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MEASURING AND IMPROVING ENERGY EFFICIENCY INDICATORS FOR A GREENER ROMANIA

Abstract. *Increasing energy demand, the current problems of global climate change and the interaction of political and economic interests in the energy markets determine governments, researchers and professionals to be more aware of energy use. The European Union established the ambitious objective for the year 2020 to lower energy consumption by 20%, improving energy efficiency.*

Energy efficiency indicators are considered an essential instrument to design and support effective energy efficiency policies. International and national databases are aimed at monitoring energy efficiency trends through various indicators. This study proposes smart metering technology as an important technological innovation to monitor energy consumption and to improve energy efficiency.

Keywords: *energy efficiency, energy databases, smart metering.*

JEL Classification: A1, L94, L97, O30, Q43

1. Introduction

Energy plays a fundamental role in defining human condition. It is said that the standard of living and the quality of civilization are proportional to the amount of energy that society uses, energy leveraging the development of all business segments of society.

According to the Energy Information Administration's international report, global energy consumption will increase around 50% by 2035. Total energy consumption will increase from 505 quadrillions Btu in 2008 to 619 quadrillions Btu in 2020 and 770 in 2035 (**Figure 1**).

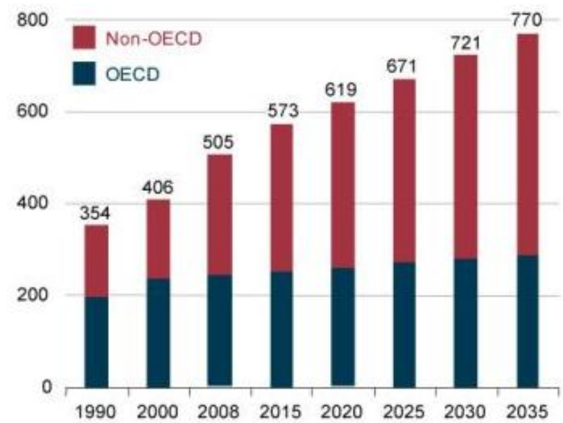

Figure 1 – ***Global energy consumption, 1990-2035 (quadrillions Btu)***
Source: International Energy Outlook 2011

Energy efficiency is the center of all strategies for smart and sustainable growth, and also the transition to a resource efficient economy.

In 2006, the EU adopted the 2006/32/EC Directive on the promotion of energy services and energy efficiency. According to this directive, Romania, as a Member State, has the obligation in the period 2008-2016 to reduce final energy consumption with an annual average rate of at least 1% of the average of the period 2001-2005.

The European Council has adopted an integrated policy for energy and climate change, including 20-20-20 energy targets by 2020:

- Reducing greenhouse gas emissions by 20% compared to 1990;
- Reducing energy consumption by 20% through increased energy efficiency;
- Covering 20% of energy consumption from renewable sources.

Following the Treaty of Accession of 25 April 2005, constituent treaties, regulations and directives of the European Union become an integral part of the Romanian legislation. So energy target, taken in the national strategy, relates to reduction of energy consumption through energy efficiency.

Energy efficiency is one of the most profitable ways to enhance security of energy supply and reducing greenhouse gas emissions and other pollutants. In many ways, energy efficiency can be seen as the largest energy resource in the world.

Therefore, investments in energy efficiency will help achieve 3 objectives:

- Sustainable economic growth;
- Ensuring energy security;
- Reduction of greenhouse gas emissions.

2. Energy databases

An important part of monitoring the effect of energy policy strategies are the databases, necessary for strategic analysis and assessment, especially for preparing and interpreting reports an energy consumption and energy efficiency progress.
Internationally there are large databases managed by international organizations with long tradition in making energy statistics:

- International Energy Agency (IEA), conducting detailed statistics on energy balances, rates and fees for various forms of energy, CO_2 emissions and developing energy forecasts;
- Statistics Division of the United Nations (UN Statistics Division) conducting detailed statistics on energy and environmental protection;
- Statistical Office of the European Commission (EUROSTAT) carrying out complex statistics on energy balances, major macro indicators of energy efficiency, prices for different forms of energy. As the official database of the European Commission, all energy targets are based on information from this database;
- ODYSSEE MURE project, funded by the European Commission under the "Intelligent Energy Europe Programme", includes energy efficiency indicators at macroeconomic level, sectorial and subsectorial for 29 countries (EU27, Norway and Croatia). This project focuses on two major databases:
    - ODYSSEE database with energy efficiency indicators, CO_2 indicators and all the data needed to calculate these indicators.
    - MURE database for assessing the impact of energy efficiency measures.

