in the Energy Efficiency Policy of the Republic of Uzbekistan

The replacement of all obsolete equipment "will require huge investment, which are not available at the moment and constitutes one of the main problems of the economy, the solution of which is not realistic in the short term" (Resolution of the Cabinet of Ministers of the Republic of Uzbekistan, 13th of April, 2009). Nevertheless, some energy management techniques can be used in the short and long term planning for overcoming of this problem and, consequently, achieving of the main goal of increase of energy efficiency.

For example, it is widely accepted in Uzbekistan that the first step in development of an energy saving strategy for an enterprise is an energy audit – a complex of technical and managerial measures, aimed at defining of the reasons for overconsumption of all types of energy and search for optimum solutions for their elimination: energy management which includes consumption monitoring with use of the metering devices, as its integrated part. According to the Law "On Energy Saving" annual energy audits are compulsory for the enterprises with annual energy consumption of 4200 t of oil equivalent and more than 1000 t of motor fuel.

Uzbekistan needs considerable amount of stationary and portable metering devices for establishment of monitoring of energy consumption and analysis of potential for energy savings. Energy Management system at an enterprise should have direct automated link between monitoring and control of consumption.

Another legally obligatory administrative measure, that imposes the use of ICT as part of energy saving infrastructure, is energy labeling. The compliance of equipment produced with the requirements set by the relevant standard as regards energy efficiency requirements shall be stated by the producer by means of energy labeling (Law on the Rational Use of Energy, 1997). Furthermore, according to the Law on the Rational Use of Energy tasks that are imperative for the effective implementation of the energy saving programme include:

- monitoring of all types of energy consumption on each enterprise through the metering devices;
- creation of databases for monitoring and analysis of the energy saving programmes implementation.

Installation of metering devices at the users end allows revealing the source of losses, where the necessary energy saving measures should be implemented. Therefore, installation of energy meters is an essential element for implementation of the energy saving programme; though the meter per se does not eliminate the sources for energy losses. Additionally, as demonstrated by the statistics, the installation of the metering devices plays quite disciplinary role and reduces energy consumption of the user for about 10% (CAREC, 2010). Uzbekistan had already started the practical implementation of the installation of new generation of metering devices. According to the Uzbek energy supply company Uzbekenergo, automated electricity control systems had been put into operation testing in the Tashkent HS, New-Angren and Tashkent HPP, series of O'rta-Chirchiq hydroelectric power plants, substation Tashkent-500 kV, and 110 kV power lines in Qashqadaryo region. Automated electricity remote control systems covering household electricity in over 60,000 flats have been introduced in Tashkent and Angren. Nowadays those objects have almost no debts for consumed electricity, and electricity marketing organizations receive monthly about 2.3 million kWh of additionally considered electricity. According to the Ministry of Economy, 361,400 electronic meters providing more accurate assessment of electricity consumption have been installed in power networks over the nine months, this year, within the implementation of the power industry modernization program (Baybulatova, 2010)

With regard to information dissemination and training, the ICT use is limited to the few stand alone information centres and organisations, distributing information mainly in the form of publications, presentations, seminars and workshops. Among those, the Energy Management Laboratory in the Tashkent State Polytechnic University and the Energy Centre of Uzbekistan, created with the technical and financial support of the EU can be mentioned. There are also some state supported organisations, like the Fuel and Energy Efficiency Commission created by the decision of the Cabinet of Ministers, Decree N357 of 15 July 1993 (Abdullaev, Nasyrov, 2010). The activities of these organisations are not coordinated and networking between them is practically absent.

5. Conclusions

As had been discussed in this article, the role of ICT in the technology of energy (and especially electricity) generation, transmission and distribution is quite well understood in Uzbekistan. The technological implications of ICT for energy saving are rather well planned and similar to measures that are developed in the EU. It is the administrative, institutional and financial improvements that have to be introduced for making the best use of the existing potential of ICT in energy saving.

With regard to use of the ICT in energy (and in particular electricity) saving strategy of Uzbekistan the following recommendations can be proposed:

1. To develop a relevant chapter on use of the ICT in energy (and in particular electricity) saving in the energy policy of Uzbekistan.
2. Create the Energy Saving network under the auspices of the Ministry of Energy of Uzbekistan with the objective to:
   - Increase of visibility of energy saving technologies in the electricity sector through creation of a relevant web site;
   - Consolidate and support knowledge-sharing between professionals in construction sector, industry and agriculture with regard to energy saving best practices;
   - Support and supervise training and operation of energy auditors especially with regard to use of the ICT;
   - To establish exchange of experience and information with the relevant networks in the EU and other parts of the world.
3. On the basis of the results of the electric meters change campaign, which had been recently implemented in Uzbekistan, to develop a short and long term programme for refurbishment of metering equipment in the industrial and agricultural sector for securing necessary funds from IFIs
4. To create a network of non-government organizations (including ones working with women and youth) for implementation of creative forms of collaboration and problem-solving at the community level through calls for ideas and competitions.

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Using an Atmospheric Pressure Chemical Vapor Deposition Process for the Development of "Smart Windows"

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Abstract: The interest in electrochromic vanadium pentoxide coatings has increased during the last few years, because of their use in windows that can control the solar light transmission, contributing therefore significantly to energy saving in buildings. Large area uniformity, low production cost and durability of the coatings can play a very important role in fabrication of such "smart windows". In that respect, atmospheric pressure chemical vapor deposition (APCVD) process is more advantageous over the other conventional techniques, which are already used in industry for the fabrication of these coatings. Since, it is easily integrated to float glass plants, no expensive vacuum systems are required and high production rates may be realised. In this paper, the effect of the gas precursor ratio and the substrate temperature are considered. Their importance in achieving optimum morphology and the proper oxidation state of vanadium oxide is highlighted.

Keywords: Smart windows, Chemical vapor deposition, Vanadium pentoxide.

3. Introduction

A lot of attention is given to materials that can be used in "smart windows". Responsive coatings can regulate a more comfortable living environment, while saving energy usually consumed for appropriate lighting or air conditioning (Brigouleix et. al., 2001). A typical example is electrochromic films, which show reversible changes in optical properties in response to an applied voltage. One of the studied oxides for electrochromic devices is vanadium pentoxide (V_2O_5) (Ottaviano et al., 2004); a foreign atom such as Li^+ can be inserted or removed from its lattice switching reversibly from a bleached to a coloured state through the following reaction (Talledo and Granqvist, 1995).

(bleached) $V_2O_5 + xLi^+ + xe^- \Leftrightarrow Li_xV_2O_5$ (coloured)

As with many coatings, CVD routes are more attractive for the production of vanadium oxides on glass than other conventional techniques, since the stoichiometry and the morphology of the films can be controlled simply by tuning the vapour flows in the coating zone (Manning et al., 2004; Vernardou et. al., 2006). In addition, the simplicity of CVD, particularly when performed at atmospheric pressures (APCVD), would make such a process compatible with in-line glass manufacturing processes.

The aim of this work is to study the influence of gas precursor ratio and substrate temperature on the structure, stoichiometry and intercalation process of the films grown by APCVD.

4. Experimental

The APCVD reactor used in this work is an in-house design and consists of a cold-wall reactor connected to an arrangement of stainless-steel heated pipes, valves and bubblers as shown in Figure 1. Bubbler 1 was used for the VCl_4 and bubbler 2 for the deionised H_2O. The carrier gas was nitrogen, which was passed through the apparatus during all operations of the reactor. During the growth, two series of experiments were performed. The first one regarded various gas precursor ratios of VCl_4:H_2O (1:1, 1:2, 1:3, 1:5 and 1:7) at 450 ^oC, while the second one different substrate temperatures (450, 500 and 550 ^oC) for constant ratio of VCl_4:H_2O, 1:7. The deposition time for all the samples was 2 min. The substrates used during the APCVD experiments were commercial SiO_2-precoated glass (Pilkington, UK), all of dimensions 22 cm × 8.5 cm × 0.3 cm. Prior to coating, all substrates were cleaned with H_2O and detergent, rinsed thoroughly with H_2O and deionised H_2O, and allowed to dry.

Raman measurements were performed with a Nicolet Almega XR micro-Raman system operating at wavenumber range 100 – 4000 cm^{-1} using a 473 nm laser. UV-Vis transmittance measurements were carried out using a Perkin Elmer Lambda 950 spectrometer over the wavelength range of 300 – 1100 nm. Scanning electron microscopy (SEM) was carried out on a Jeol JSM-6390LV electron microscope. For the SEM characterization, all samples were over-coated with a thin film of gold, in order to make them more conductive. Cyclic voltammetry experiments were performed using an electrochemical cell with typical tri-electrode configuration and a computer-controlled AUTOLAB potentiostat/galvanostat. Vanadium oxide coated glass substrates acted as the working electrode biased in the range between -0.5 V and +0.25 V. Ag/AgCl and a Pt foil were employed as the reference electrode and the counter electrode respectively. The measurements were performed in 1 M, $LiClO_4$ / polypropylene carbonate solution, which acted as the electrolyte, at a scan rate of 10 mV sec^{-1}. The coatings were cycled up to 500 times. To study Li^+ interacalation, deintercalation process with respect to time, chronocoulometry was carried out at -0.5 V and +0.25 V for a step of 10 sec.

Each characterization was performed on at least three samples prepared under the same conditions for consistency and reproducibility.

