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Thursday, September 22nd, 2016

Prediction of Energy Production from String PV System under Mismatch Condition

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Abstract— **An analysis of energy production from string photovoltaic (PV) system, with unequal PV modules, has been presented in this paper. Brief guidelines for PV cell-based modeling of PV systems have been provided. Mismatch power losses have been investigated for wide ranges of irradiation and ambient temperature. By using experimental irradiation measurements, prediction of PV string energy production has been obtained, for time period of one month. According to presented results, it can be concluded that consideration of mismatch conditions in precise energy prediction analysis cannot be neglected.**

Keywords - energy prediction, PV string, mismatch condition.

I. Introduction

Precise determination of energy production from PV systems is very difficult to achieve, mostly due to variable operating conditions (irradiation and ambient temperature) during long period of time. Recommended procedures usually rely on hourly-averaged horizontal irradiation measurements for specific locations. Many statistical methods, concerning energy prediction, are available in literature [1-3].

In the manufacturing process, it is almost impossible to achieve perfectly identical PV modules' IV curves, because the electrical parameters of PV cells slightly differ from each other. In addition, material degradation is present during exploitation time, which significantly contributes to even greater differences between individual PV modules in PV system. Several authors have analysed mismatches in I-V curves of PV modules in order to determine corresponding power losses in PV arrays [4,5]. It had been shown that power losses are approximately 4%, for wide ranges of irradiation values. Degradation of PV modules, during the years of operation, reduces the efficiency of PV system up to 20% until the end of lifetime [6]. Mismatch losses in PV string certainly depend on year of operation, initial differences in IV curves of PV modules and current operating conditions.

Prediction accuracy of energy production from PV string is affected by differences in IV curves of individual PV modules. In this paper, through the energy prediction analysis, it will be assumed that PV string always operate at maximum power point (MPP), which is justified due to usage of inverter with algorithm for tracking MPP. MPPT algorithms for PV strings have been investigated in previous paper [7].

II. PV Cell-Based Modeling of PV String

In order to properly determine mismatch power losses in PV systems, it is essential to use PV cell-based modelling. One-diode MATLAB-based model of PV cell has been created by using recommendations from [8]. Low irradiation effects have been included in modelling process by threatening of PV cell's series resistance, parallel resistance and diode ideality factor, as functions of irradiation and operating temperature, with corresponding analytical expressions recommended in literature [9-11].

A. PV module model

PV module modelling has been realized by using MATLAB/Simulink software [12]. The chosen PV module consists of 60 polycrystalline Suntellite 156M PV cells,

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connected in series, with electrical data for Standard Test Conditions (STC) presented in Table I. Every 10 PV cells form sub-string, which is shade-protected with one bypass diode.

TABLE I. PV CELL SUNTELLITE 156M ELECTRICAL PARAMETERS

Efficiency [%]	17.00-17.19
P_{MPP} [W]	4.16
V_{MPP} [V]	0.531
I_{MPP} [A]	7.834
V_{OC} [V]	0.63
I_{SC} [A]	8.35
FF [%]	79.08

B. *Modeling of mismatch condition*

In this paper, mismatch condition refers to PV string consisting of PV modules with unequal IV curves.

It is assumed that there are 5 PV modules with unequal IV curves in PV string consisting of 12 PV modules. Electrical parameters of chosen PV module (PV1), together with 4 variations, obtained by using MATLAB random generator (returns uniformly distributed random numbers), are presented in Table II. Random values are obtained within specified limits (e.g. ± 2% for I_{MPP}), which corresponds to practical data for new PV cells [13]. Different PV modules' parameters under nominal operating conditions (G = 800 W/m^2 and T = 20°C).

Corresponding IV curves are shown in Fig.1. According to data presented in Table II and Fig.1 it can be seen that modules PV2, PV3 and PV4 are less efficient than base module PV1. It can be assumed that their efficiencies are lower due to material degradation process. In the case of module PV5, corresponding efficiency is slightly higher than efficiency of base module PV1. PV5 is the newest module in PV string.

TABLE II. DIFFERENT PV MODULES' PARAMETERS UNDER NOMINAL OPERATING CONDITIONS (G=800 W/M^2 AND T=20°C)

PV module	I_{SC} [A]	V_{OC} [V]	I_{MPP} [A]	V_{MPP} [V]	P_{MPP} [W]
PV1	6.82	34.28	6.29	26.78	168.32
PV2	6.79	32.32	6.18	24.51	151.47
PV3	6.84	32.80	6.26	25.14	157.24
PV4	6.82	33.53	6.25	25.80	161.09
PV5	6.81	34.72	6.28	27.11	170.10

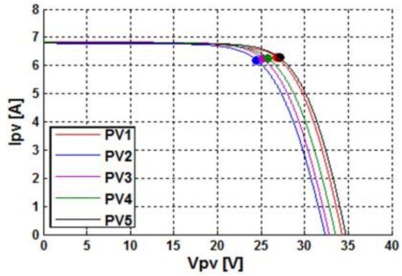

Figure 1. I-V curves of five PV modules with unequal electrical parameters.

The analysed PV string with different PV modules electrical scheme is presented in Fig. 2. The locations of different PV modules in PV string are also determined randomly.

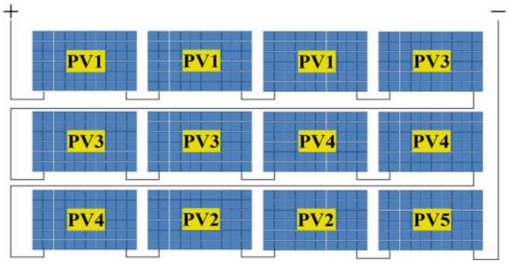

Figure 2. PV string with different PV modules electrical scheme.

In order to verify PV string model and to determine mismatch power losses, several simulations have been performed. Obtained results can be classified in two study cases: mismatch power losses under different irradiation and ambient temperature values.

C. *Mismatch power losses under different irradiation values*

Maximum powers of PV strings with equal and unequal PV modules have been compared in the case of variable irradiation condition. Irradiation intensity has been varied from 1000 W/m^2 to 200 W/m^2, with constant ambient temperature value of 20 °C, in order to determine efficiency decrease of PV string with unequal PV modules. Corresponding results are presented in Table III. By analysing results from Table III, several conclusions can be obtained:

- Mismatch losses are lower than 5% for every considered irradiation value.
- When decreasing irradiation intensity, mismatch losses are also decreasing.
- In low irradiation area (< 200 W/m^2), mismatch losses start to increase.

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TABLE III. MAXIMUM POWER OF PV STRING WITH EQUAL AND UNEQUAL PV MODULES FOR DIFFERENT IRRADIATION VALUES

	Irradiation [W/m^2]	1000	800	600	400	200
Equal PV modules	P_{MPPe} [W]	2469.8	2019.9	1549.6	1051.8	522.9
Different PV modules	P_{MPPd} [W]	2355.5	1932.6	1486.1	1010.2	502.0
P_{MPP} decrease	$(P_{MPPe} - P_{MPPd}) / P_{MPPe}$	4.63 %	4.32 %	4.10 %	3.96 %	3.99 %

TABLE IV. MAXIMUM POWER OF PV STRING WITH EQUAL AND UNEQUAL PV MODULES FOR DIFFERENT AMBIENT TEMPERATURE VALUES

	Temperature [°C]	-5	10	25	40
Equal PV modules	P_{MPPe} [W]	2248.5	2113.5	1971.9	1822.7
Different PV modules	P_{MPPd} [W]	2162.9	2027.3	1883.9	1731.4
P_{MPP} decrease	$(P_{MPPe} - P_{MPPd}) / P_{MPPe}$	3.81 %	4.01 %	4.46 %	5.01 %

D. Mismatch power losses under different ambient temperature values

Maximum powers of PV strings with equal and unequal PV modules have been compared in the case of variable ambient temperature. Ambient temperature values have been varied from -5 °C to 40 °C, with constant irradiation value of 800 W/m^2, with the goal of PV string with unequal PV modules efficiency determination. Corresponding results are presented in Table IV.

By analysing results from Table IV, two basic conclusions can be obtained:

- Maximum mismatch losses to be expected are 5%.
- When increasing ambient temperature, mismatch losses are also increasing.

III. STATISTICAL PREDICTION OF PV STRING OPERATING CONDITIONS

Statistical prediction of power production from PV systems is based on horizontal irradiation and ambient temperature measurements. In this paper, available experimental measurements are used for location of small town Han Pijesak in Bosnia, with WGS coordinates: 44.01^0; 18.55^0; 1155 m.

Aquisition system provided measurements of horizontal irradiation and ambient temperature for every 10 minutes in May, for the year of 2009. The obtained irradiation and temperature values have been hourly-averaged in order to form daily diagrams. In the next step, daily diagrams have been mounthly-averaged and average day in May has been determined.

Hourly-averaged horizontal irradiation and ambient temperature values for average day in May have been presented in Fig.3 and Fig.4, respectively.

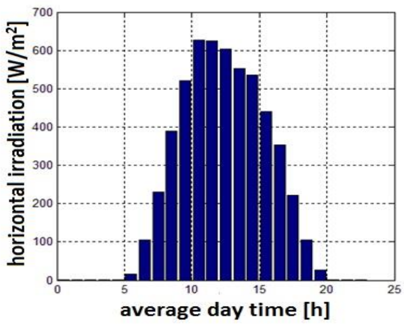

Figure 3. Hourly-averaged horizontal irradiation values for average day in May.

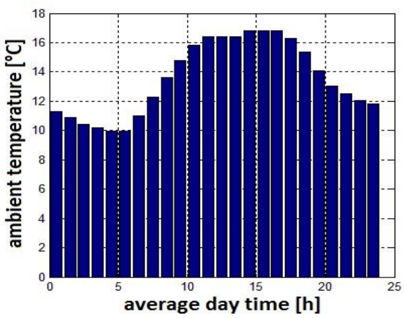

Figure 4. Hourly-averaged ambient temperature values for average day in May.

A. Determination of irradiation on PV string surface

Based on the procedure given in [14], horizontal irradiation can be divided into direct and diffuse component. In addition, reflected component can be determined by using corresponding reflection coefficient.

In order to determine irradiation components on PV string surface, position angles need to be defined. Corresponding tilt and azimuth angles (Σ=45^0 and ϕ_S=24^0) are illustrated in Fig.5.

In the process of determining ambient reflection coefficient, it is assumed that household with PV string on its roof is located on a grassy surface. The adopted reflection coefficient value is ρ=0.15. Hourly-averaged irradiation component values for average day in May have been presented in Fig.6.

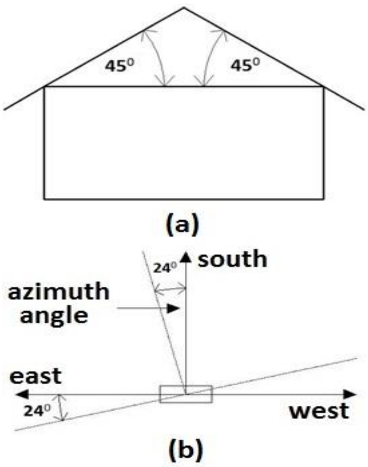

Figure 5. PV string position angles: (a) tilt angle; (b) azimuth angle.

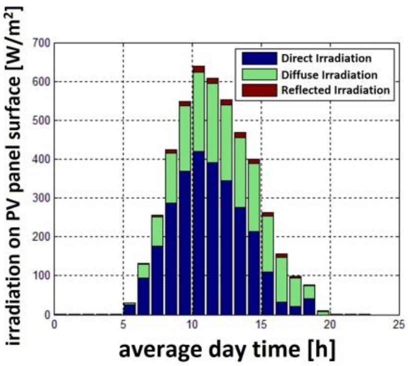

Figure 6. Hourly-averaged irradiation component values for average day in May.

From Fig.6 it can be seen that diffuse irradiation component significantly participates in total irradiation on the PV string surface.

B. Determination of PV string operating temperature

By using irradiation and ambient temperature data, it is possible to determine operating temperature of PV string, according to following relation:

$$T_{PV} = T_{amb} + (\frac{NOCT - 20}{0.8}) \cdot I_{PV}, \quad (1)$$

where: T_{PV} is operating temperature of PV string; T_{amb} is ambient temperature at certain location; $NOCT$ is nominal operating temperature of PV cell; I_{PV} is irradiation value on the surface of PV string.

The value of $NOCT$ for considered PV cells is 47 °C. Based on hourly-averaged ambient temperature values (Fig.4) and hourly-averaged irradiation component values (Fig.6), hourly-averaged operating temperature values of PV string have been calculated according to (1). Corresponding results are presented in Fig.7.

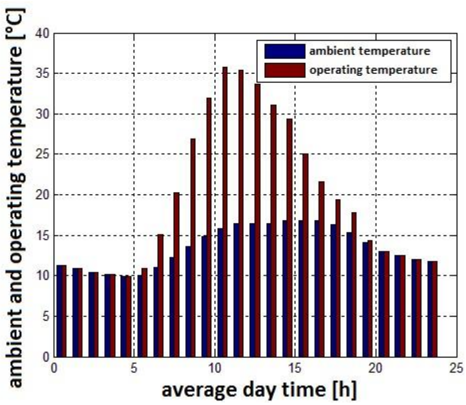

Figure 7. Hourly-averaged ambient and operating temperature values for average day in May.

IV. PV STRING ENERGY PRODUCTION

On the basis of prediction results, related to operating conditions, it is possible to statistically predict energy production from PV string during certain period of time and to determine energy decrease in the case of mismatch condition. PV string hourly-averaged power reductions, due to PV modules with unequal IV curves, are presented in Table V.

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TABLE V. PV STRING HOURLY-AVERAGED POWER REDUCTIONS DUE TO UNEQUAL PV MODULES DURING THE AVERAGE DAY IN MAY

Time interval	Ambient temperature	Irradiation	PV string with equal PV modules	PV string with unequal PV modules	Power reduction
5h - 6h	10 °C	28 W/m^2	37.41 W	34.79 W	2.62 W (7%)
6h - 7h	11 °C	132 W/m^2	291.49 W	278.27 W	13.22 W (4.5%)
7h - 8h	12.2 °C	256 W/m^2	684.90 W	658.13 W	26.77 W (3.9%)
8h - 9h	13.6 °C	425 W/m^2	1140.10 W	1095.74 W	44.36 W (3.9%)
9h - 10h	14.8 °C	550 W/m^2	1457.25 W	1399.48 W	57.77 W (4%)
10h - 11h	15.8 °C	637 W/m^2	1667.59 W	1600.13 W	67.46 W (4%)
11h - 12h	16.4 °C	610 W/m^2	1597.22 W	1532.79 W	64.43 W (4%)
12h - 13h	16.3 °C	554 W/m^2	1458.86 W	1400.65 W	58.21 W (4%)
13h - 14h	16.4 °C	465 W/m^2	1232.84 W	1184.26 W	48.58 W (3.9%)
14h - 15h	16.7 °C	400 W/m^2	1063.33 W	1021.64 W	41.69 W (3.9%)
15h - 16h	16.7 °C	262 W/m^2	695.15 W	667.81 W	27.34 W (3.9%)
16h - 17h	16.7 °C	154 W/m^2	354.52 W	338.89 W	15.63 W (4.4%)
17h - 18h	16.3 °C	98 W/m^2	205.75 W	195.98 W	9.77 W (4.7%)
18h - 19h	15.4 °C	77 W/m^2	157.37 W	149.72 W	7.65 W (4.9%)
19h - 20h	14 °C	15 W/m^2	12.06 W	10.82 W	1.24 W (10.3%)

According to results presented in Table V, the following conclusions can be obtained:

- As earlier determined, around 4% PV string power decrease is present during the longest time period (9h).
- Due to low irradiation effect, mismatch condition reduces PV string power up to 10%, in short time periods when the sun rises and sets.
- PV string with equal PV modules energy production during average day is 12.056 kWh, while in the case of mismatch condition (different PV modules), the corresponding value is 11.569 kWh. PV string energy loss during the average day is 0.487 kWh.
- On the mounthly basis (during May), calculated PV string energy loss is 15.097 kWh.

V. CONCLUSION

Power production of PV systems could be significantly affected by mismatch condition, mainly due to different degradation processes of PV modules during exploitation period. Based on the experimental measurements, statistical approach and PV cell-based modelling, it is shown that PV string energy loss is around 4% (15.097 kWh during May), due to mismatch condition. In order to achieve precise prediction of energy production from PV systems, it is important to include power losses due to mismatch condition, especially if PV modules are older than 10 years. Presented methodology in this paper, related to PV string, can be used in the case of any other PV system.

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Circuit Breaker Voltage Drop Analysis

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Abstract - **Circuit breaker analysis is done using voltage drop data collected in last 10 years. Data includes 42 power stations 35/10 kV, with 426 minimum oil circuit breakers, (109 circuit breakers on 35kV, and 317 circuit breakers on 10kV). Measurement is done on every 2 years. Available data regarding circuit breakers, beside voltage drop, are: manufacturing year, rated voltage, feeder type and circuit breaker rated current. Aim of analysis is determining life span of circuit breaker, as function of voltage drop on its poles.**

Keywords - circuit breaker (CB), voltege drop, lifespan

I. Introduction

The maintenance of circuit breakers (CB) deserves special consideration because of their importance for routine switching and for protection of other equipment. Electric transmission or distribution system breakups and equipment destruction can occur if a CB fails to operate because of a lack of preventive maintenance. The need for CB maintenance is often not obvious as CB may remain idle, either open or closed, for long periods of time. The electrical contact is a crucial component in CB. An increase in the contact resistance can cause the failure of the breaker. If the contact resistance starts to increase significantly the increase in value will grow exponentially. The IEC 56 international standard sets an acceptable reading of up to 20% increase from the original test value. Over this value, it is necessary to perform an open inspection.