Nationally, statistics are collected and published annually by the National Institute of Statistics in the Yearbook and the Energy Balance. Also, the National Energy Observatory (OEN), founded in 2004 by ICEMENERG, performs databases on production and consumption of energy and energy efficiency nationwide.

Energy databases contain macroeconomic data, data on energy production and consumption, prices and tariffs, data and information on energy institutions.
Key indicators managed by the national energy databases are:

- **Economic indicators**, used as input in the calculation of energy efficiency indicators and necessary to develop energy forecasts and strategies. They allow assessment of the economy as a whole and disaggregated at economic sectors and subsectors levels.

Table 1 – Economic indicators for Romania, 2000-2010

	U.M	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
GDP Growth Rate	%	2.4	5.7	5.1	5.2	8.5	4.2	7.9	6.3	7.3	-7.1	-1.3
GDP in Euro Current Prices	MM Euro	40. 278	44. 865	48. 637	52. 569	61. 030	79. 746	97. 787	124. 654	139. 762	117. 529	122. 008
GDP in Euro 2005	MM Euro 2005	60. 356	63. 796	67. 050	70. 536	76. 532	79. 746	86. 046	91. 467	98. 144	91. 176	89. 990
Population	K	22. 435	22. 408	21. 795	21. 734	21. 673	21. 624	21. 584	21. 538	21. 504	21. 470	21. 462
GDP in Euro/Capita	Euro/ capita	1795	2002	2232	2419	2816	3688	4530	5788	6499	5474	5685
Inflation Rate	%	-	-	22.5	15.3	11.9	9	6.56	4.84	7.85	5.59	8.00
Exchange Rate RON/Euro	RON / Euro	1. 995	2. 603	3. 126	3. 756	4. 053	3. 623	3. 524	3. 337	3. 682	4. 237	4. 209

Source: National Institute of Statistics - Statistical Yearbook

Economic indicators presented in **Table 1** illustrate the 2 periods characterizing the Romanian economy between 2000 and 2010: economic development period 2000-2008 and the 2009-2010 period of recession.

GDP, expressed in Euro constant prices- reference year 2005, increased by 62.6% during 2000-2008, and in 2010 decreased compared to 2008 by approximately 9%.

During the economic development period was an increase of 3.62 times for the GDP/capita, and in 2010 GDP per capita fell by 14% from that of 2008.

- **Energy indicators** are indicators of energy consumption and its structure, and underlying the rationale energy efficiency strategies.

Table 2 – Energy indicators (toe) for Romania, 2000-2010

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Primary energy consumption	36. 374	37. 971	36. 480	39. 032	39. 018	37. 932	39. 571	39. 159	39. 799	34. 328	34. 200
Final energy consumption, including:	22. 165	22. 438	23. 370	25. 153	27. 332	25. 102	25. 312	25. 028	25. 303	22. 387	22. 250
Industry	9017	9351	10. 616	10. 892	11. 285	10. 505	9998	9989	9415	6612	6750
Transports	3508	3975	4305	4319	5915	4244	4407	4739	5400	5377	5370
Population	8433	7197	7284	7879	7910	8055	7889	7559	8090	8037	7980

Source: National Institute of Statistics - Energy Balance

The indicators presented in **Table 2** illustrate the evolution of energy consumption in Romania, between 2000 and 2010, detailing the structure of final energy consumption.

During the economic development, the primary energy consumption increased by 9.4%, while final energy consumption increased by 14%. During this period, the share of the transport sector increased from 15.8% in 2000 to 21.3% in 2008, while the proportion of consumption in industry decreased from 40.7% in 2000 to 37% in 2008 and the share of consumption recorded by population decreased from 38% in 2000 to 32% in 2008.

During the economic crisis of 2009-2010 was a decrease in the consumption of primary energy by 14% and the final energy consumption by 12%. Share of energy consumption in industry decreased to 30.3% in 2010, while the consumption share of the transport sector increased from 21.3% in 2008 to 24% in 2010 and the share of energy consumption of the population increased to 35 9% in 2010.