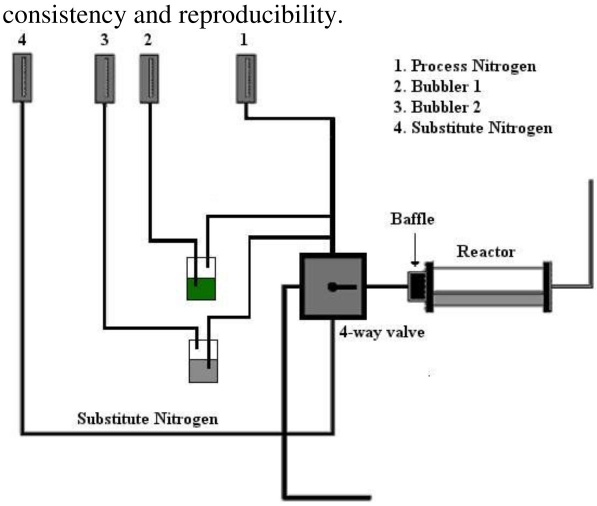

Figure 1. A schematic presentation of the APCVD reactor.

5. Results and Discussion

The films produced in the APCVD reaction of VCl_4 and deionised H_2O were yellow, adhesive and they passed the Scotch tape test. In addition, these coatings had similar properties (structural, morphological, optical and electrochemical) after approximately six months, indicating their stability with time.

Figure 2 displays the Raman spectra of V_2O_5 films deposited on commercial SiO_2-precoated glass for precursor ratio of VCl_4:H_2O, 1:7 at 450, 500, 550 ^oC and deposition time of 2 min. The peak positions agree with the literature spectra to within ± 2 cm^{-1}. The high-frequency Raman peak at 995 cm^{-1} corresponds to the terminal oxygen (V=O) stretching mode, which results from unshared oxygen (Lee et. al., 2003). Peaks at 705 cm^{-1} and 530 cm^{-1} could be attributed to stretching modes of the V-O-V bridging bonds with the bending motions of these bonds assigned to 486 cm^{-1} (Abello et. al., 1983). Peaks located at 406 cm^{-1} and 283 cm^{-1} are assigned to the bending vibrations of V=O bonds

(Julien, 1997). Two more low frequency Raman peaks at 197 cm^{-1} and 145 cm^{-1} can be distinguished, which correspond to the lattice vibrations (Jehng, 1983). Raman spectra were obtained at various points on the surface. It was observed that only a single phase was detected apart from the samples grown at 450 °C. The specific pattern (see Fig. 2) shows the presence of peaks at 842 cm^{-1}, 881 cm^{-1} and 932 cm^{-1} indicating that the samples are possibly sub-stoichiometric with an oxygen deficiency. The peaks disappeared when the films are heat-treated possibly due to partial filling of oxygen vacancies and increase in the order of the films.

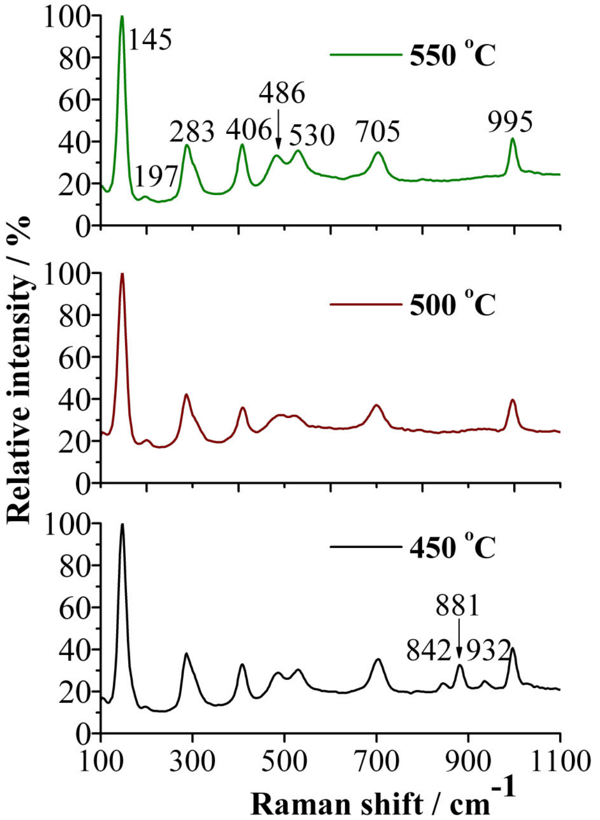

Figure 2. Raman spectra of vanadium oxide films grown for a deposition time of 2 min and gas precursor ratio of VCl_4:H_2O, 1:7 at 450 °C, 500 °C, 550 °C.

For gas precursor ratio of VCl_4:H_2O, 1:1, 1:3 and 1:5 at 450 °C, the vanadium oxide films presented only the peaks at 842 cm^{-1}, 881 cm^{-1} and 932 cm^{-1}. This indicates the necessity to use excess H_2O (VCl_4:H_2O, 1:7) in order to get V_2O_5 as a result of the proper oxidation of the vanadium species (see Figure 2). Thus, it is possible to define a frame of APCVD operating parameters wherein single-phase V_2O_5 may be reliably expected to form: these conditions involve a precursor ratio equal to 1:7, with a substrate temperature of > 500 °C.

SEM images of vanadium oxide films deposited at 450 °C for gas precursor ratio of VCl_4:H_2O, 1:1, 1:5 and 1:7 are shown in Figure 3. As the oxygen flow increases, dense stacks of long grains are formed and film crystallinity gets improved as verified by Raman measurements (not shown here for brevity). This behaviour may originate from enhancement of the mobility of the species on the developing film surface promoted by the increased oxygen flow.

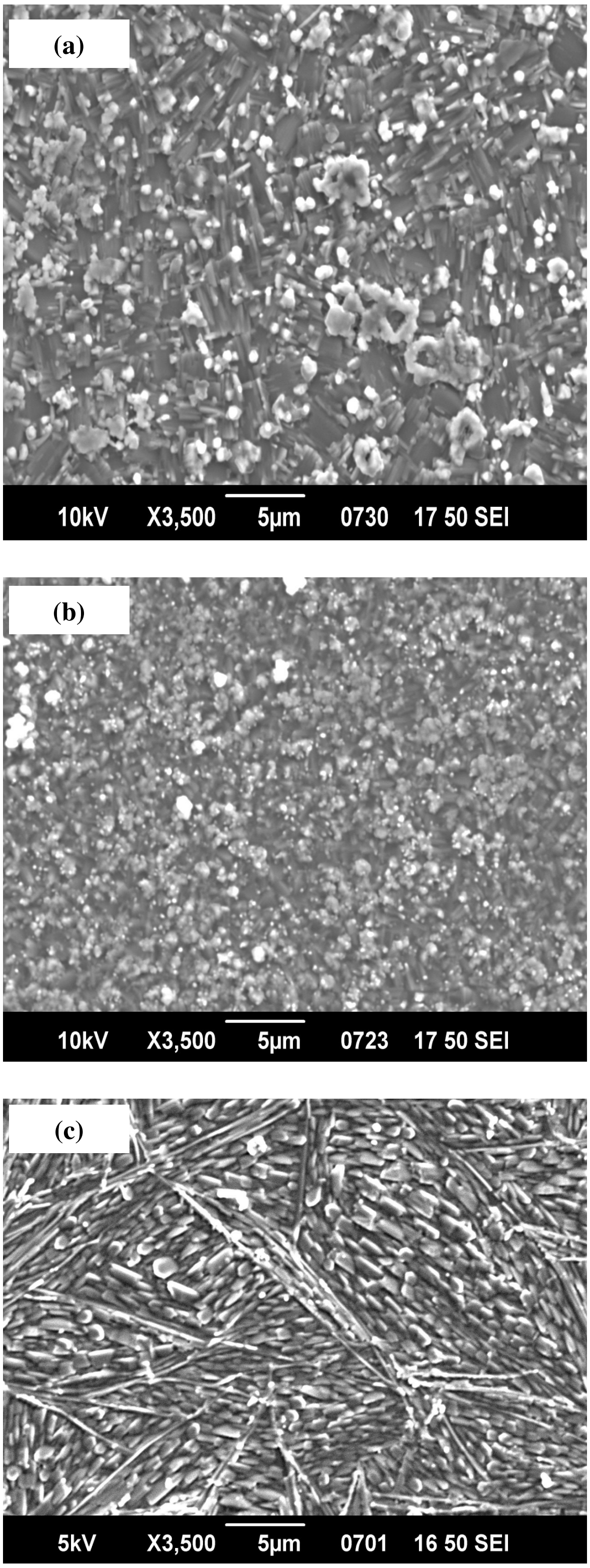

Figure 3. SEM images of vanadium oxide films grown at 450 °C for gas precursor ratio of VCl_4:H_2O, 1:1 (a), 1:5 (b) and 1:7 (c).

As the growth temperature increases from 450 °C to 550 °C (Figure 4), surface diffusion is activated, the surface morphology becomes flattened, and columnar grains of uniform size and shape are formed.

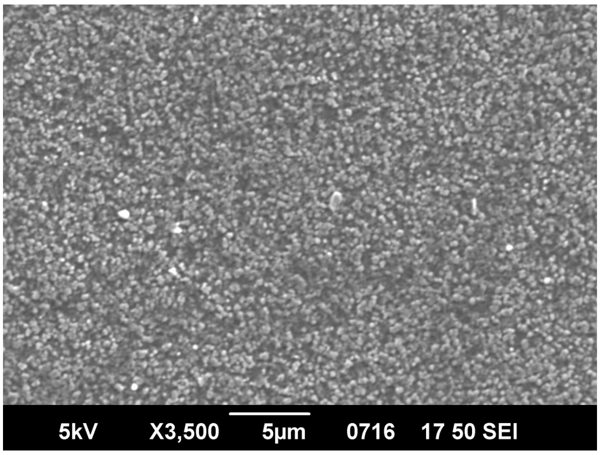

Figure 4. SEM images of vanadium oxide films grown at 550 °C for gas precursor ratio of VCl_4:H_2O, 1:7.