Circuit breakers manufacturer "Minel" describes measurement procedure and gives maximal permissible voltage drop values in [1]. Similar work has been done in [2], where CB's are analyzed on international level, with detailed CB's working data available. Also collected CB's data can be used for maintenance and mean time between failure analysis, such as in [3].

The aim of this paper is to find the average time needed for CB to reach its maximal contact resistance (or voltage drop), using collected data. Obtained time can be considered as CB's life cycle.

II. CB Contact Resistance

The real contact between two surfaces happens through a number of micro contacts, spread randomly inside the limits of the visible contact area. It is the sum of the areas of all the micro contacts that constitutes the effective contact area. Since the resistance of an electrical contact is inversely proportional to the contact area, the smaller the effective area the greater the resistance.

When a current I pass through an area A that has a resistance R, The Energy E absorbed by A is:

$$E = RI^2t \quad . \tag{1}$$

Where t is the time duration of I. Area's temperature T is directly related to E by the following equation:

$$E = \lambda T \; , \tag{2}$$

λ is a function of the heat dissipation rate.

For a constant current, if R increases, E increases, leading to increasing temperature of the contact. If temperature continues to increase the material of the contact can reach its melting point, leading to its destruction. Main elements affecting the contact resistance are oxidation, contact wear, fretting and temperature.

A. Oxidation

A thin layer of insulating oxide covering the area of a single micro contact would have little effect on the conductivity of the contact as a whole. As soon as the oxide layer extends to a significant number of micro contacts, the current

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bearing area would reduce, thus increasing its resistance. Increased resistance will increase the contact temperature, leading to its destruction. All ambient atmospheres that contains gases capable to react with the contact's material, such as O2, SO2, H2O, H2S, etc., would be favorable to producing oxide layers even though the contact is closed. With time, the gas would succeed in penetrating and reacting with the contact surface to degrade its characteristics and to increase its resistance. The resistance change is not significant until a certain point in time where the degradation increases fast. Similar results are obtained for copper contacts in oil. These results show interesting behavior and indicate the urgency of a maintenance intervention when a contact's resistance starts to increase.

B. *Contact wear*

Mechanically, contact wear is happening because of the movement and friction of the contacts and electrically due to the arc effect. Contact wear directly affects the contact resistance and makes it increase dramatically if the wear is in an advanced state.

C. *Fretting*

A form of accelerated oxidation is possible, if the contact surfaces experience a cycling movement relatively to each other. For example, the contacts would not close at the same area each time.

D. *Temperature*

For an increasing temperature **T** of the contacts, the material of the contacts may soften to the point where it will reduce the contact force, leading to a quick increase of the contact resistance.

Measuring the contact resistance is usually done by using the principles of Ohm's law:

$$V = RI \, , \tag{3}$$

V - voltage across the contact,
I - measured current,
R - resistance.

If we apply a current *I* and we measure the voltage *V*, the resistance *R* can be obtained directly by dividing *V* by *I*.

$$R = V/I \, . \tag{4}$$

Since the interrupting chamber is a closed container, we have only access to the entry and exit conductors; the measured R between these two points would be the sum of all the contact resistances found in series, (fixed, make-break and sliding contacts). According to the IEC 694, article 6.4.1, the current value to use should be the closest to the nominal current the interrupting chamber is designed for. If it is impossible to do so lower currents can be used but not less than 50A to eliminate the galvanic effect that might affect the readings.

III. DATA ANALYSIS

A. *Collecting data and classification*

Data used in this paper are collected in last 10 years, during transformer substation revision. CB's voltage drops are measured on every two years, according to the manufacturer's instructions [1]. Power station revision covers 42 power stations 35/10 kV with 426 minimum oil CBs (109 CBs of 35kv, and 317 CBs of 10kV).

Measurement has been done with DC current of *I*=100*A* measuring voltage drop on every CB's pole. Table I shows voltage distribution among all currently available data of CB's voltage drop, with values divided into 4 categories depending of voltage drop level.

TABLE I. DISTRIBUTION OF ALL AVAILABLE CB POLES VOLTAGE DROP DATA

Voltage drop [mV]	Number of CB's poles
$\Delta u \leq 5$	316
$5 < \Delta u \leq 10$	628
$10 < \Delta u \leq 20$	234
$\Delta u > 20$	91

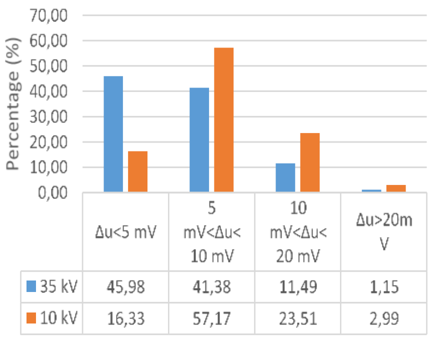

Figure 1. Correlation between CB's voltage drop and their rated voltage level

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TABLE II. DISTRIBUTION OF 10KV CB'S POLES WITH RATED CURRENT OF 630A AND VOLTAGE DROP LESS THAN 10MV

Voltage drop [mV]	Number of CB's poles
$\Delta u \le 5$	33
$5 < \Delta u \le 10$	150
$10 < \Delta u \le 20$	71
$\Delta u > 20$	16

In manufacturer's manual, voltage drop values for different type of CBs are shown. That value depends of CBs nominal voltage, and nominal current. Permissible voltage drop of CBs with rated current 630A are: CB with rated voltage of 35kV – 9mV, CB with rated voltage of 10 kV – 10 mV. Because of greater amount of data regarding 10 kV circuit breakers in this stage, all further analysis in this paper will be done for permissible voltage drop value of 10mV.

TABLE III. DISTRIBUTION OF ALL CB'S POLES REGARDING FEEDER TYPE

Feeder type	Number of CB's poles
Overhead feeder	73
Underground feeder	197

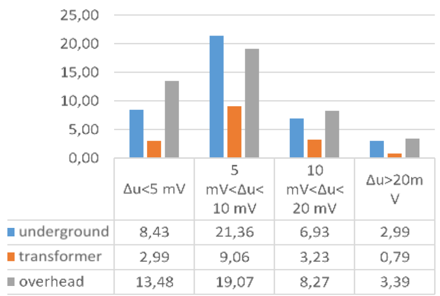

Figure 2. Gathered CB data depending of mounting location and voltage drop

On Fig. 2 overall data values are shown, with percentage of all CB's types and their voltage drop values.

B. *Data analysis and maximal voltage drop reaching time determination*

Fig. 3 shows voltage drop distribution on 10kV CB's, on both feeder types (underground and overhead) for 630*A* rated CB's current. Data distribution is used for finding average time in which CB's voltage drop will reach its maximal value. Using equation of the line through two points (representing average value increase), time period is calculated. Line of average value increase is generated in Microsoft Excel.

$$y = 0.2565x + 1.2852\,, \qquad (5)$$

$$t = \frac{10 - 1.2852}{0.2565} = 33.97\ years\,. \qquad (6)$$

Average time in which maximal voltage drop value is reached is 34 years ((5) and (6)). After this period CB should be repaired or replaced. Further analysis will be done for different criteria regarding circuit breaker, such as feeder type (underground and overhead).

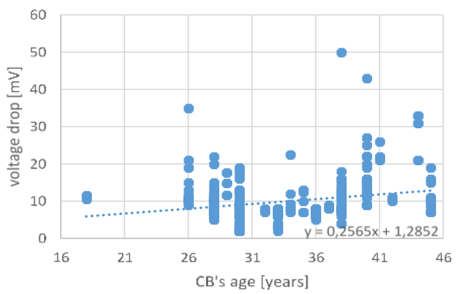

Figure 3. Voltage drop and age correlation of 630A CB's on 10kV feeders - underground and overhead

C. *Maximal voltage drop reaching time determination on overhead feeders*

Voltage drop measurements on 10kV overhead feeders are shown in Fig. 4. In Equations (7) and (8) average time of CB's is shown, based on maximal voltage drop.

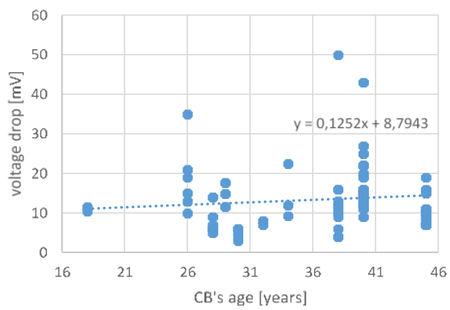

Figure 4. Voltage drop and age correlation of 630A CB's on 10 kV overhead feeders

When analyze separately, overhead feeders have dramatically lower lifespan, than in overall analyze.

$$y = 0.1252x + 8.7943\,, \tag{7}$$

$$t = \frac{10 - 8.7943}{0.1252} = 9.63\,years \quad . \tag{8}$$

D. Maximal voltage drop reaching time determination on underground feeders

All CB's on underground feeders are mounted on 10kV voltage level. In Fig. 5 their voltage drop is shown, with line which represents measurements mean value. Lifespan of CB's on underground feeders is around 39 years ((9) and (10)).

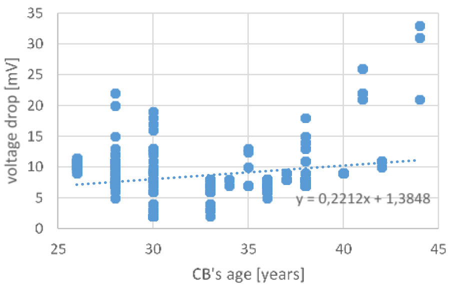

Figure 5. Voltage drop and age correlation of 630A CB's on 10 kV underground feeders

$$y = 0.1252x + 8.7943\,, \tag{9}$$

$$t = \frac{10 - 8.7943}{0.1252} = 9.63\,years \quad . \tag{10}$$

Presented analysis shows that CB's on overhead feeders have greater probability of reaching maximal voltage drop value than CB's on underground feeders. According with existing data, that probability is almost four times greater on overhead feeders, where calculated time is 9.63 years.

IV. Conclusion

This paper analyze CB's voltage drop, and shows importance of CB's data gathering and analyze which can be very useful for existing and also future modeling and planning. Future papers should take into account other parameters which can influence CB's lifespan, such as feeder length, number of customers.

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Improving the Mining-energy Complex Management System and the Environmental Protection Policy Based on Energy Indicators and Environmental Monitoring

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Abstract — **Environmental protection management in mining-energy complexes based results from the monitoring system enables the creation of the basis for assessing the adverse effects of the energy sector, overcoming environmental problems and defining energy indicators. Creating environmental policy based on preventive protective measures contributes to the improvement of the management system and solving of many environmental problems.**

Keywords - management, mining, energy indicators, environmental policy

I. INTRODUCTION

Mining-energy complexes produce adverse effects on the quality of air, water and soil. It is necessary to evaluate the results of primary coal energy conversion into secondary energy in order to create an adequate environmental policy and launch campaigns for the preservation of natural balance. Irrational use of energy resources has led to excessive emission of pollutants and the need to improve the organization of environmental monitoring.

II. ROLE OF THE MONITORING SYSTEM IN CREATION OF ENVIRONMENTAL PROTECTION POLICY IN MINING-ENERGY COMPLEX MAINTAINING THE INTEGRITY OF THE SPECIFICATIONS

Adequate organization of the monitoring system is a prerequisite for determining failures in the functioning of the environmental protection system. Correction of environmental protection policy, based on the application of preventive measures for environmental protection, in the process of converting primary energy into secondary energy, helps to prevent uncontrolled emissions of pollutants.

Environmental monitoring system in mining-energy complex can be organized as a part of:

- global monitoring of the energy sector impact,
- national monitoring by the state,
- regional monitoring of the territory with significant energy resources and
- local monitoring on the territory of mining and energy complex.

Endangering the environment through the mining-energy complex operation has launched the extensive study of the cross-border transfer of pollutants and international cooperation in solving rising environmental problems. Stockholm United Nations Conference on the Human Environment (1972) has approved basic principles of building a global monitoring system, which can also solve problems of the energy sector. Basic principles for the creation of the Global Environmental Monitoring System have been worked out within the framework of the United Nations environmental issues program.

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TABLE I. TECHNICAL MONITORING OF MINING-ENERGY COMPLEX

Includes	**A set of measures and activities for monitoring environmental quality parameters**
	Tracking and improving environmental quality
Research subject	Physical and chemical effects on selected samples
	Changes of biological processes in the surrounding environment
	The level of air, water and soil pollution
	Changes that occur in plants and animals
	Collection of information on the state of the environment
	Forecast of the quality of the basic elements of the environment
Result	Proposed activities that point to taking the necessary actions to protect the environment and correct the environmental policy

III. IMPROVEMENTS IN THE ENVIRONMENTAL PROTECTION MANAGEMENT SYSTEM OF MINING-ENERGY COMPLEX AND ENERGY INDICATORS

Assessment and forecast of the environmental quality, as well as the analysis of annual reports on the state of the environment, influences the formation of policy and the environmental management system. Local monitoring of mining-energy complex includes monitoring of the environmental quality level on the territory where surface mines and thermal power plants are located. It is necessary to perform monitoring on the power plant location, and after the start of the power plant operation, it is necessary to introduce monitoring of the region. The aim is to assess the facilities' impact on the environment and to define energy indicators.

Proposed activities to improve the environmental protection management system in mining-energy complex include:

- establishing mining-energy complex pollutant emissions levels and the analysis of stakeholders' attitudes;
- determining the position of dominant harmful substances emission flows and considering complaints from the population of the surrounding settlements;
- provision of standard tests and implementation of internal monitoring in order to implement the corrective measures in a timely manner.

Creating a set of energy indicators for mining-energy complex depends on data availability and relevance. Monitoring system results are obtained in the [1]:

- observation stations (places where data is collected, processed and generalized)
- territorial and regional centers (center for the analysis of data obtained from the observation stations, compiling of local forecasts and assessments of the environmental state in a particular territory) and
- national center (center for assessment of the environmental state on the national and global scale).

Energy indicators can be formed based on the analysis of the collected information and data on the energy sector impact on the environment. Necessary data on:

- characteristics of the environment,
- environmental composition characteristics for different time intervals,
- characteristics of pollution emission in the surrounding environment and
- short-term and long-term forecasts of the environmental pollution level.

Energy production may have a negligible detrimental effect on the territory of the region, but at the same time, it can significantly increase the concentration of pollutants on the local level, therefore it is necessary to create a local monitoring system. These results are very significant because they can enable the prevention of accidents and provide corrections of the environmental policy. Construction of internal quality control system in accordance with the technological process of mining-energy complex provides the best solution for real monitoring of the degree of vulnerability of the environment.

IV. DEFINING THE INDICATORS OF ENVIRONMENTAL QUALITY IN MINING-ENERGY COMPLEXES

Organization of the monitoring system within the mining-energy complex should include planning of measuring network based on

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data on the climatic characteristics of the area covered by the monitoring system, the number of emitters in the monitored area, and type, capacity and geographical location of the emission source. Depending on the factors of the monitoring source, there is monitoring of pollutants, and monitoring of pollution sources, and according to the type of the environment, the monitoring system is divided into atmosphere monitoring, soil monitoring, and surface water monitoring [1].

Monitoring of pollutants is monitoring of changes in the natural composition of basic elements of the environment, resulting from the emission of pollutants from anthropogenic sources, which can be organized based on a set of indicators. A common criterion for assessing the impact is to compare the recorded value in the monitoring of pollutants with threshold values for emissions.

Defining air quality indicators involves monitoring air quality parameters and data processing in order to determine the effect of the emitted pollutants.

Measuring stations for monitoring the impact of open pit dust emissions and gaseous products of coal combustion can be organized as:

- fixed stations (for systematic and long-term measurements)
- route stations (for continuous monitoring by means of a mobile laboratory on cars) and
- mobile stations (for monitoring the current concentration of emission sources, under the smoke plume).

Air environment monitoring includes placement of measuring points in the area where the largest concentration of pollutants is expected. Concentrations of sulfur dioxide, nitrogen oxides, soot and suspended solids must be continuously measured at the selected measuring points. Carbon monoxide and carbon dioxide concentrations are also status indicators, within a set of air quality indicators; therefore, air monitoring should also include those. The obtained data, along with the information on daily electricity production, the degree of production capacity engagement, coal quality, as well as meteorological parameters and data on electro-filter operation included in air quality monitoring, are all able to provide the assessment of spatial and temporal dispersion of pollutants.

The formation of water quality indicators includes:

- monitoring of physical-chemical, biological and organoleptic indicators of water quality

- data processing, in order to determine the impact of solid, liquid and gaseous pollutants and monitor changes in the water.