Energy efficiency indicators are calculated based on the economic and energy indicators. These are:

- Indicators for monitoring trends in energy efficiency;
- Indicators of energy efficiency comparison between countries;
- Diffusion indicators for measuring market penetration of technologies, equipment.

3. Indicators for monitoring energy efficiency

Energy Intensity is a very important indicator for the energy evolution of an economic system and for the energy efficiency assessment in a country. It is calculated as the ratio of energy consumption expressed in physical units and economic variables expressed in monetary units.

At the national level,

- **Primary Energy Intensity (PEI)** is defined as the ratio between the Total Primary Energy Consumption (TPEC) and Gross Domestic Product (GDP) in Euro.

$$PEI(t) = \frac{TPEC(t)}{GDP(t)} \ (kgep/euro)$$

- **Final Energy Intensity (FEI)** is defined as the ratio between the Total Final Energy Consumption (TFEC) and Gross Domestic Product (GDP) in Euro.

$$FEI(t) = \frac{TFEC(t)}{GDP(t)} \ (kgep/euro)$$

Final energy intensity, for a given economic sector of final consumption or industry, is calculated as the ratio of final energy consumption in the economic analysis and gross value added in the economic analysis.

Table 3 - Primary energy intensity and final energy intensity, Romania, 2000-2010

	U.M.	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Primary energy intensity	tep/ 1000 Euro 2005	0.603	0.595	0.544	0.553	0.510	0.476	0.460	0.428	0.406	0.377	0.380
Final energy intensity	tep/ 1000 Euro 2005	0.367	0.352	0.349	0.357	0.357	0.315	0.294	0.274	0.258	0.246	0.247

Source: ICEMENERG – OEN

Primary energy intensity and final energy intensity values are still above the EU average, which means, among other things, that Romania produces at high costs and consumes energy inefficiently. By 2020, Romania must meet targets to reduce energy intensity by an average of 3.7% annually.

The **Specific Energy Consumption** directly characterizes energy use efficiency to obtain a product or service and is the amount of energy consumed nationwide in average, in a given year, to obtain a unit of product or service.

$$SEC(t) = \frac{CEF(t)}{M(t)},$$

where,

SEC (t) - the specific energy consumption;
CEF (t) - energy consumed for a year to produce the product reviewed / service / all equipment in question nationwide;
M (t) - the amount of products / services obtained in one year / number of devices nationwide.

ODEX indicators are percentage indicators, selecting a specific year for which the indicator is 100%, are calculated values for other years. They do not present the energy efficiency, but its evolution.
If:

- ODEX indicators> 100% ➡ efficiency has worsened;
- ODEX indicators <100% ➡ efficiency has improved.

ODEX indicator is calculated as the ratio between the energy consumption in year *t* and the energy consumption that would have been required in year *t* if energy efficiency would have been the same as the one from the year t_0.

$$ODEX(t) = \frac{I(t)}{I(t_0)}, \quad \mathrm{I(t)} = \sum_{k=1}^{n} FEC_k(t) = \sum_{k=1}^{n} Q_k(t) * SC_k(t)$$

where,

FEC_k (t) - final energy consumption for subsector k in year t;
Q_k (t) - the amount of goods or services obtained in subsector k in year t;
SC_k (t) - specific consumption recorded in the subsector k, in year t.

In the period 2000-2010 ODEX index decreased by 20% across the economy of Romania. Evolution was better than the European average of 10%. Population and industry have contributed to this improvement. In the period 2000-2010, energy efficiency increased by 24% in industry and by 30% in the households sector.

4. Defining smart metering

Over time were conducted numerous research and development activities relating to the generation, delivery and use of energy. Many of them focus on several technological challenges, trying to provide society affordable energy and with environmental responsibility. This is the reason why researchers recommend smart meters that measure how much energy is consumed and transmit recorded data in almost any predefined range.

Even if the concept of "smart metering" is frequently used at present there is no generally accepted definition of concrete which is actually smart metering.

According to the authors A. Morche, J. Parsons and J. Kester, the energy smart metering means measuring devices with support systems and data management infrastructure for transferring and managing metered data, which records energy consumption, periodically or upon request, in more detail than conventional, transferring the data recorded by the supplier for monitoring and billing.