Transmission spectra of the vanadium oxide samples prepared at 450 °C, 500 °C and 550 °C are shown in Figure 5. The transmission in the visible region is slightly higher for the oxide samples grown at 450 °C, which may come from either reduced reflectance due to optical trapping (Younkin et. al., 2003; Crouch et. al., 2004) at the rough surface or from decreased thickness. In addition, there is a small peak for the samples grown at substrate temperature higher than 450 °C, which is in agreement with the literature for crystalline V_2O_5 (Ottaviano, 2004).

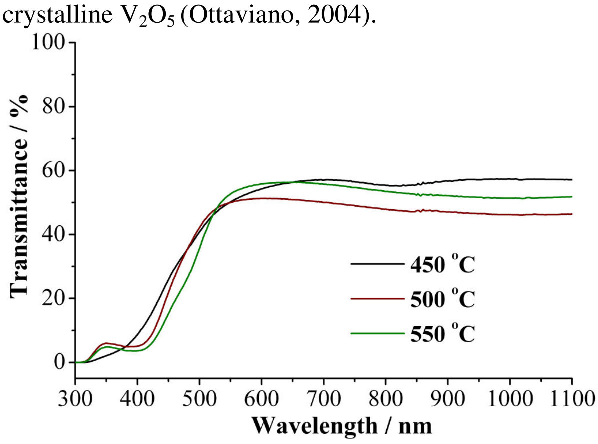

Figure 5. Transmission spectra of vanadium oxide films prepared at 450 °C, 500 °C and 550 °C for a gas precursor ratio of VCl_4:H_2O, 1:7.

In order to check the electrochemical stability of the vanadium oxide films as a function of gas precursor ratio and substrate temperature, voltammetric cycling was carried out, which was repeated 500 times per sample. Figure 6 shows the cyclic voltammogram of the film grown at 550 °C, using a scan rate of 10 mV/s and sweeping the potential from -0.5 V to +0.25 V and back. It can be observed that the current density increases from 1st to 200th cycle and shows no appearance of degradation after 200 cycles. This increase in current density may be associated with changes in the vanadium oxidation states when the electrode is kept in open circuit conditions (Menezes et. al., 2009). Hence, the electrode must be cycled in order to increase the amount of active redox sites. On the other hand a decrease by two degrees of magnitude of current density is evident after a smaller number of runs for samples prepared under different deposition parameters, indicating that the amount of incorporated charge was decreased during long-term cycling.

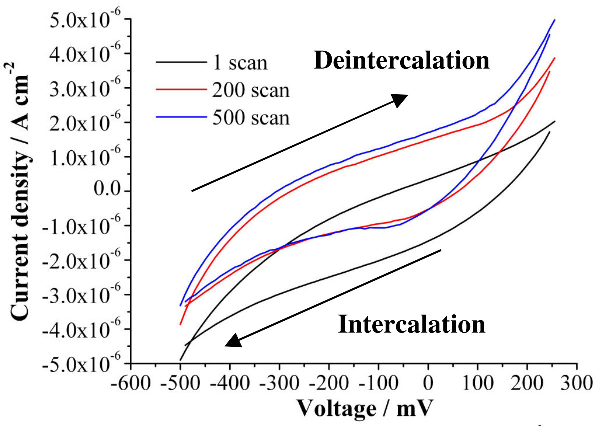

Figure 6. Cyclic voltammograms of the 1st, 200th and 500th cycle for the sample grown at 550 °C using a scan rate of 10 mV s^{-1}. Electrode active area was 1 cm^2.

It may be assumed that the vanadium oxide prepared under the particular conditions, exhibits greater channels allowing improved ion intercalation in comparison with the other films. However, the estimation of the roughness and the surface area ratio are under investigation to understand better the intercalation process of the APCVD grown samples.

To study Li ion intercalation, deintercalation process with respect to time, chronocoulometry was carried out for the grown sample at 550 °C at -0.5 V (intercalation process) and +0.25 V (deintercalation process), for a step of 10 s as shown in Figure 7. For long term measurement, the intercalated charge density increased from 5.1 x 10^{-5} C cm^{-2} for the 1st cycle to 5.44 x 10^{-5} C cm^{-2} for the 200th cycle and finally to 5.68 x 10^{-5} C cm^{-2} for the 500th cycles. For the 1st and 200th cycle, the intercalated/deintercalated charge ratio was about 1.0; showing that the process was reversible, while for the 500th cycle was about 0.8.

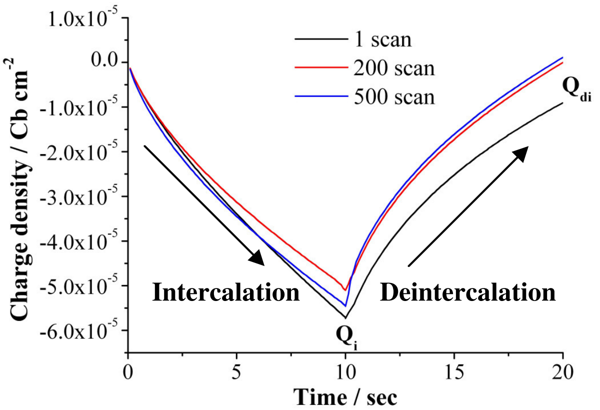

Figure 7. The chronocoulometric response recorded at a potential step of -0.5 V and +0.25 V for a time step of 10 s in 1 M $LiClO_4$ / polypropylene carbonate as an electrolyte for the vanadium oxide sample grown at 550 °C.

6. Conclusions

Vanadium oxide thin films were grown using an APCVD reactor varying the substrate temperature and the gas precursor ratio. Substrate temperatures of 550 °C presented enhanced electrochemical response, which is repeatable after 200 cycles. We suggest that this is related to the columnar structure of the film, which favours the intercalation, deintercalation of small ions such as Li. The capability to control the oxidation phase and properties of the films by altering the growth parameters may be significant for the production of smart windows and related applications.

7. Acknowledgements

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The influence of design methodology on the energy recourses economy

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Abstract:A new specialty has been introduced at the Siberian Federal University. It is named "Building Design". It is very important to give students the knowledge of problems,which are connected with the severe climate of Siberia. It is concerned witheconomic, ecological, energy, healthy and many other problems.

Severeclimate makes the economy of energy recourses too difficult. But it is necessary to solve the problem because only this way could bring Siberia to good ecological and economy situation.

Energy saving can be reached by increasing heat transfer resistance.But comfortable conditions for people could not be reached without good air exchange, which requires more energy resources.

Nowadays a new system of building regulation has appeared. Self–regulation organizations are to solve the complex problem. Saving of health, life, property,cultural values and ecology is their responsibility.

It is necessary to give engineers the knowledge of technical solutions, economic and ecological situation because energy economy must not prevent human's health.

Keywords: energyeconomy, building design, human's health

1. Building thermal protection. The economy of energy resources is an important problem of our days. Not so long ago solving this problem became an actual process in Russian civil engineering. The field of building is very wide. Many interests are meeting here. The building process includes wonderful works of architects, building industry and building sites. Many people work here: investors, designers, builders. They solve many economic and law problems in their work. The results of it are the new buildings, which are to be comfortable for people.

The economy of energetic resources is very difficult in Siberia. Continental climate gives very hot summer days (about + 40^{o} C) and very cold winter (about - 40^{o} C). The key role in solving this problem in the building process is played by a designer, because he is the one, who sees all the aspects of the task. He must solve multicriterionoptimization problem to make new building safe, comfortable and ecological in a low price. Designers know methods of decreasing energy usage by compactness of buildings, new systems of heating and air conditioning. But the most important and effective method is the increasing of heat transfer resistance, because it prevents the severe climate of Siberia influence on characteristics of internal environment.

New building regulations for heat transfer resistance appeared 10 years ago in Russia. Many structural decisions have been worked out during this period. They include various combinations of structural materialsand elements. Now we can say that we can solve the problem of decreasing energy use byincreasing heat transfer resistance. But many other problems appeared.

Often new technical decisions do not satisfy the requirements of longevity and ecological safety. It is better for the cost of wall when structure and worming functions are combined. But now often we can seewall construction which has warm cover in it.As usual longevity of structural materials is bigger than of warmer ones. We have no natural warm and strong materials. Synthetic materials, made on the base of brick earth and glass (foam glass) take much energy for preparing. But they are warm, strong and durable. For example, red brick can live for 500 years, but Rockwool and Styrofoam not more than 25 years. So those wall constructions are to be reconstructed very often. It will take energy resources. And it is very important, that these variants of wall structure are not good for human's health because they prevent natural air exchange.

The traditions of civil engineeringphysics recommends to make multi-layer wall structures with the position of bigger thermal conductivity layers to warm site of the wall. Besides facade systems look better because they are easier for reconstruction.

Normative documents in the area of civil engineering physics regulate some characteristics of functioning building, but they do not touch the field of building industry and building sites. Everybody knows that economic evaluation of the building, for example, must be complex and includesinvestment and exploitation costs. Ecological normative documents for building do not touch building material industry, utilization of old building constructions and many other interesting aspects. So the analysis of energy resources use must include the process of materials preparing, building constructing, exploitation and utilization of old buildings. There is a difficulty in walling design: the most ecological walls with a good heat transfer resistance have big cost and took much energy for their preparing. It is almost impossible to solve the complex problem because the investors want to have buildings of low cost, construction organizations want to decrease construction deadline, exploitation organizations want to have low cost and little quantity of energy use and people want comfortable conditions of internal environment. But comfortable conditions for people could not be reached without good air exchange, which requires more energy resources.