Wastewater quality in mining-energy complex is estimated on the basis of chemical composition and toxicity of pollutants contained within them. Monitoring of the physical-chemical (salt content, metals, dry residue, hardness and acidity) and biological parameters (bacteria and microbes and the amount of organic impurities) of the wastewater represents an integral part of water pollution monitoring, where the concentration of arsenic, sulfate and ammonia must also be considered as water quality indicators. A complete analysis of the water quality can be carried out if the water pollution monitoring also includes the determination of the surface area exposed to oil, lubricants and mine dust, during the wetting of roads and creation of water curtains during the transportation.

Defining the indicators of soil quality involves monitoring of land quality indicators, which include air migration, water migration, phyto-accumulative, trans-locational, organoleptic and general sanitation indicators [2].

Soil monitoring at the site of the mining-energy complex includes monitoring the presence of emitted pollutants [3], or those that are characteristic of the process of coal digging, disposal, and combustion. The area of the destroyed agricultural and forest land and the amount of buried humus layer are indicators [4] of soil quality, indicating the influence of the organization of surface mining on soil quality, so they should also be a part of the soil pollution monitoring in order to create a more realistic picture of anthropogenic environmental impact.

V. CONCLUSION

Improving the environmental protection management system in mining-energy complexes and planning the procedures to implement adequate measures for the protection of the environment, as part of the environmental policy, is based on forecasting the state of the environment and application of energy indicators to preserve the quality of air, water and soil. The policy of preventive measures application and timely corrective actions are prerequisites for the operation of mining-energy complex in accordance with principles of the sustainable development.

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Iceberg Energy Security Model in the Function of the Small and Medium-sized Enterprise Sector

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Abstract—**Energy security is an integral part of the dynamic enterprise business environment and implies securing adequate energy security based on the balance between cost and benefits, which is achieved through the maintenance and improvement of energy management systems, which, in turn, allows enterprises to: constantly improve energy characteristics, constantly increase energy efficiency and conserve energy. The paper presents the *Iceberg* models as one of the examples of maintaining energy security and decreasing ecological risks in the small and medium-sized enterprise sector (SME sector).**

Keywords - energy security, Iceberg model, SME sector

I. INTRODUCTION

In this day and age, special attention of the scientific community is paid to energy efficiency and management, given that the demand for energy is on a constant rise and that there is a real danger of exhausting fossil-fuel energy sources. Considering the rising needs for energy and the real danger of exhausting fossil-fuel sources, it is necessary to make an effort with the aim of securing a continuous energy supply at affordable prices, and taking care of protecting and conserving the environment.

Energy security represents a complex field of scientific research based on modeling energy processes, analyzing losses, network reliability and resistance to breakdowns, statistical expertise as well as danger of injury in technological systems, risk analysis, energy supply issues and other repercussions [1].

Energy security is a term which involves many issues related to economic growth and political power. A precise definition of energy efficiency is difficult to create, since it has different meanings to different people from the perspective of the time in which one lives and works; however, based on the aforementioned facts, one can conclude that:

"In the service of sustainable development, energy security represents a continuous energy supply with affordable prices, from easily accessible sources, resistant to malfunctions, based on the energy process design, loss analysis, system reliability, statistical expertise and danger of injury in technological systems" [2].

A continuous improvement of energy characteristics in technological systems requires the implementation of efficient practices and energy management processes based on experience programs (models). Every enterprise, no matter the type, size or sector affiliation, can develop an efficient program of energy efficiency.

The direct consequences of the application of energy efficiency policies would manifest themselves through increasing security in energy supply, increasing enterprise competitiveness, as well as a general increase in living standards. At the same time, improving energy efficiency would contribute to decreasing import dependency, as well as decreasing the negative effects of the SME sector on the environment.

Improving energy efficiency is carried out as a result of the existence of state duress and incentive, as well as the economic interest of the SME sector to decrease energy costs, and in that way, increase their own profit. For reasons of necessary intervention by the state, it is of vital importance that the energy management field is also legally rounded.

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Some of the forms of an energy efficient business that can be applied to the SME sector can be:

- Energy-efficient design of new, and the revitalization of old technological solutions and energy systems;
- Avoiding compromise in designing technological and energy systems at the cost of lower efficiency, for the reason of decreasing the size of investment;
- Implementing integrated management systems based on ISO standards.

Models often used in practice are: The *4 A's* model, The Model of Short-term Energy Security *(MOSES)*, The USA' Energy Security Risk Index, The Energy Efficiency Level Evaluation Model; The *Energy Star* model, The *Iceberg* model of energy security, and others.

The paper presents the fundamentals of the *Iceberg* model of energy security as one of the more applied models that contribute to the improvement of energy performance, which is directly reflected in increasing efficiency in business and decreasing environmental impacts, viewed from the perspective of the SME sector.

II. *ICEBERG* MODEL OF ENERGY SECURITY

Energy security is not an internal issue of one field or country, but an international one, and it includes global relationships between energy suppliers and consumers, as well as relationships between developed and developing countries. The energy security system simultaneously analyzes energy demand and production pressure, as well as transport channel security.

The *Iceberg* model of energy security represents a simple economic model that takes into consideration and examines energy source transportation costs. It is based on the “iceberg” idea, considering the fact that the energy source transportation process from the supplier’s location, or the location of the production plant to the consumer’s location, necessarily implies the “invisible” part of transport costs, which is not at all negligible, and in certain cases, resembles the submerged part of an iceberg.

Next to the *Iceberg* model of energy security, some of the current and actively applied models can be:

- The *4 A's* model, which includes the following elements: availability, accessibility, acceptability, and attainability. Availability relates to the geological/ physical availability of energy sources. Accessibility includes the geopolitical and technological infrastructure. Acceptability implies accepting responsibility by society and the environment, while attainability relates to the availability of investments and services [3].
- The Model of Short-term Energy Security *(MOSES)* is a tool for estimating energy security over short time periods by quantifying energy system sensitivity for individual primary energy sources and secondary fuels. It is based on a group of quantifying indicators for two aspects of energy security: risk of energy supply disturbance, as well as resistance and capability of the national energy system to deal with such irregularities, during own transformations or energy source distribution [4].
- The USA Energy Security Risk Index points to four dimensions in energy security: geopolitical (energy import, especially from politically unstable regions), economic (a high intensity in energy and a commercial imbalance), reliability (adequate and reliable infrastructure), and the environment (related to carbon-dioxide emissions). The model is primarily based on risk assessment and the determination of the energy security risk index in America, as well as on energy system resistance [5].
- The Energy Efficiency Level Evaluation Model implies a quantitative analysis to determine the energy security index. Thereby, it is necessary to define the indicators to be used in describing different aspects and categories of energy security. Numerical values of specific indicators are obtained statistically, through technical documentation or exert analysis and estimation [1].
- The *Energy Star* model is a model that provides a proven energy management strategy, and is based on the continuous improvement in energy efficiency by reducing the environmental impact and making savings through increased competitiveness. The model was developed on the basis of good practices, and it helps companies create and

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implement their own programs and strategies of energy management [6].

In accordance with the previously presented models, some of which are meant for specific economies and markets, as is the USA energy security risk index, to models whose application is based exclusively on the enterprise or company sector, and although there are many similarities, it is concluded that only the *Iceberg* model of energy security entails that, in special and unforeseen situations, the "cost" of energy source transport can be far greater than expected, according to losses which can occur during transport.

Figure 1. Annual increase of the global commercial fleet, 2000-2014 [7]

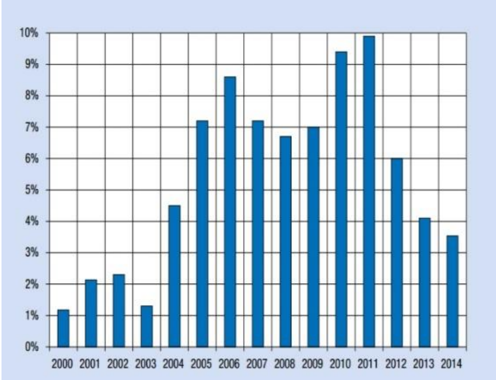

TABLE I. THE LARGEST COMMERCIAL NAVAL FLEETS IN THE WORLD (*FV - FLOATING VESSELS) [7]

Country affiliation	# of FV	Share of total World # of FV	Capacity (tons)	Share of total world capacity	Cumulative share (tons)	Average capacity (tons)	Increase(tons) 2014/ 2015(%)
Panama	8 351	9.33	352 192	20.13	20.13	44 052	0.91
Liberia	3 143	3.51	203 832	11.65	31.79	65 018	0.31
Marshall Islands	2 580	2.88	175 345	10.02	41.81	67 990	13.32
Hong Kong (China)	2 425	2.71	150 801	8.62	50.43	63 575	6.47
Singapore	3 689	4.12	115 022	6.58	57.01	33 830	8.52
Malta	1 895	2.12	82 002	4.69	61.70	43 898	8.69
Greece	1 484	1.66	78 728	4.50	66.20	63 286	4.45
Bahamas Commonwealth	1 421	1.59	75 779	4.33	70.53	54 322	2.54
China	3 941	4.41	75 676	4.33	74.85	20 756	-1.28
Cyprus	1 629	1.82	33 664	1.92	76.78	32 000	3.96
Isle of Man	1 079	1.21	23 008	1.32	78.09	55 441	-2.28
Japan	5 224	5.84	22 419	1.28	79.38	5 558	7.47
Norway	1 558	1.74	20 738	1.19	80.56	15 339	-1.20
Italy	1 418	1.58	17 555	1.00	81.57	14 556	-11.22
Great Britain	1 865	2.08	17 103	0.98	82.54	16 059	-0.35
The Korean Republic	673	0.75	16 825	0.96	83.51	10 099	-3.13
Denmark	7 373	8.24	16 656	0.95	84.46	26 606	13.94
Indonesia	1 604	1.79	15 741	0.90	85.36	3 681	2.29
India	1 174	1.31	15 551	0.89	86.25	10 157	-1.39
Antigua and Barbuda	650	0.73	12 753	0.73	86.98	10 909	-3.45
Germany	3 561	3.98	12 693	0.73	87.70	22 230	-11.69
USA	1 613	1.80	12 683	0.73	88.43	6 089	2.59
UR of Tanzania	1 313	1.47	11 703	0.67	89.10	46 256	-1.54
Bermuda	1 254	1.39	11 511	0.66	89.75	71 946	2.69
Malaysia	1 777	1.99	9 232	0.53	90.28	6 793	-0.95
Turkey	2 471	2.76	8 820	0.50	90.79	8 181	-2.64
Netherlands	1 412	1.58	8 651	0.49	91.28	7 536	0.34
Belgium	756	0.85	8 609	0.49	91.77	45 548	21.96
Vietnam	674	0.75	7 351	0.42	92.19	4 499	0.81
The Russian Federation	963	1.08	7 221	0.41	92.60	2 974	2.45
France	670	0.75	6 882	0.39	93.00	16 042	-8.85
Philippines	646	0.72	6 850	0.39	93.39	6 149	6.19
Kuwait	765	0.86	5 440	0.31	93.70	40 002	37.91
Thailand	749	0.84	5 070	0.29	93.99	7 636	0.86
Taiwan Province (China)	586	0.66	4 829	0.28	94.27	18 431	8.05
First 35 total	72 377	80.90	1 648 937	94.27	94.27	27 697	3.53
World total	89 464	100	1 749 222	100	100	22 757	3.54

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Global energy security is mostly related to the “shock” in oil supply, which emerges from transport risk. It is a fact that oil transport implies high transport costs and spent time. In addition, it is worth pointing out that there is a risk of unforeseen events, such as oil leaks from tanks, periodical pirate activity, and even military actions. In accordance with this, risk management definitely deserves adequate attention.

In recent years, with the increase of oil prices, energy security represents a burning question for every nation and region. At the same time, an increase has been recorded in the global commercial naval fleet in the period from 2000-2014, diagram 1. In the previous year, i.e. 2015, in parallel with the decline of oil prices, the growth of the global naval fleet declined, and with its 3.5 %, represents the smallest increase in the last decade

More than 40 % of the oil produced globally is delivered to other regions and countries, meaning that naval oil transport makes up one third of the total naval ocean transport, diagram 1, table 1. The *Iceberg* technology of ocean transport was formally introduced by Samuelson, and today, “Krugman’s” type of the *Iceberg* model is applied to successful solutions to the international economic problems in the field of “new spatial economy” or “new economic geography” [8].

III. KRUGMAN’S *ICEBERG* MODEL TYPE

Traditionally, agricultural and industrial products are delivered between locations, and because of this, costs necessarily arise during transport, which is what the *Iceberg* model of energy security indicates. The application of models and techniques derived from the theoretical analysis of industrial organizations allows questioning the economic geography and incorporating findings and experience coming from informal tradition into formally organized models, i.e. “Krugman’s” type.

The basic goal for creation and development, and therefore the goal of “Krugman’s” *Iceberg* model of energy security, is to shed light on one of the key questions about geographic location. This means that the question to which an answer is expected is the following: why and when is production concentrated in specific regions, while simultaneously ignoring and leaving other areas relatively undeveloped [9]?

For example, if we take oil as the unit of a product to be delivered from location 1 - production, to location 2 - processing or consumption, “Krugman’s” definition of the *Iceberg* transport costs is given in the equation:

$$Q_2 = Q_1 e^{-\tau D}, \tag{1}$$

in which Q_2 represents the amount of oil delivered to location 2, and Q_1 represents the amount of oil produced at location 1. τ represents the “melting” of the iceberg, and D stands for the transport distance.

With the aim of determining prices of the delivered oil, the cost of acquisition at production location 1 at price P_1 per product unit is placed for consumers at location 2, according to the equation:

$$P_2 = P_1\left(\frac{M_1}{M_2}\right), \tag{2}$$

where P_2 represents the cost per unit of the delivered oil, M_1 represents the amount of the delivered oil. According to equation “(1)”, (M_1/M_2) can be presented as $Q_1/Q_1e^{-\tau D}$, which leads to the following equation:

$$P_2 = P_1\left(\frac{Q_1}{Q_1 e^{-\tau D}}\right) = \frac{P_1}{e^{-\tau D}} = P_1 e^{-\tau D}. \tag{3}$$

By taking into consideration (1) and (2) and applying them to both sides of the equation (3), with the transport distance of D, we get:

$$\frac{\partial P_2}{\partial D} = \tau P_1 e^{\tau D}, \tag{4}$$

and

$$\frac{\partial^2 P_2}{\partial D^2} = \tau^2 P_1 e^{\tau D}. \tag{5}$$

Equations (4) and (5) present the relationship between the transport distance and the delivered oil prices. From these equations, we can see that all the functions of the *Iceberg* transport costs

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are strictly convex, according to the transport distance D and the parameter of transport risk τ.

The analytical expressions relate to the "Krugman" type of the *Iceberg* model of only one country. It is possible to expand this simple model into a two-country model. In the two-country model, a market trade analysis matrix can be used to display the balance between oil producing countries. If this model is expanded from two to *n* countries, the conclusion that can be made from the expanded *n*-national model would be that the best solution is the creation of a global supply network with a minimum production risk and transport costs [8].

In the same way, a production entity can be viewed as part of the SME sector of one state's macro-economy, and the change of economic gradients can be analyzed with minimizing transport costs. At the same time, it is possible to follow production system shares in a total national income, as well as the tendency of enterprises to be located in a region which has significant potential at its disposal, as well as attractive resources, or an area characterized by larger and more specific requests for a certain type of final product.

IV. *ICEBERG* MODEL OF ENERGY SECURITY IN THE SME SECTOR

It is necessary to achieve the progress in energy security in all levels of the technological cycle: production, transport, transfer, distribution, consumption and energy management. Given the fact that energy security is an important assumption in sustainable development, developing and improving competitiveness in both domestic and global market, activities in the domain of the development of the most affordable energy transport and transfer systems, their connection to neighboring energy systems represents the basic activity of each trade subject. Knowing the characteristics and understanding the specificity and structure of individual transport technologies contributes to the choice of the optimal way to realize transport, which is a crucially important factor in energy security.

Even though the *Iceberg* model of energy security is traditionally used in the global transport technology, and considers the effects of international production, transport and distribution of energy sources, it can be simultaneously used in modeling the energy security of technological systems, such as small and medium-sized enterprises.

If the basic idea of the *Iceberg* model is modified, it can find a real application in considering factors of the loss and effects of supplying the technological process with the necessary energy sources, as part of a certain production technology in the SME sector.

By taking Samuelson's analysis of the cost of the *Iceberg* transport technology into consideration, the maximum value of the function is defined for the specified problem. In the equation pertaining to the amount of the transported energy source from location 1 to location 2, only a part of the total amount of the τ_1 initial energy source reaches location 2, and the rest is attributed to losses, i.e. "melting" of the iceberg on the way. The optimization method of the function's value can be presented as:

$$\begin{aligned} MaxV = P_2Q_2 - r_1(1-\tau_1)\tau_2Q_1 \\ - r_2(1-\tau_2)Q_1 \end{aligned}, \qquad (6)$$

meaning,

$$\begin{aligned} MaxV = (c - d\tau_1\tau_2Q_1)\tau_1\tau_2Q_1 - \\ - r_1(1-\tau_1)\tau_2Q_1 - r_2(1-\tau_2)Q_1 \end{aligned}, \qquad (7)$$

where:

P_1-is the total energy source cost;
P_2-is the price of energy source at the destination;
Q_1-is the total amount of energy source;
Q_2-is the amount of energy source at the destination;
τ_1-is the percentage of the supplied energy source produced at location 1;
τ_2-is the percentage of the delivered energy source;
r_1-is the cost of risk management at location 1;
r_2-is the cost of risk management at location 2.