A smart metering system:

A. Measures consumption during key legal metrology requirements;

B. Stores data measured at different time periods;

C. Allows access to these data to both consumers and suppliers or their agents and has at least one of the following functions:

- Provides analysis of the data and display them in a significant way to the consumer;
- Transfers data concerning consumption to the supplier, in order to correct invoicing without requiring access at home;
- Measures and records information on continuity and quality of supply, and provide them with other data to the distribution system operator for planning and evaluation of losses;
- Allows remote control (eg, interruption and restoration);
- Allows pricing messages for different periods of time, in response to the request;
- Allows remote changing of tariffs, duties or other rates, without requiring access at home.

5. Literature review

Over the past decades, automatic reading, based on one or two directions of communication has evolved.

The report "Future of Energy", produced by Oracle company in 2011, brought together experts from Europe, Middle East and Africa to highlight critical issues in energy and to find solutions that smart grids, smart meters and green energy become a reality in 2050. Oracle software smart metering is a set of solutions that offer customers new ways to conserve energy, reduce bills and reduce carbon emissions. Oracle Utilities Meter Data Management can serve as the foundation for the smart metering initiatives.

Intel initiative "Open Energy" aligns and mobilizes partners in implementing Intel technologies and open standards to accelerate the global transition to „smart energy". Specifically, Intel is working to accelerate the integration and synergy of smart renewable energy sources, smart grids, smart buildings and consumers.

Cisco has begun to share its experience in networking to worldwide utilities suppliers, building innovative solutions for themselves and their clients in order to monitor energy use, optimizing energy supply, reducing energy consumption and the costs, improving system security and reducing their impact on the environment. Cisco SmartGrid solutions address critical points of the energy infrastructure: from data centers and substations, through neighborhood networks, businesses and homes.

A recent study, entitled "Build Smart Metering Solutions with IBM Informix TimeSeries" explores the idea that smart meters change how utility companies capture data, offering new opportunities for using these data. IBM suggests that in order to exploit the full potential of smart meters, the utility companies and their partners must have a data management solution that is specifically designed to reduce data loading time and reduces the need to increase data storage capacity for time series.

Ericsson was declared winner of the 2012 Award "Network and Communications Award 2012" at the "Smart Metering UK & Europe Summit 2012" from London. Ericsson won the award for their innovative communications with smart meters solution, which allows a better use of mobile networks.

6. CASE STUDY: smart metering electricity consumption in Romania

The current system for monitoring electricity consumption in Romania is characterized by physical reading of the traditional meters, recording consumption on paper and finally transfer data on electronic spreadsheets. This procedure is naive and boring, and those spreadsheets have a limited capacity when it comes to queries and reports a huge number of records.

This article proposes an architecture of a smart metering system, showing the flow of information from the meters, the communication subsystem, database and management subsystem for power consumption. (**Figure 2**)

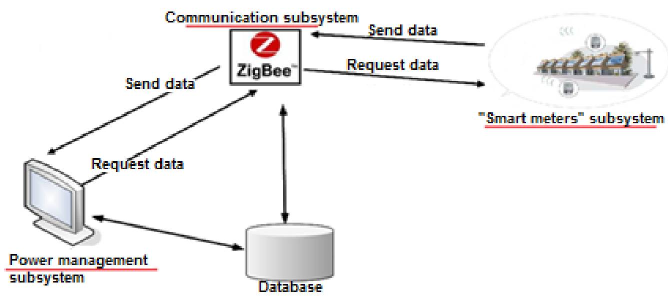

Figure 2 – Proposed architecture of a smart metering system

Given the role of smart meters to a residential or commercial customer, the proposed smart metering system has a number of features that bring many benefits to players taking part in this challenge from the electricity market:

- Measuring energy consumption and database storage of measured values and recorded in different time periods;

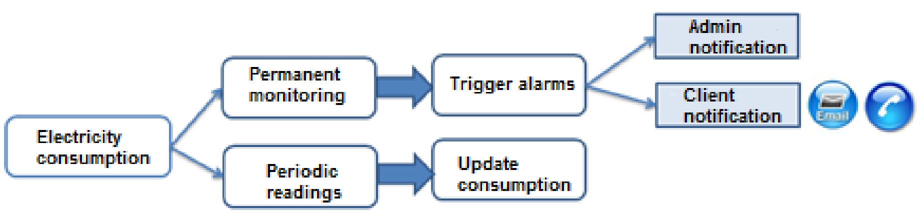

Figure 3 - Proposal for monitoring electricity consumption

- Real-time tracking (reading every 4 seconds of the data consumption).