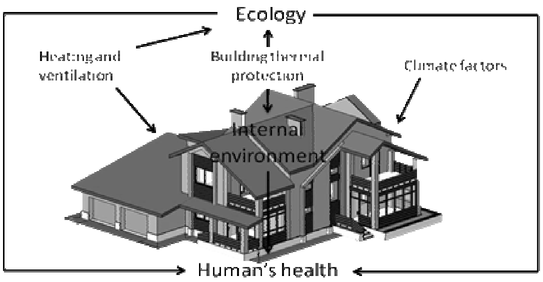


Figure 1. Interconnection of problems.

Nowadays a new system of building regulation has appeared. Self–regulation organizations are to solve the complex problem. Saving of health, life, property, cultural values and ecology is their responsibility. Self–regulation organizationsare divided into design and construction. Design organizations are to solve the complex problem with decreasing labour-intensiveness of design process. They have the rights of making normative documents. It is very good that these documents can include regional specificity and compilemuch information and results which conflict sometimes with each other.

2. Design methodology. Designer's position. For example Siberian Federal University took part in working out the standard of heat transfer resistance design in civil engineering. It includes requirements of safe energetic effectiveness and economic advisability. This is the first step to solve the large complex problem. The choice of optimal level of heat transfer resistance in accordance to standard is based on space-and-planning decisions: minimum index of compactness; better orientation of the building to solar radiation; glass coverbalconies and loggias; light areas not more than it needs for the illumination and others; constructing decisions: usage of economy and durable materials and elements, special glasses, packagingof junctions; usage of effective systems of heating and ventilation, utilization of outputairheat.The standard covers designing thermal protection of new, reconstructed, overhauled heated residential and public buildings with specified temperature and atmospheric moisture capacity, which are built in the Krasnoyarsk Territory.

The standard doesn't cover:

- Portable (movable) residential houses, temporary buildings and structures which have been situated at the same place more than two heating seasons;
- Greenhouses, hotbeds and refrigerated stores;
- Air bags, tents and pavilions;
- Buildings and structures which are heated seasonally no more than four months a year;
- Low-rise buildings, single-family wooden houses with area of heated premises more than 60 sq. m., single-room annex to these houses;

Using the present standard for buildings, which have architectural historic importance, is determined by harmonizationwith state control authorities of the protectionand usage of historic and cultural monuments of the Krasnoyarsk Territory in each case individually.

The standard is intended for improving energy performance of buildings by reducing total energy consumption in order to create thermal protection and support given characteristic of indoor microclimate.

The standard includes protection house requirements in theresult of safety, energy performance and economic reasonability.

Construction, redevelopment and overhaul of buildings should be implemented in order to provide with favorable conditions for live activity of tenants, safety, service life and fire safety of structures under the optimum relationship between capital investments and running costs on heating and ventilation.

Walling should possess the required strength, rigidity, stability, durability, meet common architectural, operational and sanitation requirements which correspond to construction regulations. In fabricated structures the special attention should be paid to strength, rigidity, durability and joint tightness.

The required extent of walling durability should be provided with using materials which possess proper resistance (cold resistance, humidity resistance, bioproofness, corrosion resistance, thermal resistance and other destructive effect of the environment), as well as appropriate constructive solutions providing in case of need with special protection of structure elements made of imperfect materials.

Walling should be designed with using materials and items which are field tested and made under the present standards.

Walling should be provided with small numbers of type and size of building elements and with opportunity of their interchangeability.

In structures with multilayer walling the layers with more thermal conduction and more vapor permeability resistance should be located on the warmer side.

On choosing materials for walling one should prefer local construction materials.

On designing buildings for improving degrees of fire resistance and reducing fire hazard of interior and exterior wall surfaces one should provide with coating made of noncombustible materials or plaster; as for protecting from moisture and precipitation impacts one should provide with waterproof painting chosen due to wall materials and application conditions.

In the case of applying combustible materials in walling the window and door openings should be framed with strips made of incombustible heat insulation materials which are authorized by State fire inspection.

Walling contacting with ground should be protected by means of moisture proofing.

Durability of heat insulating structures shouldn't be less than 25 years, durability of interchanged compactors – not less than 15 years.

2.1. Safety specifications

In designed buildings in order to provide safety for people's health the following sanitary requirements should be observed:

- Optimal parameters of microclimate in the residential and public buildings stated in Tables 1 and 2,
- Rated differentials between inside temperature and that of interior walling surface,
- Rated air exchange multiplicity stated in Table 3.

Table 1

Optimal and acceptable temperature rate, relative humidity and dew-point temperature in residential buildings

Premises	Air temerature,°C		Net temperature, °C		Relative humidity, %		Dew-point tempera-ture, °C	
	Optimal	Acceptable	Optimal	Acceptable	Optimal	Acceptable		
Living room	21-23	20-24	20-22	19-23	45-30	60	12,4	
Kitchen	19-21	18-26	18-20	17-25	-*	-	-	
Toilet	19-21	18-26	18-20	17-25	-	-	-	
Bath-room	24-26	18-26	23-27	17-26	-	-	-	
Inside corridor	18-20	16-22	17-19	15-21	45-30	60	11,2	
Ante-roomstaircase	16-18	14-20	15-17	13-19	-	-	-	

Table 2

Optimal and acceptable temperature rate, relative humidity and dew-point temperature in public buildings

Premises or category	Air temperature t_{int}, °C	Net temperature t_{su}, °C	Relative humidity φ_{int}, %	Dew-point temperature t_d, °C
The first category	20 - 22	19 – 20	45 - 30	8,4
2	19 –21	18 – 20	45 - 30	7,8
3 а	20 – 21	19 – 20	45 - 30	8,0
б	14 - 16	13 – 15	45 - 30	4,0
3 в	18 - 20	17 – 20	45 - 30	6,8
4	17 – 19	16 – 18	45 - 30	5,8
5	20 – 22	19 – 21	45 - 30	8,4
6	16 – 18	15 – 17	-	-
Bathroom and shower	24 - 26	23 - 25	-	-
Group cloakroom and toilet: for crèche and junior groups	21 - 23	20 - 22	45 - 30	12,4
Pre-school group	19 - 21	18 - 20	45 - 30	10,4
Bedroom for crèche and junior group	20 - 22	19 - 21	45 - 30	11,4
For pre-school group	19 - 21	18 - 22	45 – 30	10,4

Note:

People's position	category
Lying or sitting	1
Employed with knowledge work	2
Being at sitting position without outdoor clothes	3 а
Being at sitting position with outdoor clothes	3 б
Being at standing position with outdoor clothes	3 в
Employed with active kinds of sport	4
Half-dressed (cloakrooms, doctor's rooms, etc.)	5
Temporary staying (entrance hall, corridors, staircases, etc.)	6

Table 3

Rated repetition factor of air exchange at building premises

Building function	Amount of incoming air, m^3 /h
Residential building	30 m
Lecture rooms, classrooms	16 n
Offices and service maintenance	4 A_l
Public health institutions	5 A_l
Sport facilities, entertainment centres, pre-school institutions	6 A_l

Where m is a number of tenants in a flat;

n is a number of students in a lecture room (a classroom)

A_l is a calculated area of premises.

We should say that air exchange is not useful every time. For example: smoke in Moscow this summer or dirty air of industry cities.

2.2. Energy performance

The level of thermal protection of the designed building should be compiled with modern requirements of energy performance.

Energy performance is determined with high thermal protection qualities of walling and with efficiency of support system of rated microclimate parameters in the premises.

Energy performance evaluation of the building should be done by means of comparing the specified values of the discharge intensity of thermal energy on heating and ventilation, as well as the compactness factor and the facade glazing factor.

Table 4

Specified values of discharge intensity of thermal energy on heating and ventilation

Types of buildings	q_h^{req}, kJ/m$^3 \cdot {}^oC$ per a day.
Residential buildings with the height	
1 – 5 storeys	35-40
6 – 9 storeys	30-35
10 – 16 storeys	25-30
More than 17 storeys	20-25
Public buildings with the height	
1 – 2 storeys	30-35
3 – 5 storeys	25-30
More than 6 storeys	20-25
Hall type industrial buildings	15-30

The calculation of the discharge intensity of thermal energy on heating and ventilation q_h^{req}should by applied according to heating norms.

The calculation of the suggested value of reduced total thermal resistance of walling used in the calculation of the discharge intensity of thermal energy on heating and ventilation is assumed to determine by the formula

$R_{req} = R_o/r$, (1)

where R_o is the total thermal resistance;

r is the uniformity heat engineering coefficient.

The compactness factor of residential buildings k_e^{des} should be defined by the formula

$k_e^{des} = A_e^{sum}/ V_h$, (2)

where A_e^{sum} is the total area of the inner surface of exterior walling including the overstorey overlap and the heated lower storey overlap, sq.m.

V_h is the heated volume of the building limited by inner surfaces of exterior walling.

The rated compactness index of residential buildings k_e^{des} shouldn't exceed values stated in Table 5.

Table 5

The suggested values of the compactness index of residential buildings

Number of storeys	Index k_e^{des}	Number of storeys	Index k_e^{des}
16 and more	0,25	4 – block.	0,46
10 ÷ 15	0,29	3 – block.	0,54
6÷ 9	0,32	2 – block.	0, 61
5	0,36	1÷2mansard.	0,9
4	0,43	1	1,1
3	0,54		

The facade glazing index (ratio of the transparent walling area to the total facade area) shouldn't exceed 18% for residential buildings and 25% for public buildings.

2.3. Economic reasonability

The level of thermal protection of the building recommended for using and satisfied safety requirements and energy performance should meet the economic reasonability requirements.

The economically reasonable level of thermal protection of the building should provide the lump-sum costs recoupment connected with improving the thermal protection level of the basic version. The costs recoupment period connected with improving the thermal protection level should be defined by the formula

$T = t + K/(L_б – L_n) \cdot [(1+ e)/(1+E)]$, (3)

where K is the capital investment volume connected with improving the thermal protection level of the basic version, rubles.