Based on the condition,

$$\begin{aligned} \frac{\partial V}{\partial Q_1} = c\tau_1\tau_2 - 2d\tau_1^2\tau_2^2Q_1 - \\ -r_1(1-\tau_1)\tau_2 - r_2(1-\tau_2) = 0 \end{aligned}, \qquad (8)$$

an optimized result of the equation follows:

$$Q_1 = \frac{c\tau_1\tau_2 - r_1(1-\tau_1)\tau_2 - r_2(1-\tau_2)}{2d_1{\tau_1}^2{\tau_2}^2}. \quad (9)$$

Based on equation (8), the following equation emerges:

$$\frac{\partial V^2}{\partial^2 Q_1} = -2d{\tau_1}^2{\tau_2}^2 \leq 0,\ d > 0 \quad .(10)$$

If:

$$Q_2 = \tau_1\tau_2 Q_1, \quad (11)$$

the loss function could be presented as:

$$\begin{aligned} \ln L_2 &= \alpha \ln D + \beta \ln Q_2 \\ &= \alpha \ln \tau_1 Q_2 + \beta \ln Q_2 \end{aligned}, \quad (12)$$

$$\frac{\Delta L}{L} = \underbrace{\alpha\frac{\Delta D}{D}}_{a} + \underbrace{\beta\frac{\Delta Q}{Q}}_{b} \quad (13)$$

where:

a-is the transport loss;
b-is the effect of pollutant emission due to energy source consumption.

The optimized solution to equation Q_1 is related to transport security coefficient - τ_1, production security coefficient - τ_2 and enterprise demand flexibility - d [8].

The processes of optimization in business are influenced by the parameters unrelated to risk management costs, in different phases of energy source transport. Transport risks are numerous and depend on the means of transportation, the natural characteristics of the energy source, the transport relation length, and other factors. Transport risks are directly connected to losses and, according to this, management and objective risk assessment are important factors in overcoming potential transport losses, as well as the probability of occurrence. Transport risks are numerous and various, and these include:

- traffic or naval accidents;
- fires or explosions;
- earthquakes or volcanic eruptions;
- natural disasters;
- disposal of transport vessels including the energy sources;
- leaks or losses of the energy source;
- non-deliveries, robberies and other.

V. CONCLUSION

The role of the sector of small and medium-sized enterprises is of strategic importance, specifically because of their market and technological flexibility, and crucial to the energy security problem analysis.

Based on a modified *Iceberg* model of energy security, the paper presents, its real application in the small and medium-sized enterprise sector in the process of loss factor analysis and the analysis of the effect of supplying technological systems with the necessary energy sources. At the same time, at today’s level of technical and technological development, the instability of energy systems and the increased energy consumption are necessarily followed by an increase of harmful gas emissions, which has a consequence of negative implications on the environment. The concept of safe energy supply should be restrictive, and the mechanisms leading to energy losses reduced to the minimum. This can be achieved by:

- forming an inner-national supply chain made up of a network of producers and service providers that would supply production systems with the necessary energy sources in the shortest, most economic and most rational way;
- applying market trade and help channels.

By applying the *Iceberg* model of energy security, a very reasonable conclusion can be made: production process optimization and energy source distribution are actually feasible, and this means it is possible to optimize the consumption of the sources in the small and medium-sized enterprise sector.

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Technological Model of Coal Deposit – base for Mine Production Planning

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Abstract—**The main aim of creation the technological model of coal deposit is to help mine planners to define production plan in much more efficiently and easier way. Such model means clustering the mineable blocks into groups with respect to the defined value of the technological parameter. The act of the clustering is performed over the data obtained by measurement of distance between target value of the technological parameter and actual value of the block attribute. This distance is expressed by adequate objective function. In this paper the calorific (heating) value of the coal represents the block attribute while the target value is defined by the thermal power plant. The technological partitioning of the coal deposit is based on the application of K-mean clustering algorithm over the measured distances.**

Keywords - coal deposit, heating value, blocks, K-mean clustering, technological model

I. INTRODUCTION

The traditional block model of coal deposit means the coal deposit is divided into adequate number of blocks having the same size. Such model is created using the data obtained from exploration drilling and application of developed geostatistical methods. Each block is characterized by a certain number of attributes, such as dimensions, location, density, tonnage, heating value, ash and sulfur content. Suppose what portion of the coal deposit is defined to be mined in economical way (mineable reserves), that is, ultimate number of mineable blocks is defined.

Sahu et. al use the K-means clustering approach for classification of coal seams with respect to their spontaneous susceptibility [1]. Hammah and Curran apply the fuzzy K-means algorithm to isolate fractures in rock mass [2].

Technological model describes the spatial variability of the heating value attribute with respect to value defined by the thermal power plant.

II. THE MODEL

Let $B = \{b_n\}_{n\geq 1}$ be the set of mineable blocks in the coal deposit. Each block is characterized by a certain number of attributes. In our case these attributes are: dimensions, location and heating value. Geostatistical block model for a real life can easily contain hundreds of thousands to millions of blocks. In the presence of such number of blocks the production planning can be very hard and time consumption task.

One of methods of reducing the size of the production planning problem is to first partition the coal deposit into finite number of technological areas. Each area is composed of the set of blocks having the same distance between required and actual value of heating value attribute.

- *Definition* 1:

Let $\{b_n\}_{n\geq 1}$ be a sequence of mineable blocks. A subsequence of $\{b_n\}_{n\geq 1}$ is a sequence $\{b_{n^i}\}_{i\geq 1}$ with $n^i < n^{i+1}$ for all $i \geq 1$.

- *Definition* 2.

A point k is called a cluster point or accumulation point of a sequence $\{b_n\}_{n\geq 1}$ if for any $\varepsilon > 0$ and any $N \geq 1$ there is an $n \geq N$ such that $|c - b_n| < \varepsilon$.

Considering *Definition* 1 and *Definition* 2 we can create a cluster, composed of mineable blocks, with values of attributes belonging to predefined intervals. We refer to this cluster composed of blocks as technological mining-cut. The core algorithm of our model is based on the application of K-mean clustering algorithm. Cluster analysis is very useful way to group mineable blocks. The K-means problem is to partition data into K groups such that the sum of squared Euclidean distances to each group mean is minimized. The term "K-means" was first used by James MacQueen in 1967 [3].

If $\boldsymbol{x}$ are the objects and k are the cluster centers, K-means attempts to minimize the following objective function:

$$F = \sum_{j=1}^{K} \sum_{i=1}^{N} \left\| x_i - k_j \right\|^2, \quad (1)$$

The object $\boldsymbol{x_i}$ represents the distance function. This function takes into account the distance of the actual heating value of the *i-th* block from target value required by the thermal power plant. Hence, for the problem of technological coal deposit model, the distance function is defined as follows:

$$d_i = \frac{V - V_i}{V}, \; i = 1, 2, \ldots, N, \quad (2)$$

where:

V – target heating value required by the thermal power plant

V_i – actual heating value of the *i-th* block

Note, the value of d_i does not represent only the distance, it also indicates the quality of block with respect to target value. The quality of block is defined by sign function of d_i as follows:

$$sign(d_i) = \begin{cases} + \; if \; V_i < V \\ 0 \; if \; V_i = V, \; i = 1, 2, \ldots, N, \\ - \; if \; V_i > V \end{cases} \quad (3)$$

According to Equation (2) our objective function is now defined as:

$$F = \sum_{j=1}^{K} \sum_{i=1}^{N} \left\| d_i - k_j \right\|^2, \quad (4)$$

The number of technological mining-cuts is assumed to be fixed. We propose the five mining-cuts with following characteristics (see Table I).

TABLE I. SCALE OF MINING-CUTS

Mining-cut class	Code	Description
$VHD^{(-)}$	1	mining-cut having the very high distance and quality greater then target value
$HD^{(-)}$	2	mining-cut having the high distance and quality greater then target value
ED	3	mining-cut having the distance almost equal to zero and quality almost equal to target value
$HD^{(+)}$	4	mining-cut having the high distance and quality lower then target value
$VHD^{(+)}$	5	mining-cut having the very high distance and quality lower then target value

The algorithm of coal deposit partitioning into technological areas is defined as follows (see Table II).

TABLE II. CLUSTERING ALGORITHM

1. Initialize the number of K mining-cuts: $\mathrm{K} = \{k_j\}_{j=1,2,\ldots,5}$
2. Initialize the K mining-cuts centers in ascending order of d_i: $k_j \in [d_i^{min}, d_i^{max}], \quad k_1 < k_2 < \cdots < k_5$
3. Compute the objective (membership) function: $F = \sum_{j=1}^{5} \sum_{i=1}^{N} \left\| \frac{V - V_i}{V} - k_j \right\|^2$
4. Decide the mining-cut class memberships of the N mineable blocks by assigning them to the nearest mining-cut center
5. Update the mining-cuts centers in each mining-cut using the mean (centroid) of the input blocks assigned to that mining-cut
6. If none of the N mineable blocks changed mining-cut class membership in the last iteration, stop. Otherwise go to 3

III. NUMERICAL EXAMPLE

Block model of coal deposit were created on the basis of exploration drilling and geostatistical methods. The input parameters required for the model testing are given in Fig. 1, Fig. 2 and Table III. Note that the situation is

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hypothetical and the numbers used are to permit calculation.

Applying the Equation (2) we obtain the values of distance function within the following interval: $d\_i \in [-0.081, 0.079]$. Initial values of K mining-cuts centers (k_1, k_2, k_3, k_4, k_5) are: -0.06, -0.02, 0.02, 0.04, 0.06

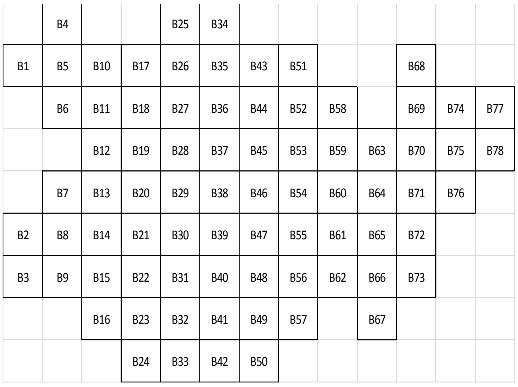

Figure 1. Block model of coal deposit

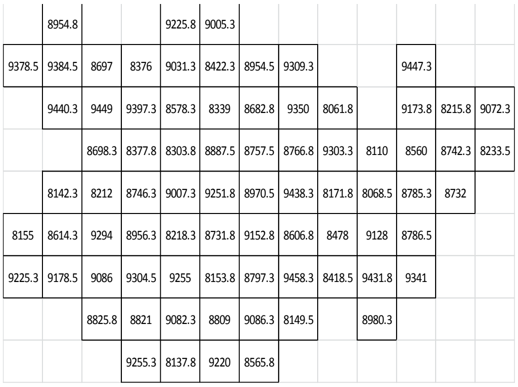

Figure 2. Model of heating value

TABLE III. INPUT PARAMETERS

Parameter	Value
Number of blocks	78
Block dimension	30×30×8 m
Mean heating value	8832 kJ/kg
Standard deviation	427 kJ/kg
Coefficient of variation	4.83 %
Minimum heating value	8062 kJ/kg
Maximum heating value	9458 kJ/kg
Target heating value	8750 kJ/kg
Number of mining-cuts	5

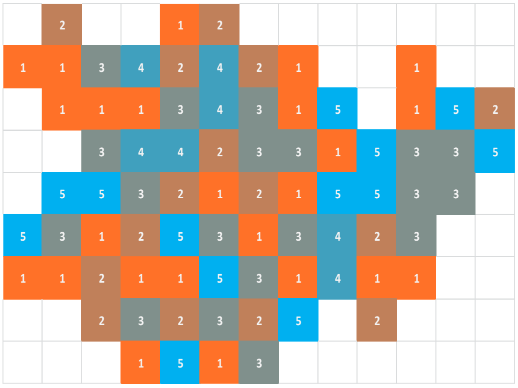

Figure 3. Technological model of coal deposit

Technological model of coal deposit obtained by proposed model is represented in Fig. 3

Characteristics of technological model of coal deposit are represented in Table IV.

TABLE IV. CHARACTERISTICS OF TECHNOLOGICAL MODEL OF COAL DEPOSIT PARAMETERS

class	code	Number of blocks	Part (%)	Interval kJ/kg	Mean kJ/kg	Standard deviation kJ/kg	Coeff. of variation (%)
$VHD^{(-)}$	1	24	30.77	9153.9458	9319	95.61	1.02
$HD^{(-)}$	2	15	19.23	8826.9128	9002	79.38	0.88
ED	3	19	24.36	8560.8821	8709	83.22	0.95
$HD^{(+)}$	4	7	8.97	8304.8478	8388	53.39	0.63
$VHD^{(+)}$	5	13	16.67	8062.8234	8156	52.67	0.64

IV. CONCLUSION

In the presence of large number of mineable blocks the production planning can be very hard and time consumption task. The first step making easier the production planning problem is related to partitioning the coal deposit into finite number of technological areas. Each area is composed of the set of blocks having the same distance between required and actual value of heating value attribute. The core algorithm of our model is based on the application of K-mean clustering algorithm. The clustering is performed over the set of measured distance data. Further research will be focused on dynamic nature of mine production planning.

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Economic Regulation of Electric Power Distribution Network

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Abstract—**This paper gives an overview of concepts from the perspective of Infrastructure Economics, Microeconomics and Industrial Organization that theoretically describe economic nature and behavior of the Electric Power Distribution Company as an economic agent. In addition, the paper focuses on challenges in the regulatory design for obtaining the optimal social welfare and incentivizing the Utility for achieving economic efficiency through implementation of transparent economic regulation.**

Keywords - Distribution system operator, infrastructure economics, SCP paradigm, regulation

I. Introduction

The Electric Power Distribution Company is in charge of operating, planning and developing the Distribution grid. As a network-based natural monopoly, it is a sole provider of electricity supply service in their area of influence [1].

Traditionally, electric power distribution was one among equally important activities within large vertically integrated Utilities, which main task was to deliver the essential good to society –electricity. Nowadays, Distribution companies are perceived and assessed separately as independent Distribution System Operators (DSO) where interrelation with other segments of the Electric Power System (EPS) are mainly in technical domain regarding day-to-day operations.

Historically, for satisfying the needs of society the EPS were mainly state-owned, because as a large-scale infrastructure it required big investments for developing the network grid and covering large operational expenditures for maintenance. Nevertheless, there were examples of privately-owned EPS in cases when Governments had insufficient budgets. Therefore, the Electric power industry is depicted as national or regional monopoly subject to price control regulation, where a regulator is setting new tariffs periodically. The system was understood as a holistic formation, where technological and economic sustainability of the system could only be strived through regulation of the EPS as *Natural monopoly*[1] [2].

For such complex system to function properly and bring the optimal social welfare, technical sufficiency and economic efficiency has to be reached at all time and through all phases of the service provision. During 80s there was an increasing awareness "that a lengthy period of state ownership, without the forces of competition or the incentives of the profit motive to improve performance, eventually resulted in excessive costs, low service quality, poor investment decisions, and lack of innovation in supplying customers" [3]. However, due to monopolistic nature of EPS, the question remains to what extent it should be left for market forces to act on its own or, in other words, how much the regulatory hand should be used for control of the Electric Power Sector.

Consequently, it was recognized that economic efficiency can be further increased if the system is approached independently through its functional phases: generation, transmission, distribution and retailing, as not all of them have the characteristic of natural monopoly and should not be regulated in such manner. After deregulation and liberalization of EPS, the generation and retailing of Electric power are viewed as activities that can be undertaken on a

[1] The case when market efficiency is achieved only with existence of a single economic agent under regulation.

competitive market level, whereas network activities, electricity transmission and distribution, are considered to be natural monopolies and still in need of regulation (Fig. 1) [4].

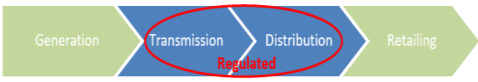

Figure 1. Electricity value chain

It is obvious that distribution, together with transmission, has to stay regulated as natural monopoly. The simple justification lies in avoiding the redundancy of the large-scale distribution network, which is very complex and asset specific. Any duplication of the grid would not be cost-effective, as the price of providing the service would be doubled or even tripled, in proportion to redundancy factor: number of distribution companies owning power lines through the same region.

From a regulatory point of view, economic problem of infrastructures might be explained with *Tragedy of commons*[2], where infrastructure is seen as a scarce resource with limited capacity. This dilemma is always present within concept of Common Pool Resources. From a market perspective, Electric Distribution Networks and other infrastructures in general should be considered as Natural Monopolies mainly because of two reasons: *Economies of scale*[3] and *Sunk costs*[4]. Common Pool Resource and Natural Monopoly are two concepts that are essence of Infrastructure Economics, as elaborated in the second section of this paper.

By using basic principles of neoclassical economics on price theory, an optimal output of the distribution grid can be theoretically determined. Of course, this requires vast number of assumptions and calculations for simplification of complex operation costs and its presentation as an average cost per unit of provided service (distribution of electricity). Fair-return revenue for the DSO should be equal to the average cost of managing the grid and can be further presented as fees charged to consumers that exploit the grid. This rationale is elaborated in the third section of the paper.