Feedback accurate and timely information on energy consumption allows consumers and authorities to react quickly enough and to direct efforts towards the most effective, bringing benefits to society and the environment measures.

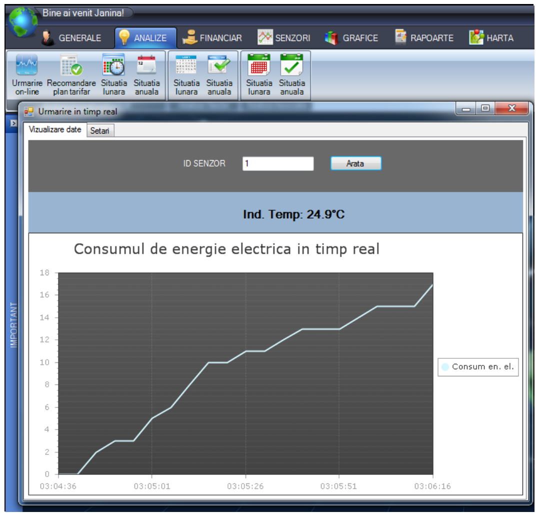

Figure 4 - Real-time monitoring interface

Permanent monitoring provides a better control over electricity use by:

- Identifying abnormal power consumption caused, for example by malfunctioning equipment and improving the situation in the future.

Figure 5 - User interface - equipment status

- Triggering alerts based on measurable factors.

If you look in terms of temperature sensor placed on the electricity counter operate normally in the range-40^{o} - 85^{o}C, and any temperature outside this range may mean the destruction of equipment, may intervene freezing, melting or even cause a fire. These conditions automatically alert the alarm and correct information should be sent to the recipient.

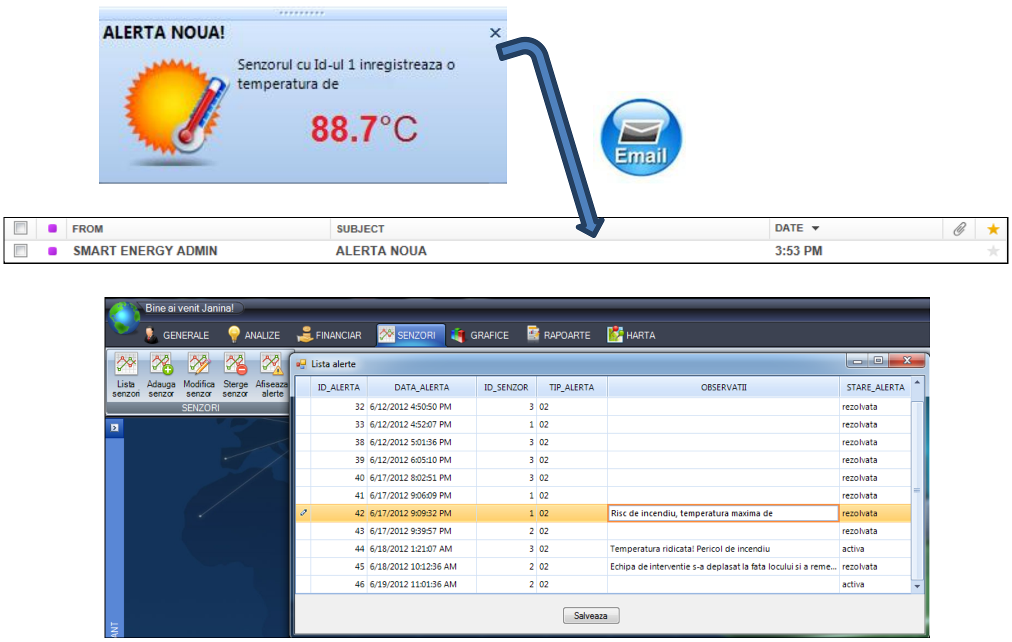

Figure 6 – Temperature alerts

Also among the most important features of the system are processing and presentation of data concerning electrical energy consumption in the form of various tests, flexible tables where exceptions are marked according to conditions imposed by the user, dynamic and interactive reports and charts, monthly and yearly. All these ways of presenting data are useful for: monitoring and adjusting consumption patterns; electricity distribution network optimization according to areas of consumption, which include infrastructure optimization.