$L_б$ is a magnitude of running costs for supporting rated parameters of the microclimate under the basic version, rubles per year, defined by the formula…

L_n is a magnitude of running costs for supporting rated parameters of the microclimate under the given version;

e is a predictive magnitude of annual growth power rate;

E is a rate of discounting;

T is a service life (stated by the customer), a year;

t is a number of the current year.

The magnitude of annual running costs L for supporting rated parameters of the building microclimate should be defined by the formula

$L = 0,28\, c_e \cdot Q_h^y$, (4)

where c_e is the rate cost of thermal energy according to the selected heating source, rubles per kilo joule per hour;

Q_h^y is thermal energy consumption (micro joule) on heating and ventilation of the building during the heating period.

The choice of the optimal version of the building thermal protection should be done by comparing economic indicators of alternative versions for space-and-planning and constructive building solutions taking into consideration the costs on heating and ventilation systems.

The reduced costs M including the lump-sum cost and the current cost taking into consideration the rate of discounting and the predictive growth power rate during the rated operating life should be used as an indicator

$M = K+ L\, [(1+ e)/(1+E)] \cdot (T- t)$, (5)

The optimal version for space-and-planning and constructive building solutions taking into consideration the costs on heating and ventilation systems should be that meeting the condition

$(C2 - C1) \le (F1- F2) \cdot T$ (6),

where $C1$ and $C2$ are costs of basic and given versions of walling, rubles per sq.m.;

F1 and *F2* are the thermal loss (kilowatt per hour per sq.m a year) via walling according to basic and given versions defined by the formula

$F = 0{,}024\ c_e \cdot D_d / R_o$, (7)

where c_e is the same as in the formula4;

D_d is degree per a day during the heating period ,°C·a day;

R_o is the reduced total thermal resistance of walling , $m^{2o}C$ per watt;

T is the operating period of walling, a year.

The degree per a day of the heating period should be defined by the formula

$D_d = (t_{int} - t_{ht})\ z_{ht}$ (8)

where t_{int} is taken from Table 1 and 2;

$t_{ht} z_{ht}$ –is an average temperature of outside air, ^oC, and duration, a day, during the heating period.

2.4. Choice procedure of the optimal level of thermal protection

1. The choice of the optimal level of thermal protection is done according the types of walling and type of the building.
2. Choosing the optimal structure of walling according to the thermal protection conditions is considered by the following order:
    - Select the competitive walling structure variant;
    - Specify the estimated climatic parameters for the construction site;
    - Specify the estimated microclimate parameters of the building according Table 1 and 2;
    - Define the quantity of degree per a day during the heating period;
    - Calculate the value of the reduced total thermal resistance for the walling versions compared;
    - Define the economic reasonability solution for walling;
    - The optimal version of wall structure should be of the minimum value.
3. Choosing the optimal version of the building according the thermal protection conditions is considered by the following order:
    - Design versions for space-and-planning building solutions, heating and ventilation systems using the walling calculation results;
    - Define economic parameters of the building by the trial method (version by version) according to requirements;
    - Define characteristics of the reduced costs of different building structures and compare these characteristics;
    - The building structure which has a minimum value of the reduced costs among alternative variants is considered as the optimal one.

Now the standard does not include the analysis of the process before and after the exploitation of the building, and it does not touch the process of building reconstruction (as it was said above, those processes took energy and have influence on ecological situation).

Very new self–regulation organizations appeared this time. Their task is building examine to energy requirements. The main defect of this system is an absence of ecology aspect.

3. Student's study. The most important task is to teach students to make technical decisions based on good knowledge of situation and normative documents. A new specialty has been introduced at the Siberian Federal University. It is named "Building Design". Professors tried to give students the knowledge of problems, which are connected with the severe climate of Siberia. It is concerned with economic, ecological, energy, healthy and many other problems.Study process includes architecture, heating and ventilation, structural design and other projects. The complex work is done only in the diploma paper. Students make energy performance certificate of the building, which shows the quantity of energy for exploitation needs, but does not touch the ecology problems. The main difficulties are tosolving complex problem in practice.

This year we tried to make this task for research student's work. This work for a comparison of wall constructions on the base of energy and ecology problems helps students to realize the situation. For example students know the differences between old and new regulations.

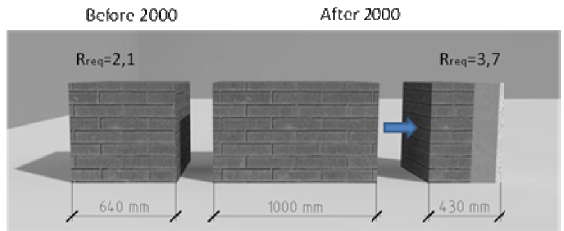


Figure 2. New requirements.

They took into comparison five variants of the wall and tried to find the best one.

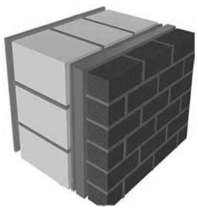


Figure 3. The 1st wall's structure

First wall consists of tree layers: red brick, Styrofoam and foam concrete. Foam concrete is made of sand, lime, cement and aluminum powder. It is not toxic. It is durable and fireproof (3-7 hours). It has good frost-resisting (about 200 cycles) due to air bubbles, where ice and water could take place. Styrofoam consists from air for 98%. Its thermal conductivity is very low. Combinations with other materials are to be done make a good fireproof. Red brick layer is the facade one.

Figure 4. The 2nd wall's structure

Second wall variant consists of red brick Rockwool and facade system. This wall structure presents the variant of ventilated facade system, which prevents climatic effect. The layers are divided due to their functions: warm, waterproof, fireproof, soundproofing and other. It allows executing all requirements in optimal way.

Third wall variant consists of red brick, Rockwool and Stucco. Rockwool has good fireproof resistant, stability in aggressive atmosphere and very good thermal protection characteristics. Physical characteristics do not depends upon atmospheres ones. Furthermore, Rockwool helps to make soundproof protection and does not prevent ventilation through the facade surface.

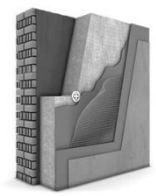


Figure 5. The 3rd wall's structure

Fourth wall variant is the complex lightweight concrete panel with Styrofoam layer inside. Concrete has a low cost and long life. The most difficulties are closely related with "bridge of cold" because of ties between facade and internal lairs. Moreover there are many difficulties in contact construction.

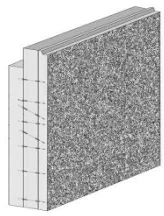
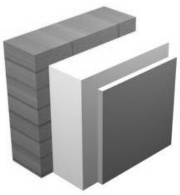


Figure 6. The 4th wall's structure



The fifth variant consists of red brick aerocrete and plasterboard. Red brick layer is the facade one. Aerocrete is made at the building yard. Plasterboard makes good internal surface. This variant has difficulties in winter building.

The comparison of variants shows the actual differences. It looks very difficult to choose the best variant because the criterions are not determined. But it is more interesting to determine them.

Figure 7. The 5th wall's structure

Table 6

Comparison of calculated thicknesses of insulation

Struc-ture of the wall	Foam con-crete, Styrofoam, brick	Brick, aero Crete, Gypsum plasterboard		Brick, Mineral wool, Stucco		Brick, Mineral wool, hinged facade		Expanded clay light-weight concrete, panel
		380 mm	510 mm	510 mm	640 mm	510 mm	640 mm	
Thickness of the insulation, mm	130	430	410	130	120	150	140	250

Table 7

Comparison of calculated specific consumption of thermal energy for heating buildings

Structure of the wall	Foam conc-rete, Styro-foam, brick	Brick, Mineral wool, hinged facade	Brick, Mineral wool, Stucco	Expan-ded clay light-weight concrete, panel	Brick, aero crete, Gypsum plasterboard
Calculated specific consumption of thermal energy for heating buildings (kJ/(m^2·°C ×day)	67,39	68,94	70,24	67,0	67,39

Table 8

Comparison of the longevity of wall's structures

Structure of the wall	Foam conc-rete, Styro-foam, brick	Brick, aero crete, Gypsum plasterboard	Brick, Mineral wool, Stucco	Brick, Mineral wool, hinged facade	Expan-ded clay light-weight concrete, panel
Longe-vity, years	150	150	125	125	100
Before the over-haul, years	50	50	15-25	20	50

4. Conclusion. In the field of building design we have to investigate energy saving together with the issues of safety, ecology, people's health and economy.

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USE EFFICIENCY: A First Level Audit Analysis of Selected University Buildings from 9 EU Countries

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Abstract: USE EFFICIENCY is a European Project under the Intelligent Energy Europe II Program. It involves 13 partners from 10 EU countries. Its overall aim is to improve energy performance in University buildings and in this context establish training programmes for University students with a practical approach. Students are the main actors within the project. They will learn about energy efficiency in a close cooperation and interaction with professors and technical experts. The training programmes will be developed in relation to specific case studies focusing on improvement of University buildings at the 9 participating universities, with an active involvement of students in the analysis work. Prior to more detailed analyses at the universities (second level audit) a first level audit has been carried out aiming at an overview of state-of-the-art at the Universities.

Scope of this paper is to present the results of this first level audit analysis of the energy performance of selected University buildings from the 9 University partners. The rationale of the general approach is explained and the methodology followed during the first level audit is analysed. For the sake of simplification of data collection and for the compatibility of the results between partners, the Operational Rating approach has been selected. The results are presented in proper graphs, with the values corrected according to the national climate factors, showing for example the area-specific final energy consumption related to the benchmarks of national energy ordinances – the final energy consumption index for heating and electrical energy consumption- of the selected buildings of all universities.