Based on the neoclassical theories, Joe S. Bain Jr. in his book “Industrial Organization”, (1959) recognizes Structure-Conduct-Performance (SCP) paradigm as most effective approach for analyzing markets and behavior of market agents in relation to their performance. This paradigm can be used as the basic framework for developing regulatory tools, because it reveals the presence of *market failures* [5] *(imperfections)*, thus allowing authorities to achieve satisfying level of social welfare by addressing those issues. The application of the SCP paradigm on regulation of DSOs is presented in the final section of this paper.

II. Economics of Infrastructures

In theory of Microeconomics, the ultimate efficiency can be achieved only through open competitive markets. These markets are described through “Perfect competition” market structure, where productive efficiency is achieved through the least-cost supply and economic efficiency is measured through maximization of social welfare[6].

However, it is hard to apply the same logic to infrastructures as physical network-industries. Main economic reason why this is not so easily applicable to Infrastructures is existence of market imperfections, which in the long-run cannot be overcome only by market forces. This requires regulatory intervention for industries with large-scale infrastructures to obtain the optimal output to society.

In general, every market can manifest, to different extent, a long list of market imperfections, such as: market concentration, principal-agent problem, economies of scale, public and common goods, incomplete information, transaction costs etc. But, two most dominant failures observed in infrastructures are *Common Pool Resource* and *Natural Monopoly*.

The notion of *Common Pool Resources* (CPR) “refers to a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential

[2] The essential resource will be scarce without proper regulation for its utilization, due to economic nature of stakeholders.
[3] The average production or service costs decrease with the large-scale increase of the output volume.
[4] Upfront unavoidable costs for establishing base structure for service provision that are almost impossible to recover.
[5] *Market failure* occurs when a market, even with proper institutional support, is economically inefficient [5].
[6] Optimal allocation of resources and goods leads to maximized social welfare.

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beneficiaries from obtaining benefits from its use" [6].

Infrastructures are obviously man-made resource systems where significant problems are associated to crowding effect and overuse, which are mostly related to insufficient incentives to invest and poor management of already existing assets. Therefore, the focal point of governance when utilizing infrastructures should be on proper allocation of costs and benefits among grid stakeholders. In other words, market externalities [7] should be properly internalized. This aspect is very noticeable when dealing with environmental impacts.

For solving all these problems, infrastructures have to be perceived by their physical nature: a system of interconnected links and nodes, which requires coordination of activities due to its complementary, taking into consideration that infrastructures are "complex socio-technical systems, in which technological, economic, political and social features strongly interact" [8].

With four essential infrastructure service functions: System management, Capacity management, Interconnection and Interoperability, a proper setting for addressing CPR problems can be created.

System management is mostly related to short-term management activities for network coordination that will sustain the system and provide a satisfactory level of service quality. This is considered to be very critical activity for liberalized infrastructures, because without proper regulation, Economic agents are mainly focused on commercial aspects of the industry and efficient utilization of the existing grid. Thus, they have a tendency to pay less attention on network activities in a long-run, on a strategic development level.

On a strategic level, network access and scope are important issues, as networks are scarce resources due to capacity limits of nodes and links. These issues are resolved with *Capacity management* system function, which defines under what conditions economic agents are allowed to use the network, with spatial and temporal differentiation. All of this, in the same time, has "to be properly facilitated by suitable regulation, for instance with respect to tariffs and technical quality standards" [9]. Usually, as a management tool, sophisticated load flow and balancing models are used for real-time operations that will take into consideration capacity constraints of a system. Also, for managing the network a certain form of indicative planning is needed, where behavior of agents and given incentives are taken into consideration when capacity and capability expansion of the network is estimated in a long-run [10].

Interconnection among links and nodes is a crucial aspect of the networks, related to physical system boundaries. In relation to distribution network, an insufficient degree of interconnections and also low number of redundant links in high user-concentrated areas (urban networks) can affect the system reliability and security of supply [11].

The last function for addressing CPR problems would be *Interoperability* of a system, where interaction among network elements enables systems' complementarity. In general, "interoperability defines the technical and institutional conditions under which infrastructure networks can be utilized". This requires certain level of standardization through technical norms and standards and regulation of network access. For a proper functioning of the system, coordination of the system use, as well as the rules for entry and exit are of most importance. As providers of public service, DSOs have to maintain the universal access philosophy in their real-time operations and long-term planning, considering that use of electricity, as an essential good, is a right of everyone. The bottom line is that Distribution Network infrastructure, as a CPR, is in need of a well-defined regulatory framework which can grasp the system's complexity, capacity, scarcity and necessity to society [12].

From Microeconomics perspective, a Distribution Network can be also approached through theory of N*atural monopoly*. It is a monopoly where only one economic actor within an industry or market manages to overcome market failures and becomes the sole supplier of a product or service to society. In the case of network-based natural monopolies, the

[7] "*Externalities* arise when an economic agent, is affected by another agent´s production or consumption decision, which are not taken into consideration by the latter in its production or utility function. The failure to take this impact into account leads to inefficient resource allocation" [7].

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dominant market failure is reflected through big investments, which are ex ante fix costs that are theoretically not included in strategic behavior of an actor when determining the optimal output to the market. These investments are considered as *Sunk costs*, which are hard to recover through selling product or providing service in a short-run, or not recoverable when leaving the business due to high degree of asset specificity. Distribution Network is a good example of a natural monopoly. As stated, large investments are needed in building and maintaining the network. The network has a sole purpose, to transport Electrical power to end-consumers. If a company decides to change its core business, invested capital cannot be recovered easily and to the fullest, because of assets' economic value depreciation over the years and existence of *opportunity costs*[8]. However, the same sunk costs are barriers for new entrants to enter the distribution business [13].

Other aspect of a natural monopoly in general is *Economies of scale*. The significant contribution of Economics of scale in a Distribution Business derives from increase in grid connections. Meaning that when connecting one consumer to the grid requires almost equal investments in comparison to significantly larger number of consumers that are relatively close to each other. Most of sunk costs are related to distribution poles or costs for placing underground cables in urban areas, which has to be done regardless if there is one or multiple consumers nearby. So, average costs for providing a service decreases with every extra end-consumer connected to the already existing line in a local area. Same logic can be applicable for Distributed Generation. The effect of economics of scale is common in all network industries.

Also, interesting to mention is the concept of *Network effect* that is easily confused with Economics of scale. In general, Network effect represents a situation where increase of network users increases the system´s capabilities and adds an economic value to the service provided (e.g. increased presence of Distributed Generation). This benefit relates mostly to quality and security of Electricity supply for end-consumers, meaning that Distribution Company can provide a better service with small or no extra costs for managing the grid. This concept is closely related to the grid Interoperability function.

It is evident why Distribution network and other similar utilities are seen as natural monopolies and why the utilization and expansion planning of a network system has to be carefully carried out (common pool resources). However, the question remains: *Why a natural monopolist should not be left alone to behave as its economic nature imposes, but needs to be regulated?*

III. NEOCLASSICAL APPROACH TO ECONOMIC REGULATION – LOOKING FOR A BREAK-EVEN POINT

Electric Power Distribution business, among many other infrastructure businesses (gas or water supply, roads and railroads, etc.), is the provider of essential goods to society. Thus, there is a strong need for appropriate transparent regulation, as it might be tempted to overcharge the service it provides, due to its monopolistic nature. As a consequence, it will decrease the overall social welfare.

From a Neoclassical perspective on Microeconomics, there is always a universal market equilibrium point, applicable to any market structure (perfect competition, oligopoly or monopoly), where marginal revenue equals marginal cost $(MR = MC)$. This point represents rational behavior of economic actors where, in theory, the optimal output to supply the market is determined. For an actor, above that point it is not cost-effective to have any more outputs.

In perfectly competitive markets (Fig. 2) there is no extra profit acquired and marginal revenues (MR) are represented only by price (P). Also, important to notice is that all market participants are price-takers, so their residual output will not affect the price in the market (under condition that number of participants is significantly large). The only challenge for each economic agent is to set its optimal output. For achieving equilibrium in a long-run, economic agent will operate at minimum average costs (MC=ATC) for recovering its true costs of production (productive efficiency). In the same time, the quantity has to reflect the allocative

[8] The made investments presented as sunk costs could have been used for other alternative investments that might bring greater return than being invested in the grid.

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efficiency[9] of the market where marginal costs can be covered with the established market price (*MC*=*P*) [14].

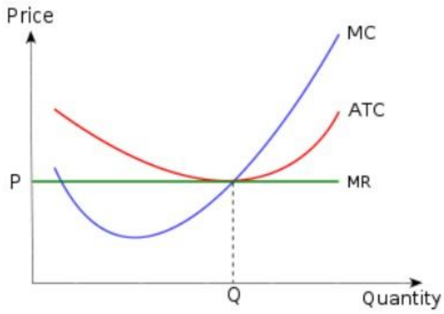

Figure 2. Perfect competition

In the case of natural monopoly (Fig. 3) these equalities are not valid, due to economics of scale there will be a continuous decrease of average total costs with the increase of outputs. At the point where $MR = MC$, a monopolist will set its output and obtain its extra profit, which is considered abnormal due to market failure. A monopolistic price (P_m) will be set at the point where vertical line of the optimal output (Q_m) crosses the demand curve (*D*). The extra profit obtained will be the difference between two points (P_m) and (P_f).

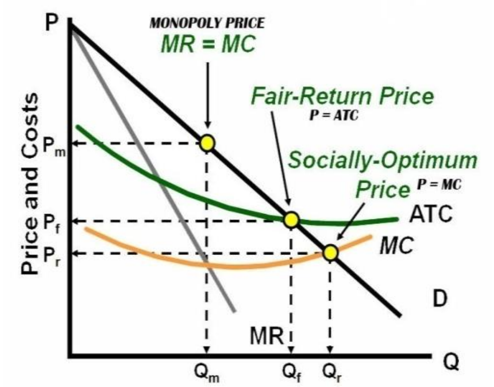

Figure 3. Natural Monopoly**Error! Reference source not found.**

The reason for regulatory interference lies with the fact that P_m is set on a level where marginal cost of one extra output (product or service provided) does not represent the true costs (*ATC*) of the monopolist, due to economics of scale.

Setting an optimal output of a monopolistic company is now a challenge for a regulator as economic welfare of society (sum of consumers´– CS and producer´s surplus –PS) might get affected (Fig. 4).

Although the output of a natural monopolist (Q_2) might be optimal from its own point of view, it is not socially acceptable, as it doesn't maximize the overall social welfare. This loss of economic welfare is also known as a deadweight loss or loss of economic efficiency (represented by a gray triangle) [16].

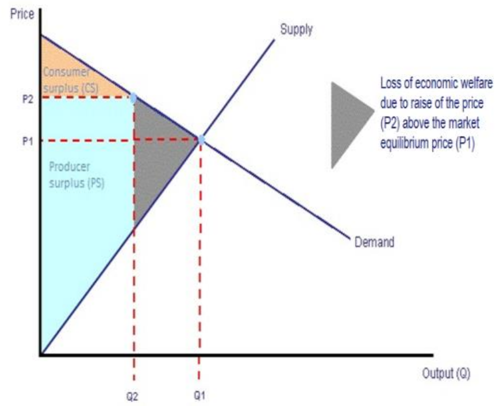

Figure 4. Loss of economic welfare

It is hard to distinguish optimal revenues that Utilities are entitled to. Setting socially-optimum price (Fig. 3), where service is provided for the price of its marginal costs, would be beneficial to consumers, but not for a utility. A utility would not be able to recover its costs, and the business would not be sustainable in the long run. This requires some kind of governmental intervention to keep the utility operational. The financial aid from the government eventually will be allocated to tax payers that are, again, consumers of utility services, so on a microeconomic level this is not an optimal solution [17]. This means that the regulated price should be somewhere in between the point of monopolistic price (*MR*=*MC*) and the socially optimal price (*P*=*MC*). A distribution company should be able to recover its overall costs, so the fair-return price (*P*) should be equal to *ATC* of the Company, acquired through service provision. This rationale is also known as "Ramsey-Boiteux"

[9] Level of output that satisfies consumers preferences, where marginal benefit to consumer (price) equals to the marginal cost of the product

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pricing, where the price should be set at the level that won't bring any extra profits to the company and where social welfare will be maximized [18].

In some cases, a monopolist might actually favor some form of regulation. By allowing the adjustment of prices, company is lowering its business risk, as the existence of regulation will create a certain "barrier to entry" for new competitors [19]. Some of the barriers might be the exclusive territorial franchise that companies receive from the regulators for certain time period (usually very long) and favorable loans or subsidies that can receive from Banks under Government warranty. Other rationale could be that companies are willing to accept such arrangement just to avoid any further interference of government (this kind of governance represents a "light-hand" regulation).

IV. SCP PARADIGM AS THE BACKBONE OF THE REGULATION

Regulation as a tool for reaching efficiency objectives is mostly focused on economic efficiency (maximizing social welfare by reducing operational costs of DSO). On the other hand, technical aspects of the system should not be overlooked by regulation, as it can affect the performance of the system (imposing technical standards for achieving system's reliability and security of supply).

One of the approaches is to structure Regulatory interference in Energy markets through SCP (Structure-Conduct-Performance) paradigm with regulatory variables that can conceptually shape the market and behavior of the economic agents in the market [20].

Important to mention about the concept of SCP is the certain ability of prediction due to its unidirectional property. Namely, depending on the structure of the market (monopoly, oligopoly or competitive market) it is possible to anticipate the behavior of economic agents, thus foreseeing the performance of the market. In the case of DSOs as natural monopolies, the performance will be based on the activities of a single economic agent in the defined region of influence. The system performance, charged price to consumers, impact on environment etc. are criteria that help regulator in adjusting the Market structure and to control the behavior of a utility. A never ending loop is created through the feedbacks that regulator gets from Conduct and Performance criteria and actions that undertakes to adjust the Market structure and influence the conduct of agents [21].

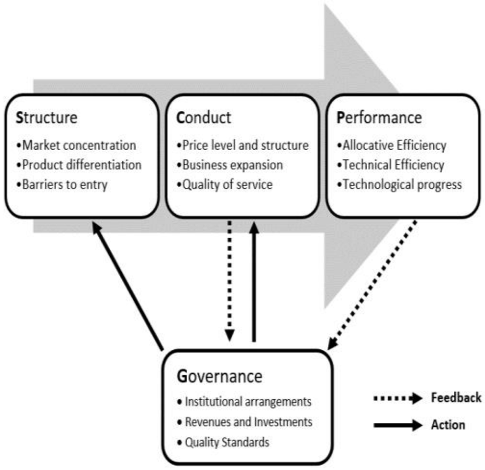

Figure 5: SCP paradigm

STRUCTURE: Electricity Distribution Business is the case of monopolistic structure where to each Utility is given the territorial franchise for a specific region. The "product" is very homogenous, as it is the electricity that comes in one form, but it can be served under different conditions (voltage level, frequency etc.) to end-consumers. The exclusivity that each of the distribution companies have can be understood as a form of barrier to entry, which is sufficient by itself.

CONDUCT: Regulating the level and the structure of the price is one of the important segments when essential goods are in stake. The regulator has different ways for controlling the price that is charged to end-consumers. Conceptually, regulator can define the price on its own. The downside is the information asymmetry between the regulator and a utility where the price can be either too generous or not high enough for the economic agent to remunerate its expenses and maintain sustainability of the grid and business in a long-run. On the other hand, if the price is not controlled, a utility might follow its economic nature and set a monopolistic price, which is not socially acceptable. Although all the companies are profit seekers, there should be adequate level of investments in the grid to satisfy the needs of society in a long-run. This will require setting proper level of incentives for distribution companies to invest in the network, even in the cases when it is not cost-effective to reinforce or

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expand the grid (providing service to scattered remote consumers in rural areas where the investments will never be recovered from network use charges obtained from consumers in the specific area).

PERFORMANCE: Regulator has to establish certain performance criteria which will contribute to the decision making process. Allocative efficiency represents the ability to find an optimal level of electricity price, which is enough for covering all accrued expanses of the utility and for making appropriate earnings. It is an art to find an optimal break-even point where the company will receive its fare revenues and consumers will have the optimal price for the service they receive. For achieving satisfactory level of technical efficiency, the regulator has to be aware of more technical aspects and operational costs for monitoring the system's performance. In the same time, regulator has to influence utilities to search for innovative technological solutions for providing the service under least costs supply.

GOVERNANCE: For any kind of regulation, sufficient level of institutional arrangement has to be set. This includes various governmental bodies: commissions, agencies and organizations that have to organize and control actors in the industry. The part of the arrangement are also all the laws, norms and licenses that are imposed on utilities. Common approach for overseeing utilities' operations is by following the dynamics of their financial statements. The regulator has the right to inspect the accounting books of utilities where statements of obtained incomes, required costs, made investments are visible. Based on this and other economic and technical input information, different methodologies can be used to establish optimal revenues for DSOs. The choice of methodology will depend on the chosen approach for regulatory design. The two opposite sides of this specter are cost-based regulation and incentive regulation and design of any enforced regulation can feet in-between. The first approach is more traditional and mainly related to the period when the utilities were vertically integrated. In this case Regulator sets the price for a DSO annually, with the aim to cover the costs of the provided service and include a rate of return on capital which would be a good signal for investing further in assets of the infrastructure. Incentive regulation will be used in the case when a regulator wants to incentivize the utility to reduce overall costs by defining a cap on price or revenue that a DSO is entitled to. This cap is set in advance for a period of 3 or 5 years, during which DSO can benefit from cost savings and achieved efficiencies. At the end of the period, new lower cap is set, thus enabling for obtained benefits to be shared with consumers [22].