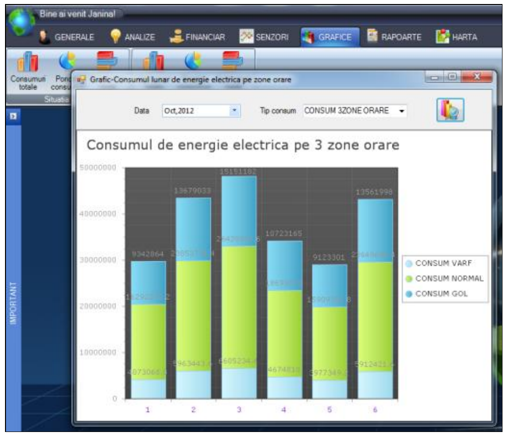

Figure 7 - User interface power consumption (kWh) in all the 6 sectors of Bucharest

7. Conclusions

Considering the fact that is expected to increase global energy consumption about 53% by 2035, governments seek effective methods of creating and distributing energy, taking into account the implications on the environment, and energy efficiency is the center of all these strategies.

At national and international level are developed and constantly updated databases to provide data and information necessary to support energy efficiency policies and strategies.

For permanent monitoring of energy consumption and energy efficiency trends, researchers and specialists propose smart metering as an innovative solution.

At the end of the paper, we proposed a smart metering system for electricity consumption in Romania, trying to bring a number of benefits to all who take part in this challenge - energy efficiency.

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REFERENCES

[1] **Andrei Morch, John Parsons, Jasco Kester (2007),** ***Smart Electricity Metering as an Energy Efficiency Instrument: Comparative Analyses of Regulation and Market Conditions in Europe*** **;** ECEEE 2007 Summer Study Save energy – Just do it!
[2] **Business Review (2011),** ***ENEL wants to implement smart meters in Romania*****;** http://business-review.ro/enel-wants-to-implement-smart-meters-in-romania-12476/
[3] **EIA (2011),** ***International energy outlook*****;** http://www.eia.gov/forecasts/ieo/more_highlights.cfm#world;
[4] **ICEMENERG – OEN (2010)**, http://www.icemenerg.ro/;
[5] **ICEMENERG (2006),** ***Dezvoltarea si actualizarea bazei de date din cadrul Observatorului Energetic National*****;** http://www.minind.ro/domenii_sectoare/energie/studii/dezvoltare_bd.pdf
[6] **ICEMENERG (2009),** ***Măsuri de creştere a eficienţei energetice în sectoarele de consum final şi metode de implementare şi monitorizare a acestora*****;** http://www.icemenerg.ro/;
[7] **Institutul Naţional de Statistică (2010),** ***Anuarul statistic 2010***, http://www.insse.ro/cms/rw/pages/anuarstatistic2010.ro.do;
[8] **Institutul Naţional de Statistică (2010),** ***Balanţa energetică 2010,*** http://www.insse.ro/cms/files/publicatii/balanta%20energetica%202010.pdf;
[9] **Janina Popeangă (2012),*****Monitorizarea şi gestiunea consumului de energie electrică utilizând date senzoriale*****;** Master's thesis, under the supervision of Professor Ion LUNGU, 19.06.2012, ASE, Bucharest.
[10] **ODYSSEE-MURE (2012),*****Energy Efficiency Profile: Romania*****'** http://www.odyssee-indicators.org/publications/country_profiles_PDF/rom.pdf
[11] **RenERg – EuReg (2010),** ***Analiza principalelor resurse si posibilitati existente la nivelul Regiunii Centru pentru producerea pe termen scurt si mediu de energie***, http://www.renerg.eu/Document_Files/Evenimente/00000058/9dn9j_Analiza%20potentialului%20energiilor%20regenerabile%20in%20Regiunea%20Centru.pdf
[12] **Research News (2010),** ***Smart meters help to save money***, Fraunhofer Press, 01.07.2010, http://www.fraunhofer.de/en/press/research-news/2010/07/smart-meters.html
[13] **SmartRegions (2011),** ***Foaie de parcurs pentru servicii de contorizare inteligentă la consumatorul final pentru România***, http://www.smartregions.net/GetItem.asp?item=digistorefile;337500;1522&params=open;gallery.
[14] **SPOS Project (2008),** ***Studii de strategie şi politici; Orientări privind securitatea energetică a României,*** http://www.ier.ro/documente/spos2008_ro/Studiul_2_-_Securitatea_energetica_RO.pdf.