Keywords: Energy Audits, Energy Efficiency, Public Buildings, University Buildings.

8. Introduction

Since the adoption of the European Energy Performance Directive (EPBD-2002) by the European Union (EU), a large number of projects were funded by the EU, aiming to reinforce and support the implementation of this directive. Many projects were funded under the Intelligent Energy Europe (IEE) I and II programmes, which had a wide diversity of actions and ideas. The IEE is the EU's funding tool to improve untapped opportunities in energy saving and encourage the spreading of Renewable Energy Sources (RES) in Europe, which are often not aided by the market conditions.

Several of the previously funded projects under the IEE programme, dealt with education in energy matters (e.g. CHECK IT OUT!-2006, PEES, 2006, FLICK OF THE SWITCH 2007) while others focused on improving energy efficiency in buildings and RES.

USE Efficiency (2009), is a project involving 13 partners from 10 EU countries. It intends to create a common stream for energy efficiency in University buildings. While focusing on training of University students, it aims to improve in long term the energy efficiency and performance of University buildings. Both Universities and students could act as "shining examples" for energy efficiency solutions and behaviour. Engineering students are the future market players-professional engineers and are the main actors of the project. They will learn about energy efficiency through specialized training programmes developed by the partners. These programmes will be based on actual case studies of University buildings that the students spend much of their time in them. Thus, a clear practical approach is adopted, which is identified as a key for the success of a training program (R.A. Cramer, 2007). Also, the diversity of functions in a University building is a crucial factor that influences its energy consumption (Wong et al, 2005), which makes an energy audit of such a building a demanding task. Students will perform energy audits on selected University buildings, aided by professors and technical experts, and will be actively involved in the analysis work. These case studies will focus on the improvement of the energy performance of the University buildings.

The detailed work to be done with the active involvement of students is the core of the project and is named as "second level audit". Prior to that, a less detailed audit, named "first level audit", has been carried out, in order to suitably identify the "critical" buildings that will act as case studies for the second level audit. Furthermore, 9 University partners from different EU countries exist and, consequently, a review of the current situation in terms of energy management and policies in all participating Universities was necessary.

In relation to the second level audit, students will attend a training course on energy issues, audit procedures, and EPBD requirements. They will be invited to present their contributions in energy efficiency improvement and the best projects will be selected for a summer school where they will meet and interact with students from other countries.

USE Efficiency focuses on the consideration of the EPBD requirements concerning energy performance of existing University buildings and on the development of student courses in due consideration of these requirements. Thus, students are also expected to learn how to apply energy performance assessment (EPA) in energy consulting of complex University buildings.

In this context the EPBD Recast (2010) is worth noticing, and which was formally approved by the European Parliament recently. The revision marks a significant leap forward for Europe in tackling energy use, particularly in new buildings. The next step is to look at how to create incentives in the existing buildings. Thus, the EPBD Recast prescribes that all new buildings across Europe must be built to a very low energy standard by 2021. It also mandates that energy efficiency measures must be taken when an existing building undergoes any type of major renovation. Furthermore, technical building systems will have to meet minimum energy performance requirements when replaced. The 1000m² thresholds will be removed. Thus, refurbishment requirements will cover almost all buildings.

The proposal for an EPBD recast was part of the European Commission's wide-ranging energy efficiency package of November 2008, which gives a new boost to energy security in Europe, supporting the 20-20-20 climate change. Buildings consume 40% of Europe's energy, and energy efficiency in buildings represents the most cost effective potential for emission reductions. Clearly there is a growing justification and political commitment to tackle energy efficiency in buildings and this requires moving swiftly towards very low-energy retrofit and passive design new build en mass.

While the political commitment will increase demand for wide-scale uptake of ambitious low-energy renovation, it is not apparent that the building industry and related value chains are sufficiently prepared to deliver the step change needed to meet it. The USE Efficiency project is one important step towards preparing the future market players for the future challenges.

9. Current Situation in participating Universities

During the first phase of the project, the current situation at the participating Universities was analyzed, focusing on the energy policies in place and the general condition of the buildings.

The Universities examined fall in 3 categories. Some Universities have an established energy policy, which requires periodical energy audit of all buildings and some have Display Energy Certificates (DECs) in place.

The construction of the buildings varies, with most universities having many buildings before 2000 and few new buildings constructed after 2000.

The most important observations facts for each University are summarized below:

a. University of Rome Tor Vergata (UNITOV) comprises many buildings distributed over a large campus. Energy Monitoring started in 1997 with the establishment of the Energy Manager and a three year monitoring started in 1998. An action plan was established in 2002, comprising of evaluation of energy tariffs and better management of existing plants plus operation of the buildings (e.g. set point temperature). In 2004, an external contractor was appointed to carry out energy audits and implementation of energy efficiency recommendations. There are discussions on an agreement of sharing money saved from energy efficiency measures between the 'energy service' company and the University. During 2010 most buildings acquired a DEC.

b. Brunel University (UNBRUN) campus is located on the outskirts of London. It is one of the very few campus-based Universities in London. The buildings comprise a variety of constructions periods from 1960s, then 1990s and then 2002 to today. Brunel University has established an environmental policy with the aim to manage its activities, buildings and estates in a way which promotes environmental sustainability. Energy management is included in this policy and the University has an Energy and Sustainability Manager. Energy saving initiatives 2008-2010 includes a programme of monitoring of gas and electricity to individual buildings, a remote data collection system which will improve the monitoring of consumption and allow for accurate building consumption targeting, and a Campus wide campaign to Save Energy and raise awareness of Brunel's carbon footprint running since 2008/09. A DEC for the whole campus exists since January 2009 and for each individual building since 2010.

c. Vilnius Gediminas Technical University (VGTU) is the third largest University in Lithuania. The buildings of University are situated in overall Vilnius and are of different architecture style and year of construction. All buildings are older than 20 years and all are partially renovated. Each year the heat consumption diminishes about 10 %, because of the implemented retrofitting such as new windows, insulation, heat substations with demand control systems. In 2003, VGTU set up a strategic planning group. Its implementation and operation includes a division of energy and building maintenance and operation service. Since 2009, several buildings have DECs.

d. Dublin Institute of Technology (DIT) has developed an Energy Management Programme similar to strategic energy management programme frameworks proposed by Sustainable Energy Ireland (SEI) and Energy Star (U.S.). This includes a number of steps:

- *Get Commitment- Through Leading by Example* under which a number of strategic steps were implemented which resulted to a 30% energy savings.
- *Identify & Understand* under which comprehensive energy audits and surveys for all the main colleges were carried out. The building rating poster originally developed is similar to the SEI's DEC.
- *Plan and Organise* under which an energy committee was established and a chairman was appointed. Energy management structure, reporting and responsibilities were established. An energy policy provides the framework and template for continuously improving energy efficiency in the DIT and is reviewed and assessed periodically. The energy policy provides a number of categorised objectives to ensure energy use is controlled, energy efficiency is continuously improved and long and short term goals are achieved.
- *Implement* Implementing the energy management programme has encompassed raising awareness, implementing energy projects and overcoming barriers to change and includes specific energy programmes.
- *Control and monitor* The energy programme and energy policy is reviewed / audited and updated annually providing an opportunity to reinvigorate the energy management campaign.

All buildings of the campus have official DECs.

e. HafenCity University Hamburg (HCU) is part of one of the biggest urban construction sites in Europe, but it is not built yet. It is temporarily located in a group of buildings in the City Nord district of Hamburg. Currently, there is no energy management in place. DECs are available for the buildings and are based on an Operational Rating (OR).

f. Aristotle University of Thessaloniki (AUTH) is the largest University in Greece. The main campus is located in the centre of the city and covers an area of approximately 430,000 m^2. In 1999 the AUTH Environmental Council was established aiming to enforce the role of the University in environmental matters. No energy management exists in the University. Only recently in 2009, a SCADA for the monitoring of thermal systems has been established, which resulted in significant reductions in thermal energy consumption. In 2010, a similar SCADA was installed to monitor electrical energy consumption in the University buildings. With the national Regulation for the Energy Performance of Buildings (KENAK) being just recently signed, there is no specific timetable to acquire DECs for the AUTH buildings.

g. The Universidad Politécnica de Valencia (UPVLC) is divided in 4 Campuses with the Vera Campus being the biggest and the main one. It is located to the north of the city of Valencia. UPVLC is implementing a monitoring system to increase savings in minimum 18% of the actual consumption. An energy team has been organised within the "Instituto de Ingeniería Energética"(IIE) to define the energy policy. Official DECs are not available yet.

h. The Engineering College of Aarhus (IHA) consists of 11 smaller and larger building parts, dating from different periods. In 2014 it will be relocated to a new building. Currently there is no stated Energy policy, mainly due to the relocating plans. No official DECs exist either.

10. First Level Audit Analysis

3.1 Rationale of the general Approach

USE Efficiency focuses on the consideration of the EPBD requirements concerning energy performance of existing University buildings and on the development of student courses in due consideration of these requirements. Students are also expected to be trained on the application of Energy Performance Assessment (EPA) in energy consulting of complex University buildings.

National transpositions of EPBD compliant EPA methods are different and each participating University will have to introduce to the students the national EPA procedures.

Within 1st level audit analysis the overall goal is to give a strong standardized methodology that may be used for all University buildings whenever required. The methodology has to be simple, clearly defined and transferable to similar situations like energy management in large building stocks. In particular, 2 out of a maximum of 6 buildings of the partners University campus are to be properly identified for further analysis in a 2nd level audit.