Regulator can explicitly control certain aspects of utilities' business. One such regulatory variable is the future investment of utilities. The regulator's primal long-term objective is to ensure the sustainability of the electric power distribution system, where sufficient system's capacity has to be installed to meet the future demand at acceptable level of quality. The quality standards in the electricity industry can be seen, namely, as reliability of supply (the number, duration and severity of the power supply interruptions), voltage quality (avoiding harmonics, voltage drops, etc.) and consumer's satisfaction (quality of the service provided).

V. CONCLUSION

Regulation of Distribution Network, as a large infrastructure, seems to have feasible solutions when it is observed strictly from the viewpoint of Microeconomics and treated as a Natural Monopoly. However, these socio-technical systems involve large number of stakeholders with different interests and theoretical economic assumptions cannot be rigidly used when designing the regulation.

For that reason, establishing relations between the market structure, behavior of economic agents and the overall performance of the market (SCP paradigm), should be taken into consideration when imposing the regulatory constraints on utilities.

The challenge of regulation design should not be in satisfying the needs of various stakeholder groups (utility, government, society, environmental groups etc.), but in development of transparent frameworks and methodologies. These adopted concepts should include straightforward performance indicators, which will represent stakeholders' interests in the market in a transparent and unbiased way. Furthermore, by applying advanced IT solutions, the information asymmetry between the regulator and utilities can be significantly reduced with the development of Reference network models that will contain all relevant information needed for calculating allowed overall expenses for remuneration of DSO's grid maintenance and expansion costs, among others.

Consequently, a positive environment will be created for implementation of incentive regulation, which will give a stimulus to Utilities to pursue technological innovation and new methods for resource and asset optimization. The main driver for DSOs with incentive is the reduction of operational and investment cost, which would be a pure profit for the utility as an economic agent, who in essence is always a profit-seeker.

In conclusion, a regulator is left with the challenging task to create suitable institutional arrangement where obtained long-term benefits will be appropriately shared between a DSO and consumers. These benefits should, on one hand, reflect the adequate level of revenue for DSO, which will enable sustainable utilization and further development of the grid. On the other hand, the charged tariff prices, as a consumers' distributed benefit, should reflect obtained economic efficiency by the DSO from the prior regulatory period [23].

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Numerical Investigation of Novel Swill Burner for Low NOx Oxy-fuel Pulverized Coal Combustion and CCS

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Abstract—**Oxy-fuel combustion is considered as a promising technology for carbon capture and storage (CCS). Although much effort is made to implement oxy-fuel combustion to real scale energy boilers significant challenges remain. In this work, Computational Fluid Dynamics (CFD) combustion model was used to study novel swirl burner concept performance under conventional and oxy-fuel conditions. The proposed model is composed of advanced sub-models for different combustion phenomena (devolatilisation, particle ignition/combustion, radiation, NO_x emissions) and thus is able to simulate pulverized coal combustion under different operating conditions including both in air and in oxy-fuel atmospheres. Numerical simulations of air and oxy-fuel combustion were performed for different O_2 excess ratios. The obtained numerical results showed good accuracy when compared with experimental data from semi industrial 0.5 MW_t test stand. Moreover, it was shown that novel burner model is able to stably operate in all investigated scenarios. Calculated temperature distribution is similar for both conventional and oxy-fuel combustion cases which is paramount for possible boiler retrofit to oxy-firing technology. The obtained numerical data were used to choose the most appropriate burner configuration.**

Keywords - pulverized coal, swirl burners, oxy-fuel, Computational Fluid Dynamics (CFD), NO_x emissions

I. INTRODUCTION

There is general consensus that the primary source of greenhouse gases emissions is CO_2. CO_2 makes up to 75% of total greenhouse gases emissions [1], while 35% of total CO_2 emissions come from coal thermal power plants [2]. As it is expected for this trend to continue, it is clear that is necessary to develop and implement new technologies for low CO_2 combustion [3].

Oxy-fuel combustion in which fossil fuel is burnt in a mixture of pure O_2 and recycled flue gas consisting or CO_2 in order to obtain flue gas with high CO_2 concentration, making it ready for separation [4]. Oxy-fuel combustion is considered as CCS technology with high potential since it can be implemented on existing thermal units ' boilers and because it, to big extent, eliminates need for additional post-combustion CCS measures.

Switching from conventional (air) to oxy-fuel pulverized coal combustion introduces significant changes in combustion process itself. These changes are mainly caused by differences in thermo physical properties of main combustion gases, N_2 during air combustion and CO_2 during oxy-fuel combustion: higher specific heat capacity of CO_2 compared to N_2, lower molecular diffusivity in CO_2 than in N_2, different radiative properties (with the emphasis to gaseous mixture absorption coefficient values), and different values of important transport properties such as viscosity, thermal diffusivity, etc.

The above mentioned differences cause changes in burner flows. The higher CO_2 specific heat demands higher O_2 fraction (about 30% of O_2 in CO_2 on molar basis) in gases introduced into burner for oxy-fuel combustion in order to establish similar adiabatic flame temperatures to those obtained during air combustion (with 21% of O_2 in N_2). These differences in O_2 amounts at burner inlet lead to reduction of total volumetric flow through the burner. Since velocity of primary gas has to be kept at the same level in order to maintain coal particles in suspension

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primary mass flow is increased during oxy-fuel combustion due to higher CO_2 density compared to N_2. This leads to decrease of recycled flue gas amount available for secondary stream and consequently to decreased secondary flow velocity [5].

It can be concluded that above mentioned differences strongly influence burner aerodynamics and lead to changes in flow patterns and heat distribution inside furnace. Moreover, described differences also change all combustion phases: particle heating, particle devolatilisation, char combustion, and NO_x emissions. This in turn affects flame ignition, flame stability and shape.

A lot of efforts are invested to overcome these challenges in novel burner oxy-fuel burner designs. Computational Fluid Dynamics (CFD) is intensively used as powerful and well proven tool for coal combustion modeling and optimization from experimental scale burners to real scale furnaces and boilers [6]. E. H. Chui and coauthors used CFD for investigation of experimental swirl stabilized pulverized coal burners. Simulations were in reasonable agreement with measured values of temperature, CO, O_2 and NO [7]. D. Toporov with coauthors developed CFD model for pulverized coal combustion under oxy-fuel conditions. Their model was validated against experimental values measured during oxy-coal combustion using experimental swirl burner [8]. S. P. Khare et al. utilized CFD modeling for ignition mechanisms comparison between an air and an oxy-fuel pulverized coal swirl burners stabilized flames. Suggested model showed, by comparison with experimental results, that CFD can be applied to pulverized fuel burners retrofit to oxy-fuel combustion [5]. A. A. Bhuiyan and J. Naser performed CFD simulations of pulverized coal oxy-fuel combustion using IFRF AASB. Numerical and measured values of surface incident radiation, flue gas recycle ratio, and carbon content in ash were in a satisfying agreement [9]. F. Vega with coauthors simulated pulverized coal combustion with experimental oxy-fuel burner using CFD modeling. Numerical optimization of key geometrical parameters (burner diameters, furnace size, and burner quarl angle) was performed in order to stabilize particle ignition and combustion using new burner concepts [10].

The main aim of this study is implementation of already developed and also authors' suggested sub-models for different combustion processes into a single framework. The proposed comprehensive CFD combustion model incorporates sub-models for: devolatilisation, particle ignition/combustion, gas radiative properties determination, and NO_x formation into CFD solver ANSYS FLUENT 13.0. The most important feature of suggested CFD model is its ability to accurately simulate pulverized coal combustion under wind range of operating conditions. However, it is necessary to underline, that its usage, in the scope of this work, is limited to different cases of conventional and oxy- fuel combustion.

The main idea of this study is CFD optimization of novel oxy-fuel burner performance during both conventional and oxy-fuel combustion of pulverized South African coal in semi industrial 0.5 MW_t stand.

Totally five scenarios for different O_2 excess ratios were simulated, and calculated numerical results enabled identification of the most appropriate burner configuration for dual mode combustion (in air and in recycled flue gas).

II. Experimental Investigation

The experimental investigation was performed in 0.5 MW_t semi-industrial stand for burner investigation. The experimental stand, primarily designed for testing of swirl burner performance during pulverized fuels combustion under conventional conditions was retrofitted with a system for flue gas recalculation so it can operate under oxy-fuel conditions, Fig. 1.

A. 0.5 MW_t experimental facility

The elements of experimental stand are schematically represented in Fig. 2. Investigated burner prototype is placed on furnace front wall (1). The main element of experimental facility is cylindrical furnace with inner diameter of 700 *mm* and total length of 7000 mm (2). Coal used

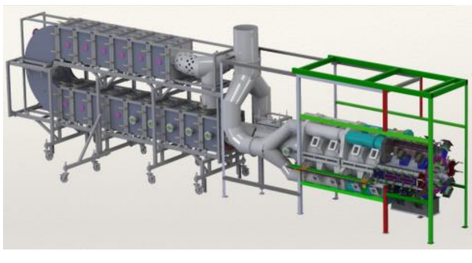

Figure 1. Drawing of modernized 0.5 MW_t experimental stand

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for experiments is pulverized in the mill (3) and stored in the coal bunker (4). Desired O_2/CO_2 mixture for oxy-fuel combustion startup is generated in the collector (5). Duct (6) is used during conventional combustion and during oxy-fuel combustion start-up to transport primary oxidant to the burner. Primary oxidant, transported through the duct (6) is heated to desired temperature using electric heater (7). Heavy oil, introduced by the pump (8) is used for the furnace start-up and flame support. Duct (9) is used during conventional combustion and during oxy-fuel combustion start-up to transport secondary oxidant to the burner. Secondary oxidant is pre-heated using oil heater (10) supplied from the heavy oil storage (11) and heated to the final desired temperature using electrical heaters (13).

The test furnace is equipped with a system for flue gas recirculation which enables to perform experiments in oxy-fuel conditions similar to those in industrial furnaces (12). Primary (6) and secondary (9) ducts which transport O_2/CO_2 mixture from the collector to the burner during oxy-fuel combustion start-up are switched off when oxy-fuel combustion mode is established. Desired O_2/CO_2 mixture during oxy-fuel combustion is achieved by mixing recycled CO_2 reach flue gas (12) and O_2 from the collector. Facility can be used for various flame phenomena investigation, as well as for emissions and slagging/fouling research. It is equipped with various ports for optical and probe measurements located on the furnace side walls (14). These ports are used for visual flame observation, flame recording, in-flame temperature measurements and gas sampling and analysis (15). Important part of the test rig is series of heat exchangers which were built-in in order to achieve heat transfer conditions close to those in real scale boilers (16). Flue gas exiting furnace passes through the scrubber (17) and then is introduced into the chimney (18).

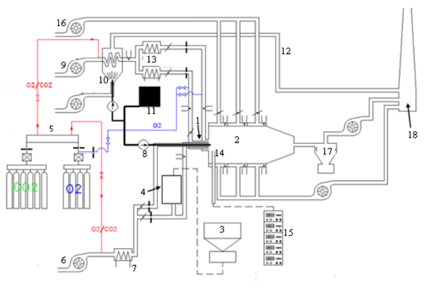

Figure 2. Shematic of modernized 0.5 MW_t experimental stand

B. Experimental burner concept and geometry

The new burner construction was designed based on CFD analysis and years of experience in swirl burner development. The new burner was designed for dual mode operation, both in air and in oxy-fuel regimes. It is planned that burner operates in air mode during boiler start-up and emergency cases. After boiler start-up burner is able to switch to oxy-fuel mode with flue gas recirculation.

In order to achieve stable dual mode operation burner was designed with the possibility of changing the flow rates between inner and outer secondary burner's nozzles using special dump, Fig. 3. Redirecting proper amount of secondary oxidant from the outer secondary annulus through the inner secondary annulus the momentum ratio between primary and secondary oxidant streams is kept constant during both combustion modes in spite of decrease of the secondary oxidant velocity during oxy-fuel combustion. As momentum ratio characterizes influence of primary and secondary flow rates on flame aero dynamical characteristics this burner design gives higher stability range as compared to typical swirl burners. Maintaining the recirculation ratio at the level 70-75%, the same heat exchange, that is, same temperature values and temperature distribution inside furnace during both combustion modes is achieved.

C. Investigated burner configurations and fuel characterization

This study was performed for a total of five different scenarios. Numerical simulations were done for four pulverized coal combustion cases in oxy-fuel mode with different O_2 excess ratios.

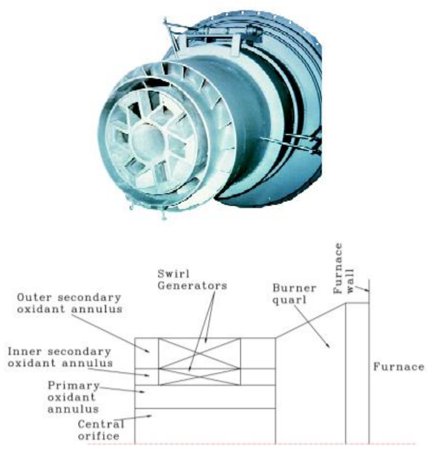

Figure 3. Dual mode burner concept

TABLE I. MAIN OPERATING PARAMETERS FOR OXY-FUEL CASES AND SELECTED AIR CASE

Case	Fuel	Load [kW]	λ
Oxy 1	South African coal	30	0.8
Oxy 2	South African coal	30	0.98
Oxy 3	South African coal	30	1.07
Oxy 4	South African coal	30	1.24
Air	South African coal	30	1.07

The most favorable burner configuration was chosen using calculated numerical values of static temperature, CO fraction, and NO_x fraction. Based on performed oxy-fuel combustion simulations, one case of conventional air combustion was chosen and numerically simulated in order to present burner's ability for stable performance in dual mode. The main operating parameters are shown in Table I.

Burner configuration parameters are shown in Table II.

TABLE III. COAL CHEMICAL PROPERTIES

Proximate analysis (as received) [%]		Ultimate analysis (as received) [%]		Higher heating value (as received)
Moisture	4.0	C	69.83	27528
Volatiles	23.5	H	3.86	
Fixed C	59.5	O	7.04	
Ash	13.0	N	1.64	
		S	0.61	

It should be mentioned that total O_2 fraction in CO_2 during oxy-fuel combustion cases was kept same (0.35 O_2 in CO_2 on volumetric basis) in order to have same adiabatic flame temperature as in air combustion case. Coal chemical properties are presented in Table III, and coal sieve analysis is shown in Table IV.

TABLE IV. PARTICLE SIZE DISTRIBUTION

Diameter (d) [µm]	Ultimate analysis (as received) [%]
200	3.078
125	15.86
90	29.66
63	49.41
32	87.06

III. NUMERICAL MODELING

Suggested pulverized coal combustion model is based on CFD code ANSYS FLUENT 13.0. Default FLUENT coal combustion model is significantly altered using UDFs making it suitable for coal combustion in different combustion atmospheres, as already stated. The main model features, and the most important sub-models will be described in detail in the following sub-sections.

A. CFD model outline

Main transport equations for mass, momentum, temperature, and species mass fractions were solved iteratively using axisymmetric solver which is known to show good accuracy with relatively low computational demand. Solver choice is based on the fact that it is widely used for swirl burner CFD simulations [5,8,11], and its usage is also physically justified based on modeled geometry symmetry and expected reactive flow symmetry [12].

B. Computational grid

Computational grid is generated using GAMBIT 2.4.6 pre-processor. Several two-dimensional grids were constructed in order to establish grid independent solution. Grid fineness was gradually increased in near burner and flame zones giving: coarse, medium, fine,

TABLE II. BURNER CONFIGURATION FOR OXY-FUEL CASES AND SELECTED AIR CASE

Case	*Coal mass flow rate [kg/h]*	*Primary oxidant mass flow rate [kg/h]*	*Outer secondary oxidant mass flow rate [kg/h]*	*Inner secondary oxidant mass flow rate [kg/h]*	*Primary oxidant temperature [K]*	*Inner secondary oxidant temperature [K]*	*Outer secondary oxidant temperature [K]*
Oxy 1	38	95.67	85.13	28.38	373	553	553
Oxy 2	38	95.67	113.51	37.84	373	553	553
Oxy 3	38	95.67	144.84	48.28	373	553	553
Oxy 4	38	95.67	173.22	57.74	373	553	553
Air	38	64.63		315.37	373	553	

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and very fine grids consisting of 142000, 343000, 411600, and 665500 finite volumes respectively. Oxy 3 case was used for grid independency test. Average static temperature values at axial distances 0.1 m, 0.2 m, 0.3 m, 0.4 m, 0.5 m, 0.75 m, 1 m, 2 m, and 3 m from burner front calculated on different computational meshes are presented in Figure 3. Fine grid is chosen for all further calculations based on these results, as temperature values calculated on fine and very fine meshes differ less than 1%.

C. Turbulence model

Standard κ–ε [36] turbulence model is the most widely used in of combustion simulations [20,23,24,25]. Realizable κ–ε [37] turbulence model was chosen for turbulence modeling in this study. Although This choice is made due to the models ' ability to more accurately predict turbulent jet spreading and recirculation zones, compared with standard κ–ε turbulence model [14].

D. Multiphase model

Eulerian approach is used for primary phase, reactive gaseous multi-component mixture, modeling. Lagrangian approach is used for secondary phase, reacting pulverized coal particles, modeling, as secondary phase volumetric fraction in primary phase is smaller than 10%. Particle-particle interactions are neglected in this approach which is acceptable due to small secondary phase volumetric fraction in primary phase. Particle – fluid interactions are taken into account by using particle in cell PIC

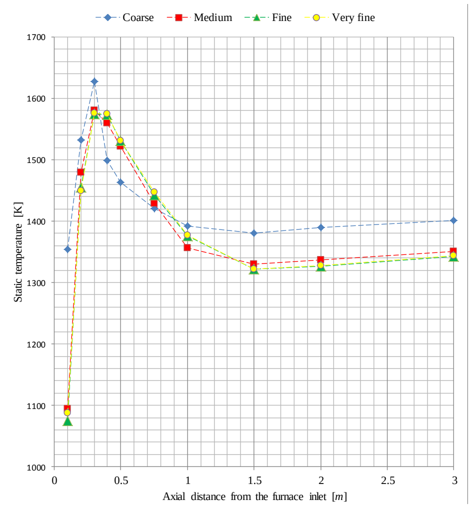

Figure 4. Grid independence study

method. In this approach particle trajectory is determined calculating force balance acting on the particle. Particle properties (position, velocity, temperature, species composition) are obtained solving system of ODEs with appropriate source terms [14]. These source terms exchange with PDEs describing Eulerian flow field at every 15 flow field equations. It is considered that final solution is obtained when convergence is reached in both phases.

E. Radiation model

DO model is chosen for radiation modeling in this work despite its higher computational cost compared with P-1 model. This choice was made due to observed P-1 model trend to overestimate radiative heat flux and temperature values [5,10,15,16]. The DO model transforms Radiative Transfer Equation RTE into a transport equation for radiation intensity in the spatial coordinates and solves it in identical manner to that used for the fluid flow and energy equations [17]. Equal quadrature divisions in all four directions (4×4) were set to solve the DO equation. Weighted Sum of Gray Gases WSGG model was used to calculate gas emissivity. Model coefficients used in case of air combustion were taken from [18], and for oxy-fuel computational cases from [19]. Input coefficients for WSGG model are implemented as UDF, and solver is able to make choice between appropriate set of coefficients based on combustion atmosphere (air or oxy-fuel). The emissivity for all wall surfaces was set to 0.8. Particle absorption coefficient and particle scattering coefficient were set to 0.8 1/m and 0.3 1/m respectively [6].

F. Coal combustion model - devolatilisation

Standard FLUENT devolatilisation models are not able to predict detailed volatile species release. All devolatilisation models which are part of default FLUENT combustion model assume that realistic volatile species are lumped in a single generic hydrocarbon which composition is governed by the coal chemical composition. As devolatilisation is of great importance for all other combustion phases (volatile combustion, particle ignition, char combustion, and NO_x formation), and thus has significant influence on flame shape and stability it was decided to implement advanced network general devolatilisation Functional Group FG

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model into FLUENT framework using UDFS. FG model takes into account coal chemical structure assuming that coal particle is network composed of aromatic clusters connected by aliphatic and ether functional groups. Functional groups can be also connected to the aromatic clusters which are not connected with other aromatic cluster. Model assumes that functional groups released during devolatilisation form light gaseous species. Total mass of devolatilized gaseous species depends of the initial functional group composition of coal. Tar release is simulated as parallel process competing for functional groups during coal devolatilisation phase. In this way, FG model is able to predict realistic volatile composition. Moreover, FG model only requires coal chemical analysis as an input parameter, and does not need often expensive experimental determination of Arrhenius kinetic constants, which makes it applicable to wide range of devolatilisation and combustion conditions [20]. Kinetic rates for different volatile species used in the implemented FG model version may be found in [20,21].

G. Coal combustion model - gaseous reactions

Gaseous reactions were modeled using finite-rate/eddy dissipation model. This model assumes that reaction rate is controlled by the slower of the two processes: species turbulent mixing rate and chemical kinetics. In order to take into account reactions of FG devolatilisation model obtained gaseous species chemical mechanism suggested by Andersen et al. [22] applicable for hydrocarbons combustion under both air and oxy-fuel conditions was used in this work. Tar oxidation reaction kinetics was adopted according to work published in [23].

H. Coal combustion model - char reactions

Char reactions were modeled using *N*-th order power law kinetics model. This model was chosen as it takes into account high values of CO_2 partial pressure present during oxy-fuel combustion with recycled flue gas. Although more complex model were already used for char oxidation during pulverized coal oxy-fuel combustion [24] recent studies showed that *N*-th order power law model provides satisfying accuracy with reasonable computational demand [25]. Model describes influence of reaction kinetics and reactant diffusion to particle surface on reaction rate. Two semi-global reactions were modeled using described approach. The first one describes carbon oxidation to CO and CO_2. The second one, Boudouard reaction, describes carbon gasification to CO by CO_2. Kinetic parameters for the first reaction were taken from [26], and for the second reaction from [25]. Diffusion coefficient values for air and for oxy cases were taken from [4]. As *N*-th order model is not available in default FLUENT coal combustion model it also was implemented by means of UDFs. Detailed description of model implementation is given in authors' previous work [27].

I. NO_x formation modeling

NO_x simulations are performed in already converged flow field as a post-processor. Two different processes were included: thermal NO and fuel NO. Thermal NO is generated by oxidation of N_2 present in oxidant. Fuel NO, which makes to about 80% of total NO formation is generated by oxidation of N_2 bound inside coal volatiles and in the char. It is assumed, in this study, that volatile N releases as HCN and NH_3 to produce either NO or N_2. The char nitrogen is released to the gas phase as NO directly. Reactions describing these processes are modeled using default FLUENT model based on the De Soete mechanism [28]. Additional reaction of hydrocarbon transformation to HCN via NO was built in as UDF using approach described in [29].

N_2 split between char and volatiles is crucial for accurate NO prediction. Moreover, initial HCN/NH_3 ratio is also very important for final fuel NO formation [30]. It is widely accepted to assume that N_2 is divided between fuel and char accordingly to coal chemical analysis, and HCN/NH_3 split is usually adopted based on previous modeling experiences for different coal ranks [25]. In the present work, authors adopted more rigorous approach: both volatile/char split and HCN/NH_3 ratio are obtained directly from FG devolatilisation model, solving appropriate transport equations.

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IV. RESULTS AND DISCUSSION

Model accuracy was established by comparison with experimental data. Comparisons between numerically calculated and experimentally determined values of averaged static temperature in cross-sections at different axial distances from burner front are shown in Fig. 4–7. Averaged static temperature values were taken in near burner zone, at axial distances: 180 mm, 440 mm, and 1300 mm from burner front. It can be seen that numerically and experimentally obtained values are in good agreement, with relative error between 5% and 7% which allows quantitative comparison.

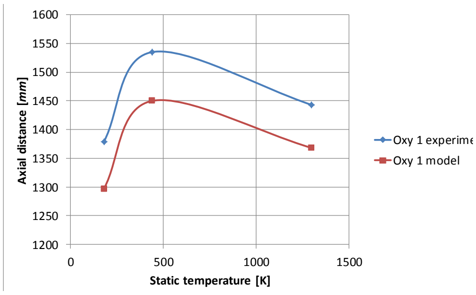

Figure 4. Comparison between experimental and numerical values of averaged staic temperature – oxy 1 case

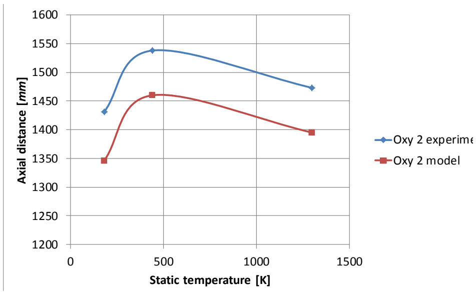

Figure 5. Comparison between experimental and numerical values of averaged staic temperature – oxy 2 case

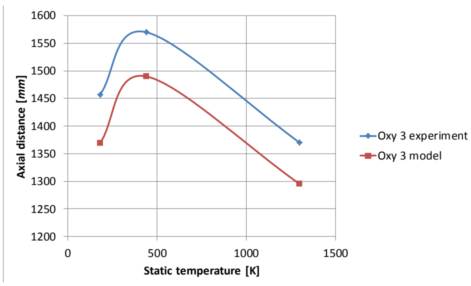

Figure 6. Comparison between experimental and numerical values of averaged staic temperature – oxy 3 case

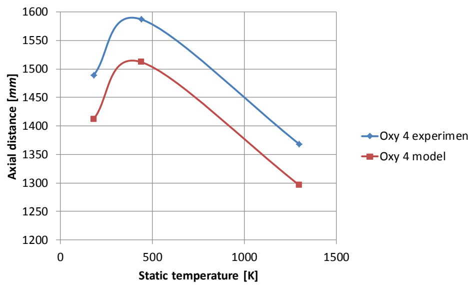

Figure 7. Comparison between experimental and numerical values of averaged staic temperature – oxy 4 case

It is worthy to underline that for temperature values at the smallest distance from the burner front are higher for oxy 3 and oxy 4 cases than for oxy 1 and oxy 2 cases which can be explained that combustion for oxy 3 and oxy 4 cases occurs in excess O_2, while combustion in oxy 1 and oxy 2 cases occurs in under stoichiometric conditions. Thus, during combustion in excess O_2, oxy 3 and oxy 4 cases, flame is attached to the burner front, while in case of combustion in under stoichiometric conditions flame is stabilized further from the burner front.

However, similar temperature values at axial distance 440 mm from the burner front points out that stable combustion and flame are developed for all four investigated cases.

Somewhat higher temperature values at axial distance 1300 mm from the burner front for under stoichiometric cases (oxy 1 and oxy 2) compared with combustion cases in excess O_2 (oxy 3 and oxy 4) point to the more intensive coal combustion and shorter flame length in case of combustion with excess O_2 coefficient values greater than one.

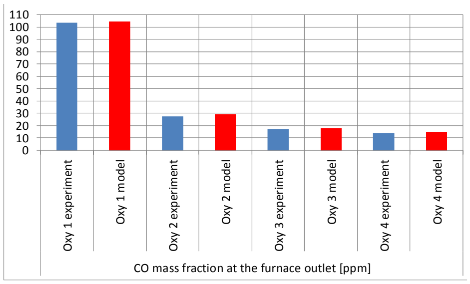

Figure 8. Comparison between experimental and numerical values of CO mass fraction at the furnace outlet

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CO mass fraction values measured at the furnace outlet are compared with corresponding numerically calculated CO values in order to further establish model accuracy. Very good agreement between those two sets of data was achieved, as can be seen in Fig. 8.

It can be seen that CO mass fraction decreases with excess O_2 coefficient increase, which shows that during combustion in over stoichiometric conditions (oxy 3 and oxy 4 cases) more complete combustion is achieved. Moreover, this trend may be explained by the fact that during combustion in under stoichiometric conditions (oxy 1 and oxy 2 cases) Boudouard reaction influence, which favors gasification to CO, is higher due to higher CO_2 content in the main combustion zone.

NO mass fraction values measured at the furnace outlet are compared with corresponding numerically calculated NO values in order to further establish model accuracy. Again, very satisfying agreement between those two sets of data was achieved, Fig. 9. This agreement between calculated and measured NO values may be mainly contributed to the sophisticated models used for devolatilisation and NO formation, which allow accurate prediction of N distribution between char and volatiles, as well as accurate prediction of NH_3/HCN split.

As expected, NO values increase with O_2 excess coefficient increase. However, due to stable combustion conditions for all investigated cases, that is due to proper burner configuration, this increase is retarded to a large degree.

Calculated static temperature distribution in near burner zone for oxy-fuel cases is shown in Fig. 10.

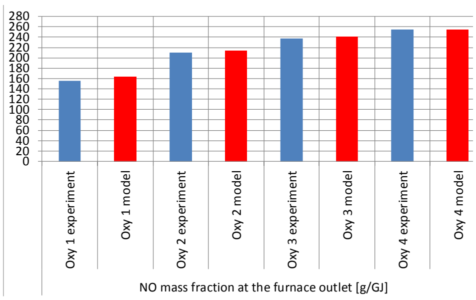

Figure 9. Comparison between experimental and numerical values of NO mass fraction at the furnace outlet

Detailed investigation of calculated static temperature distribution inside experimental furnace for calculated oxy-fuel cases showed significant influence of excess O_2 coefficient on flame characteristics. Although, as previously stated, stable combustion is present in all investigated case it can be seen that during coal oxy-fuel combustion with excess O_2 coefficient equal to 0.77 (oxy 1 case) ignition is delayed, and flame is developed far from burner front. With increase of excess O_2 coefficient to 0.95 (oxy 2 case) ignition occurs closer to the burner front than in previous case, although calculated results show that flame is not fully developed. Both over stoichiometric combustion cases, oxy 3 case corresponding to the excess O_2 coefficient of 1.05 and oxy 4 case corresponding to the excess O_2 coefficient of 1.22 show fully developed, stable flame with the ignition close to the burner front.

Based on the performed detailed analysis: comparison of both measured and numerically determined temperature values, CO values, and NO values, and comparison of calculated temperature distribution inside experimental furnace between four oxy-fuel pulverized coal

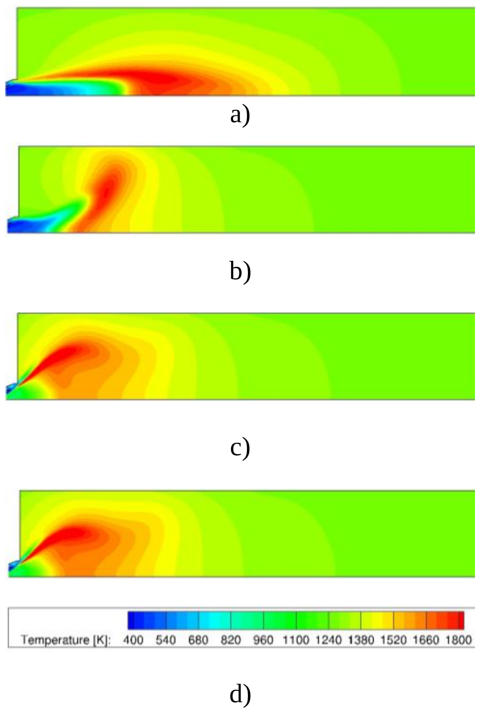

Figure 10. Static temperature distribution inside experimental furnace: a) oxy 1 case, b) oxy 2 case, c) oxy 3 case, and d) oxy 4 case

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combustion cases, oxy 3 case, corresponding to the excess O_2 coefficient of 1.05 was chosen as the most favorable one.

In the last part of this study air combustion simulation for same momentum ratio as during oxy fuel combustion (oxy 3 case) was performed. Calculated temperature distribution is shown in Figure 11.

It can be seen that stable ignition and combustion is developed in both air and chosen oxy-fuel combustion cases. Moreover, maximal temperature values, and flame lengths are similar in the both cases. Flame shapes in near burner zone are quite similar as well, although it has to be notified that further downstream flame shape, and temperature distribution differ, most probably due to influence of main carrier gases, N_2 during air combustion and CO_2 during oxy-fuel combustion, which cannot be completely neglected by burner design and aero dynamical characteristics.

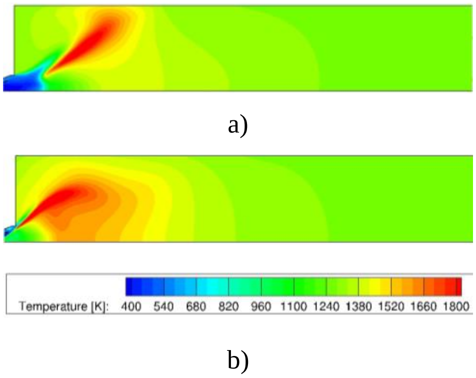

Figure 11. Static temperature distribution inside experimental furnace: a) air case b) oxy 3 case

V. CONCLUSIONS

Novel numerical model which is based on state of art numerical sub-models for pulverized coal combustion under different operating conditions was suggested.

Model was incorporated into a single framework of FLUENT solver intensively using UDF programming. Semi-industrial scale experiments with scaled swirl burner prototype for flame characterization were performed and used for model validation.

Totally four different oxy-fuel pulverized coal cases were simulated and experimentally investigated. Very good agreement between numerical and experimental data was achieved comparing static temperature values, CO mass fractions, and NO mass fractions.

Best case oxy-fuel scenario was chosen based on performed result analysis and used as a reference case for air pulverized coal combustion with same excess O_2 coefficient and same momentum ratio.

Comparison between air and chosen oxy-fuel pulverized coal cases demonstrated the proposed burner’s concept for a stable work in both combustion technologies.