EPBD does not explicitly distinguish between different levels of audits. But energy performance certificates (EPC) have to be made available for existing buildings not only in the case of a major renovation but also, according to EPBD Art.7, when being sold or newly let. Par.3 of this article applies also to University buildings as being occupied by institutions providing public services to a large number of persons, i.e. an EPC is supposed to be visibly displayed to the public – DEC - irrespective of whether the building is going to be renovated or not. It is obvious that different levels of detail of EPCs are to be applied to different situations of the building. If it is undergoing a major renovation there is much more data on the building available than in case of signing a new rental contract.

Apart from EPBD, in energy consulting it is a common approach to the energy performance assessment of large building stocks to start with an operational rating of measured final energy consumption for many buildings, compare these data with national benchmarks and sort out critical buildings with comparatively high specific and/or absolute consumption values for further analysis.
This approach to the improvement of the energy performance of large building stocks was adopted as a guideline to 1st level audit analysis.

3.2 Specific Approach to the Analysis

Procedures for 1st level audit should be characterized by:

- Easily manageable data acquisition in large building stocks where, usually, detailed data on the individual buildings are scarce.
- Operating personnel can do it. No external experts should have to be involved.
- No on site inspection of individual buildings is necessary.

Therefore an approach was chosen that takes advantage of data collected anyway for reasons apart from this project namely for compliance with EPBD and its national transposition respectively.
Specifically concerning University buildings, DECs complying with EPBD Art.7-Par. 3 are supposed to be available or should be made available soon. Regardless of whether the national transposition of Art.7 has been based on an Asset Rating (AR) or an OR, legal standards or benchmarks were to be defined in order to compare and assess the energy performance of the buildings.

3.3 Operational Rating

For the sake of simplification of data collection and comparability between partners as the preferred approach towards 1st level audit analysis an OR was preferred. A typical OR procedure is outlined here specifying the basic steps and data needed.

3.3.1 Building data

General building data are required to describe type, main utilization and size of the building, such as:

- Location (ZIP code, climate zone)
- Year of construction
- Three main types of building utilization (e.g. office, laboratory, lecture hall, storage etc)
- Reference area, e.g. net floor area and conditioned net floor area, fraction of different building utilizations
- Number of storeys, rough sketch of building shape and floor plan

The following building characteristics help to assess the pure numbers of energy consumption

- Building envelope (i.e. type of façade, fraction of total window area, U-values etc)
- Technical installations (i.e. type of ventilation, air conditioning, fraction of conditioned net floor area etc)
- Current state of repair and year of latest major renovation of building envelope and main technical installations respectively

3.3.2 Energy data

While for electricity the metered values represent the direct energy consumption, thermal energy is metered as the amount of fuel consumed and needs to be converted to energy units via gross or net calorific values of the fuels. The following energy data are needed for an OR and should be available via the national DECs:

- Accounting period, time correction
- Measured consumption of electricity for the last 3 years
- Utilizations of electricity included in the measured values (i.e. lighting, ventilation, air conditioning, cooking, IT, elevators etc)
- Measured consumption of fuels for the last 3 years
- Utilizations of thermal energy included in the measured values (i.e. heating, hot water, absorption chillers etc)
- Energy generation in the building (cogeneration, solar thermal, PV, etc), measured production of the last 3 years

3.3.3 Weather correction

Typically, the heating fraction E_{VMH} of the measured thermal energy consumption E_{VM} is considered to be directly proportional to the ambient temperature during the accounting period. Usually the accounting period is one calendar year. Thus, it is corrected from actual weather conditions to long term mean values in order to rule out accidental biases in data assessment and comparison with benchmarks.
Most common is a degree day scheme for weather correction, degree days D being defined appropriately like

$$D_z = \sum_{n=1}^{z} (t_{m,room} - t_{m,amb,n}) \left[Kd \right] \text{, where:}$$

$t_{m,room}$ is the room mean room temperature in [°C], (usually 20°C for most utilizations)
$t_{m,amb,n}$ the mean ambient temperature on day n in [°C]
z the number of days [d] per accounting period with $t_{m,amb,n} > t_{Base}$
t_{Base} the heating limit temperature in [°C]
The correction itself is figured out via a rule of proportion calculation:

$$E_{VcH} = E_{VmH} \cdot \frac{D_m}{D}\left[\frac{kWh}{a}\right]$$, where:

E_{VcH} is the corrected heating energy consumption,
E_{VmH} the metered heating energy consumption in the accounting period,
D the degree days in the accounting period,
D_m the long term mean degree days.

3.3.4 Benchmarks
Benchmarks for operational rating schemes for building energy consumption are usually derived from statistics of many comparable buildings. Energy consumption benchmarks e_{comp} are differentiated according to typical building utilizations, weather corrected and related to some reference area and a standard accounting period of one calendar year.

3.3.5 Critical buildings
Buildings are considered to be critical for the sake of the USE Efficiency activities when some of the following criteria are fulfilled:

- Mean value of the weather corrected, area related energy consumption (e_c) of the last three years is considerably greater than national benchmarks ($e_c >> e_{comp}$).
- Very bad rating of the building energy consumption compared to national indicators or legal standards according to the national rating scheme.
- High absolute values of energy consumption, electricity as well as thermal energy.
- High consumption is not related to special secondary uses within the building (data centre, kitchen) or exceptional temporary conditions.
- Measures for considerable improvement of energy efficiency obvious or already proposed.
- Major renovation scheduled within reasonable time perspective.
- Building documentation is good enough for an EPA performed by students with a limited amount of time.
- No building specific metering is installed, but the building is assumed to not be energy efficient and to have a savings potential.

3.3.6 Special issues
German EPC and DEC procedures for existing public buildings consider the following special cases explicitly. We proposed to apply these solutions in other countries also in case that there has been no other national approach defined. We consider it important to include these problems in the student courses:

a. No building specific metering:
In case there is no metered energy consumption of a building but only of a property consisting of several buildings structures the operational rating may comprise the whole property. The benchmark to compare with is the weighted mean of the different buildings in particular when comprising different building utilizations. In that case the above mentioned building characteristics will be important to assess the results, in particular the organizational framework of building management becomes essential, and namely when is the next major renovation of the building up giving a chance to improve energy efficiency of the building.

b. Weather correction:
Only the heating fraction of the thermal energy consumption has to be corrected on a degree day basis. The thermal energy consumption for hot water generation has to be subtracted beforehand as a fixed percentage, or derived from hot water consumption. A good candidate for a first guess is the summer thermal energy consumption.
Electric energy consumption is not weather corrected due to multiple influences and lack of easily available weather data like average irradiation measurements. There is no consistent scheme of weather correction of cooling energy within a benchmarking, mainly because building properties would have to be considered necessarily. This is usually beyond the scope of benchmarking.

c. CHP integrated in the building:
Only heat and electrical energy consumed in the building should be considered.

d. Heat pumps:
The electrical energy to run heat pumps (as well as for direct electrical heating) is supposed to be compared with statistical benchmarks from conventional heating systems for the sake of simplicity. Heat pump systems will therefore be rated systematically better than conventional heating systems, the primary energy consumption in the process chain of electricity generation is being neglected. Therefore heat pump systems are to be identified clearly and to be assessed with additional thought.

e. District heating:
The question of where should losses in generation and distribution be considered, is important. Final energy consumption in the sense of the amount of energy delivered to the building limits does not include these losses. Corrections could be made in order to compare different supply systems correctly. Assumptions could be derived from DIN V 18599-5:2007.An efficiency of about 85% seems to be a plausible assumption.

f. District cooling:
In case the building is being supplied with cold water for cooling and air conditioning from centralized chillers, in Germany for the sake of simplicity, this amount of energy is added to the final energy for heating. Typical Energy Efficiency Ratios (EER) for compressor chillers or Rated Heat Ratios for absorption chillers as well as an overall rate of distribution losses of, (~15%) might be considered in the calculations. Assumptions could be derived from DIN V 18599-7:2007.

g. Building let to different tenants:
Metering of electrical energy consumption may be difficult to get from all tenants. In that case approximately 70% of the data records (a data record

being the electrical energy consumption of a rental unit for 12 consecutive months) may suffice to figure out specific values of electrical energy consumption.
Overall, to implement all these potential corrections makes sense from a technical point of view. From an organizational point of view this requires quite an amount of data to be collected. For some of these issues practical solutions have been applied introducing some simplifications for the 1st level analysis and leaving the detailed analysis to the 2nd level audit.

11. Results of the 1st level audit analysis

4.1 Documents
In the 1st level audit analysis all Universities reported the following:
a. All partners documented the national DEC-procedure, provided or generated DECs for most of the selected buildings with the national tools to be used in their countries, analyzed the data and assessed them according to the national benchmarks.
b. Furthermore the partners documented building data of the selected buildings in a Common Evaluation Data Structure derived from the DATAMINE project to allow for an overall data analysis.
c. Each partner documented the characteristics of all selected buildings in a 1st level audit report
d. The specific approach to select 2 buildings out of a maximum of 6 buildings selected for analysis was documented in a List of Critical Buildings.
e. Compendium of 1st level audit analysis.

4.2 Data Analysis
Some of the energy data of the buildings were analyzed and compared across countries.
In Figure 1 the area-specific final energy consumption of all selected buildings across all countries are compared. In this graph, heating energy is on the x-axis and electricity on the y-axis.

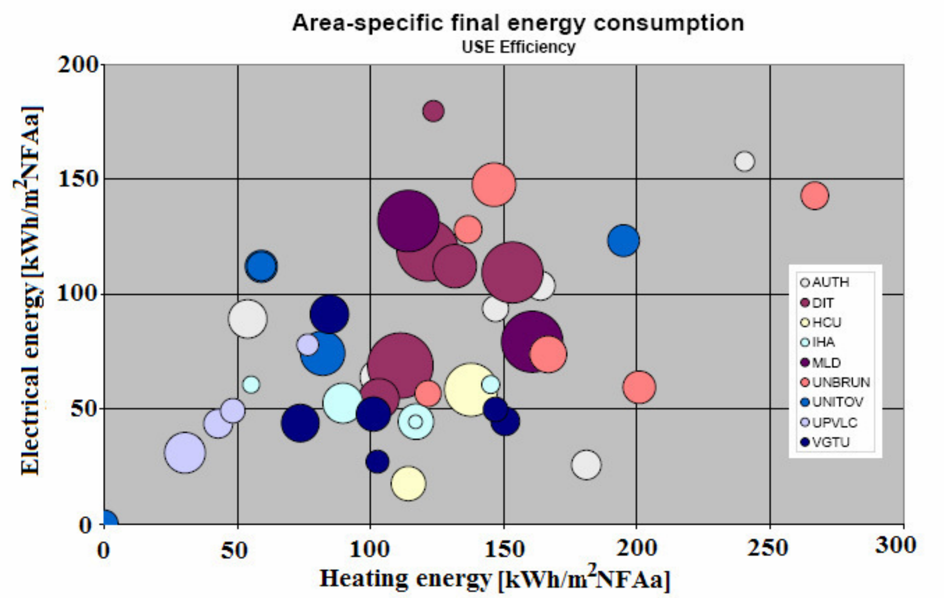

Figure 1: *Area-specific final energy consumption of the selected buildings of all universities within 1st level audit analysis.*

The values were weather corrected with the national climate factors to a long term mean weather. They have not been differentiated with respect to building utilization, thus office buildings are compared to auditoriums, laboratories etc. This is obviously difficult to compare and further data elaboration is appropriate. As a third dimension the building area is represented by the area of the bubbles in order to have an estimation of the importance of the building with respect to the total amount of final energy consumed and paid for.
Volume-specific data, shown in Figure 2, were available only from 4 Universities. But still the difference in building utilization is supposed to be the main reason for a wide spread “cloud” of the values.
In Figure 3 only indexes are displayed, defined as the ratio of the weather corrected, area related energy consumption e_c of the last year over the national benchmark e_{comp}. An index value of 100% equals to the corresponding national benchmark. Depending on how well differentiated the national benchmark scheme is with respect to building utilization, the better the data allow to compare different building utilizations and to raw conclusions regarding the real energy performance of the building.
Of course in the national comparison it is obvious that benchmarks in Ireland seem to be easier to meet than those in Greece or Italy for example.
Finally, Figure 4 contains the building area as additional information, represented by the bubble area.

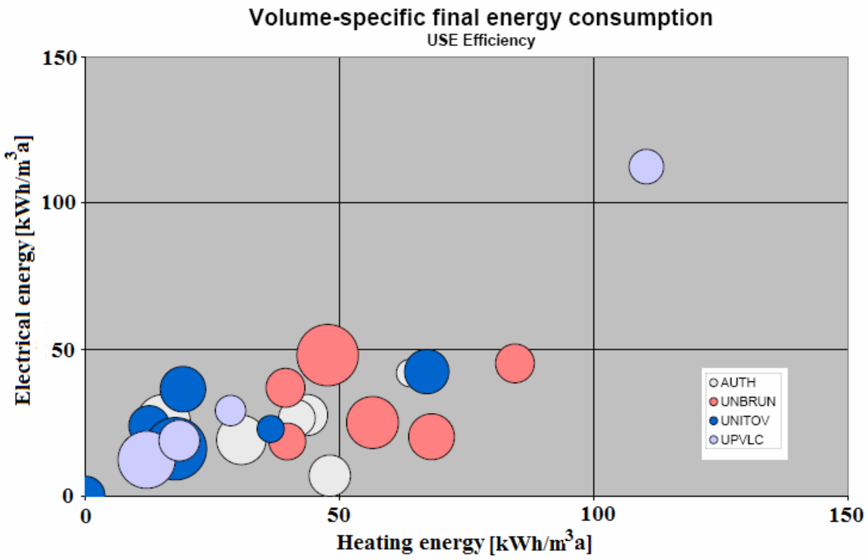

Figure 2: *Volume-specific final energy consumption of the selected buildings of universities within 1st level audit analysis.*

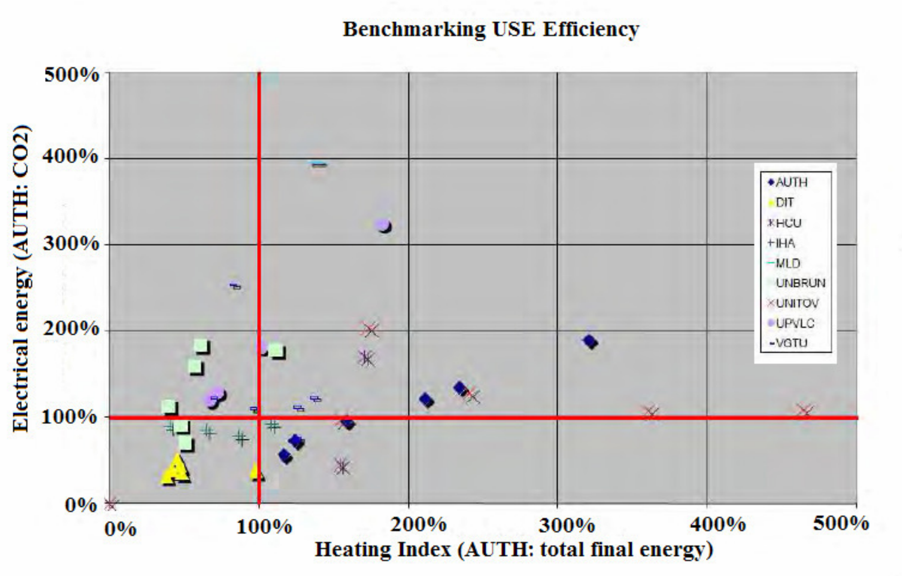

Figure 3: *Benchmarking analysis of the selected building of all universities within 1st level audit analysis.*

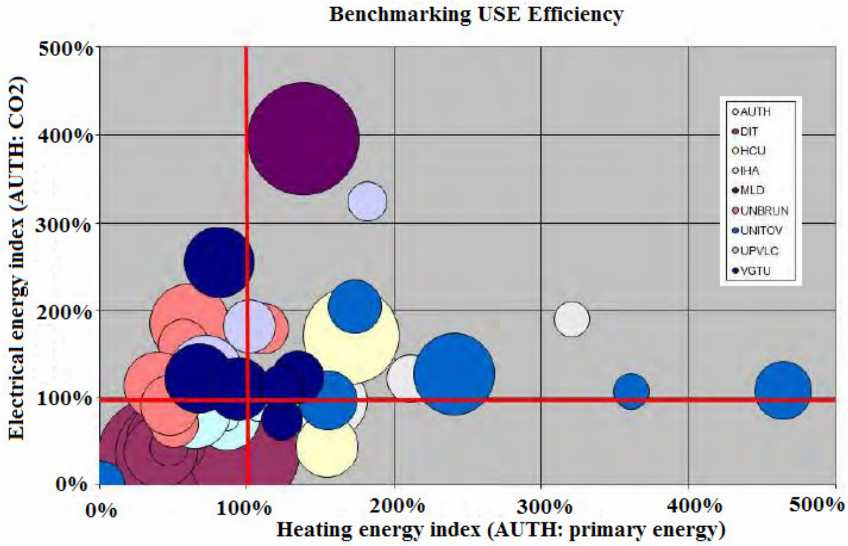

Figure 4: *Benchmarking analysis of the selected building of all universities within 1st level audit analysis with additional information on the size of the building (The size of the bubbles is proportional to the national reference area.).*

4.3 Remarks

4.3.1 Data Analysis

Problems with the data that occurred are well known from other benchmarking projects. Some problems result from a lack of correct data:

- Building areas and building specific logging data to figure out specific energy consumption values are not always available for individual buildings. In such cases assumptions have to be made.
- National benchmarks comparable with the category of the actual building are not always available, particularly in cases with multiple utilizations within one building.
- Weather data for correction may not always be available, particularly in countries where an OR is not mandatory.
- If these problems have been overruled some specific values are high, some are implausibly high. Possible reasons:
  - Procedural problems like incorrect readings from energy meters, inaccurate area values, incompatible weather data.
  - Real problems with the building envelope, inefficient mechanical or electrical installations or flawed building regulation systems that caused high energy consumption.

These questions are the starting point for further analysis within 2nd level audit analysis.

4.3.2 Student Training Courses

This typical approach to the improvement of the energy performance in large building stocks as performed in USE Efficiency and particularly in 1st level audit analysis will be part of the student training courses. These courses are scheduled prior to the 2nd level audit analysis, which would constitute a type of practical experience. Main points would be:

- An Operational Rating (OR) as a first step to identify buildings with a critical energy performance should be explained.

- The special issues related to Benchmarking should be discussed.

- The above mentioned typical difficulties in the analysis of consumption data are to be addressed.

- Students should perform a Benchmarking on their campus together with the building operation personnel.

- Students should be introduced to the process of the selection of critical buildings.

12. Conclusions

The scope, the targets and up to date actions of the Intelligent Energy Europe USE Efficiency project have been presented in this paper. The overall aim of the project is to improve energy performance in University buildings involving University students as main actors. The current situation in the participating Universities regarding energy management and energy policies was analysed. The results clearly show that a great diversity exists in European Universities in terms of energy management and policies, some having clear structure, goals and results and others being at a very primitive level.

The actions of the project included a first level audit of several buildings from the 9 participating Universities. This focused on establishing the state-of-the-art at the Universities and on the selection of two buildings per University for a detailed second level audit. A simple and transferable methodology for the 1st level audit was described that may be used in similar situations of energy management in large building stocks.

The results presented here, showed that Universities with established energy management programmes have a significant overall better energy performance.

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