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Assessment of Energy Security based on Energy Indicators – a Serbian Example

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Abstract— **Consumption of natural resources grows in recent decades due to growing demands caused by economic development and demographic growth of the global population. The importance of efficiency in energy production and use is important, and it is described by a set of indicators. Energy balance is a measure for checking efficiency and energy savings achieved in energy consumption. Energy indicators describing energy security level are presented in case of the Republic of Serbia. Some measures to increase the energy security level of Serbia are also proposed.**

Keywords – energy security, energy balance, indicators, multi-criteria assessment

I. INTRODUCTION

Energy resources of the world are very limited, and the reserves of fossil fuels are concentrated in a small number of countries. Abruptly is increased use of natural resources, especially water and energy - which are the basis of life and socio-economic development of society. Special attention is devoted to energy efficiency and energy security, given the fact that demand for energy is constantly growing and that there is a real threat of depletion of fossil energy sources.

The energy crisis is foreseeable, because the result of increasing energy needs in the world by 3% annually and increasing of population. Thus, the shortage of energy, water and food can be expected in next 20 years. With the current rate of use of non-renewable energy sources, oil reserves will be exhausted within 30 years, natural gas within 50 years, while coal reserves will be used no more than 150 years. Limited quantity and uneven distribution of these energy sources causes to rationalize their consumption, implement energy management procedures, and use renewable energy sources more intensively.

Energy management is, in a broader sense, the management of all parameters of energy flows in a system, from production or procurement of energy, through transformation and final energy use. Energy flows are parameters which describe these processes from an economic, technical, environmental or social point of view. Energy management system enables planned and organized continuous management of energy flows in the system.

Energy management systems are established at different levels: national, regional (local) or at the level of the organization. They are part of the overall system of governance, the region (municipality) or organization, with a defined structure, the actors and their responsibilities, procedures of functioning and resources necessary to meet the objectives.

II. ENERGY SYSTEM

The energy system, as any other type of system, can be defined as a group of interactive, interrelated, or interdependent elements that form or are part of the joint entity. The elements in a system have some emergent properties, than cannot be identified when the elements are not connected.

According to the Energy Law of the Republic of Serbia, energy system comprises the electricity system, the natural gas, petroleum or petroleum products system, which consists of energy facilities interconnected to form a unique technical and technological system [1]. The development of energy systems must comply with the strategy for sustainable, competitive and secure energy that primarily involves competition, participation of different energy sources, sustainability, innovation and improvement of technology [2]. The following main characteristics of the development of energy systems are identified: adaptability, integration, interactivity, optimality, resistance, predictability, sustainability, energy efficiency, innovation and technology improvement [2, 3].

Energy efficiency is analyzed in different contexts of energy systems. Systems approach and systems analysis as a methodological approach can be applied for analysis of energy systems. Some authors describe systems approach as a process of understanding and interpretation, where variety of logical-cognitive procedures and methodological procedures can be applied.

System analysis, proposed in [4] presents the energy system in the form of two models: environmental and behavioral. The environment model contains basic elements and/or stakeholders (energy, end-users - consumers of energy, environment and policy) and flows (demands for energy supplies and energy, energy conversion, then the losses and emissions, as well as policies). Behavior model shows the internal structure of the system, which consists of one or more conversion processes (transformations) of energy from one or multiple sources of energy and potential distribution converted to other energy conversion processes, with associated with losses and/or issues affecting the environment.

As basic processes in energy system, the processes of energy conversion and the processes of energy transport are identified. The efficiency and effectiveness of these processes significantly affect the efficiency of energetic system. Also, the problems during the conversion and transformation can be the main cause of security problems in the system.

III. PERFORMANCE INDICATORS OF ENERGY SYSTEMS

Energy performance is measurable results related to energy (e.g. energy efficiency, energy intensity, specific energy). Energy performance indicators are quantitative measures of energy performance. The concept of indicators can be used to monitor performance changes over time and to identify potential problems in energy systems. They should be selected so as to facilitate monitoring of the impact of energy system.

Key indicators of energy performance are defined in 2005, as the result of the joint work of several international organizations. Key indicators include energy performance described by a set of 30 indicators: 4 social indicators, economic indicators 16 and 10 environmental indicators [5, 6].

The complexity of energy systems indicates the necessity of applying a systems approach and systems analysis during the research. They provide a comprehensive understanding of energy systems and defining key indicators of performance.

The values of indicators are not only data, but the basis for communication between the stakeholders involved into the sustainable use of energy. Each set of indicators (social, economic, and environmental) expresses specific aspects or consequences of energy production and use. Taken together, all indicators give a clear picture of the energy system.

Indicators are the basis for the application of qualitative and quantitative methods of multiple criteria decision making during the selection of energy systems and alternative energy sources, as shown in [7].

IV. ENERGY BALANCE AND ENERGY SECURITY

With respect to energy management, the key factor is energy balance. Energy balance is a measure for checking efficiency and energy savings achieved in energy consumption. From the engineering point of view, the energy balance is defined consumption or energy production of individual energy systems in order to represent the redistribution of energy consumed or produced. In the field of energy efficiency, energy balance is applied in order to form ideas about the energy consumption of the system or its individual parts.

The exact definition of energy security is difficult to make, because it has different meanings for different people at different situations, and it is analyzed from different perspectives. The complexity of energetic system makes the problem more complex. The concept of security in the objective sense is the absence of threats to the adopted values, while in the subjective sense of fear is the absence of which would be vulnerable given the values.

Energy security is a complex field of scientific research based on the modeling of economic processes, analysis of the geopolitical situation, network reliability and resilience to disturbances, statistical expertise and injury

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emergencies in power systems, risk analysis, problems of energy supply, as well as technical, social, political and other aspects [8].

V. Energy security indicators

Energy security is a term that encompasses many of the problems associated energy, economic growth and political power. Energy security is defined as: an uninterruptible supply of energy, in terms of quantities required to meet demand at affordable prices [9]; uninterrupted physical availability at a price which is affordable, while respecting environment concerns [10]; a flow of energy supply to meet demand in a manner and at a price level that does not disrupt the course of the economy in an environmental sustainable manner [11].

Energy security can be described by corresponding indicators. Energy security indicators are special numerical values describing specific aspects of energy sector security from technical, organizational, environmental, social, and political point of view. The main purpose is to assess the emergency situations, potential risks, and problems in energy production and supply.

Some of the most prominent models for description of energy security are “The 4 A’s,” MOSES, U.S. Energy Security Risk Index, and energy security level index [8, 12-15].

Model of energy security, "The 4 A's" defines the following elements: Availability, Accessibility, Affordability and Acceptability [12]. MOSES (Model of short-term energy security) is a tool for assessment of energy security of seven primary energy sources and two groups of secondary fuels for a short period of time through the quantification of the vulnerability of energy systems, and analysis of effects on domestic production, transformation and distribution [13, 14].

In order to define U.S. Energy Security Risk Index, American Institute for Energy combines 37 indicators into four sub-indices that define the key areas of energy security: geopolitical, economic, technological and environmental protection. Energy security level index is based on: technical and technological, economic, socio-political (geopolitical), and environmental indicators [8]. The weights of groups, sub-groups and indicators can be determined by any method for determining the weight using preferences of experts [7].

VI. Energy indicators for Serbia

Energy indicators for Serbia during the last eight years are presented in Tab. 1. In this table, FE is final energy, while PE is primary energy. Data are collected from energy balances of the Republic of Serbia during the last decade.

Transformation efficiency is stabilized at level of 0.57, but primary energy consumption per capita is higher after one year of decreasing in 2014. Electricity consumption in kWh per capita is also much higher than it should be. Household electricity consumption is decreased almost every year since 2008, and it is stabilized at level of 52-53%.

TABLE I. Energy Indicators for Serbia

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Transformation efficiency (FE/PE)	0.54	0.53	0.54	0.57	0.586	0.549	0.575	0.574
PE consumption (kg en/capita)	2137	1973	2048	2255	2017	2093	1853	2116
Electricity consumption (kWh/capita)	3716	3662	3802	3895	3774	3778	3634	3828
Household electricity consumption %	56	54	53	52	53	53	53	52

Fig. 1 shows electricity generation by fuel in Serbia, presented in GWh. The most important is coal, followed by hydro potential. The other sources of energy are not enough used for electricity production, especially renewable energy sources other than hydro power. Fig. 2 and Fig. 3 present total energy production and total primary energy supply in Serbia, respectively. Natural gas and oil have increased share in consumption, and these energy sources are mostly imported.

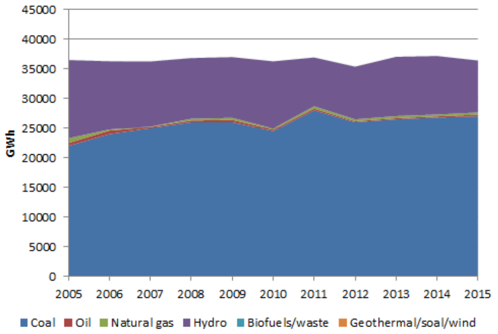

Figure 1. Electricity generation by fuel in Serbia.

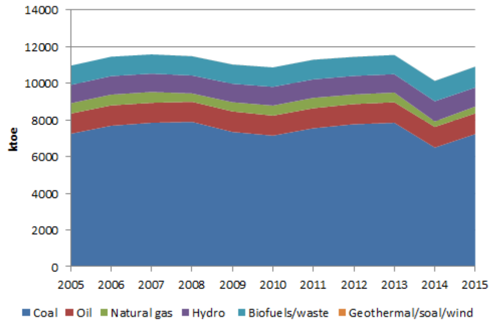

Figure 2. Total energy production in Serbia.

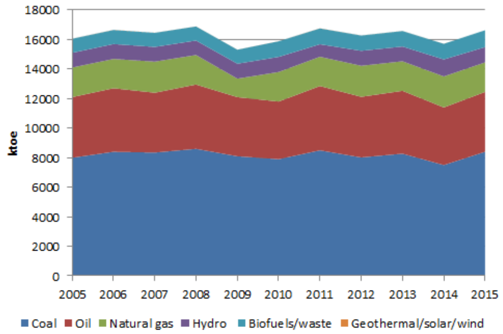

Figure 3. Total primary energy supply in Serbia.

VII. SERBIAN ENERGY POLICY

The new Serbian Energy Law, adopted in 2014, regulates the goals of energy policy and the manner of its implementation, organization and functioning of the energy market, conditions for regular and quality supply customers various forms of energy, as well as the conditions for achieving efficient energy production [1]. Also, it defines some rules do performing energy activities, with special emphasis on the requirements for energy efficiency and environmental protection when carrying out energy activities.

Energy policy of the Republic of Serbia includes measures and activities taken for achieving long-term objectives in the energy sector, including the provision of energy infrastructure development and introduction of modern technology, providing conditions for the improvement of energy efficiency on the production and consumption of energy, reconstruction and modernization of energy facilities and systems. It also stimulates the use renewable energy sources and combined production of electricity and heat, which allows decentralized planning and development of energy resources. Also, the improvement of environmental protection is one of the main objectives.

Energy policy is pursued through the implementation of the Strategy of Energy Development of the Republic of Serbia, the realization of the program and the energy balance. Development Strategy defines the long-term goals for the development of energy activities, development priorities, sources and method of providing the necessary energy, financial incentives for investments in energy facilities that will use renewable energy sources, incentives for improving energy efficiency, conditions and means to ensure the protection of environmental protection and measures to implement this protection and other elements of importance for achieving the goals of energy policy.

Also, Serbia accepted in the process of joining the European Union some obligations. In accordance with Directive 2006/32/EC of the European Parliament and the Council on the effective use of final energy, some improvements in energy production and use must be achieved.

One of the targets is to save at least 9% of final energy consumption in ten years, and also to increase the use of renewable energy sources (besides hydro potential). The Republic of Serbia is committed to increase the share of renewable energy sources in consumption for 6% until the year 2020, and to encourage the use of biofuel in the transportation sector (10% until the year 2020).

Energy law and law on construction and planning are the basis for energy reduction in energy production and use. The following mechanisms of control are introduced: certificates of energy performance of buildings, labeling all products that affect energy consumption, eco-design requirements, energy

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management systems based on standards, inspection of boilers and units for air conditioning, minimum energy efficiency requirements in energy and thermal energy systems (generation, transmission and distribution of electricity, thermal energy and natural gas), billing based on continuous measurement and consumption control, energy efficiency in local communities, public institutions, and in all public procurements.

VIII. Comparison with Neighbouring Countries

Comparison of energy indicators of Serbia and other neighboring countries is presented in this section. Energy indicators of Serbia are compared with the following neighboring countries: Montenegro, Hungary, Romania, Bulgaria, Macedonia and Albania.

The comparison is based on several criteria, whose significance is determined by expert assessment. These criteria are consistent with the criteria used in the energy security evaluation methods, and primarily are related to production, transformation and use of energy, and available infrastructure.

The analysis is presented for previous decade. Fig. 4 presents gross inland production including all sources of energy. Fig. 5 shows electrical capacity based on combustible fuels, while Fig. 6 shows capacity based on hydro potential. Some of these countries are very different in size and capacity of energy sources, but the proximity and interdependence of energy systems and the potentials for cooperation in different regional and cross-border projects is the main reason why this kind of analysis is made.

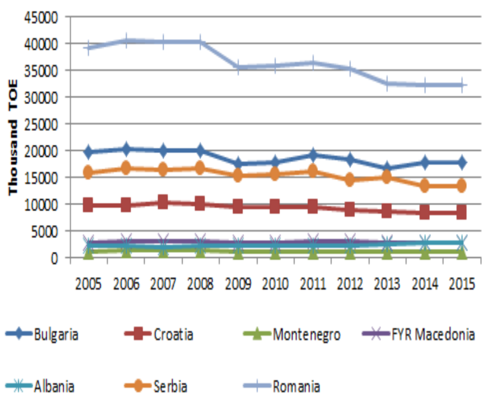

Figure 4. Gross inland production (all sources of energy included).

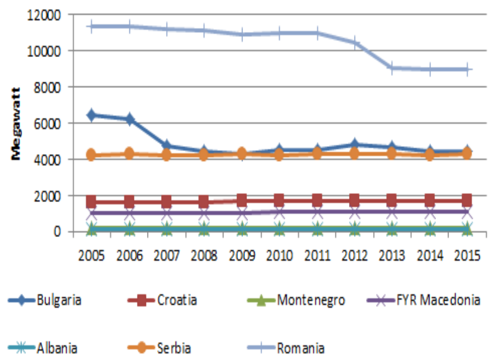

Figure 5. Electrical capacity based on combustible fuels.

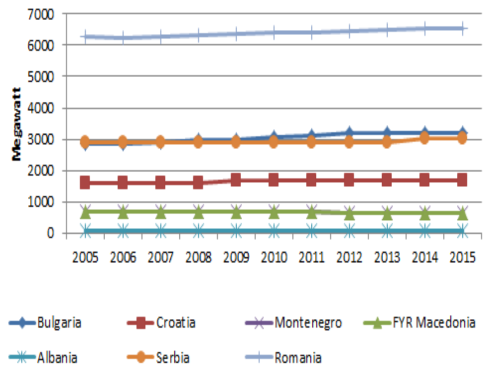

Figure 6. Electrical capacity based on hydro potential.

As largest country, Romania is the leader, although the values of some indicators show negative trend. Negative trends do not necessarily mean a deterioration of the energy system. They can be also caused by increased efficiency in the system of production and energy efficiency. Also, some problems with natural disaster, like floods in Serbia in 2014, can affect the production of electricity and energy system.

IX. Discussion on Serbian Energy Security and Future Actions

According to analysis of main energy security indicators of Serbia, we can conclude the following. There is large dependency on the imported energy, primarily oil and gas, at level of approximately 30%. Although it is not too much compared to other countries, even members of the European Union, these fuels are completely irrational spent. Energy intensity in Serbia is 3 times higher than in neighboring EU countries, and almost 5 times higher than in “old” EU member states.

Thus, the main energetic problems of Serbia are: large dependency on imported energy (more than 30%), energy inefficiency (energy intensity is 3 times higher than in neighboring EU countries, and 5 times higher than "old" EU member states), and large "greenhouse gases" emissions in the energy sector (more than 75%). Also, the consumption of primary energy per unit of gross domestic product in certain sectors is up to 5 times higher than the world average, and as much as 8 times that of the OECD countries and this is one reason for the lack of competitiveness of goods and services.

Serbia made the commitment of sustainable development, and energy efficiency is the key element of the energy policy and energy sector development strategy. The efficiency of transformation of primary energy in the final energy rose slightly in recent decade (from 0.54 to 0.57), while the consumption of primary energy per capita increased by 1% and electricity consumption per capita of approximately 100kWh. This is much slower than the increasing in the decade before 2005. The percentage share of households in total final energy consumption is declining, at around 53%, while the share of sustainable energy sources reached 15% in final energy consumption.

Serbia depends mostly on oil and natural gas from import, and thus it is necessary to define more efficient energy consumption, increase energy efficiency and use locally available renewable energy sources as much as possible.

After the energy crisis and the difficulties in the supply of natural gas in 2009, as the economic downturn in the industrial sector, primary energy consumption of primary grows by 1% per year, while final energy consumption is 1.5% higher than the consumption in 2014.

Although imports of primary energy sources grows, the projected import dependence is 32%, which decreased by 4% compared to 2008. Trend growth in domestic production of crude oil (15%) and natural gas (20%) continues, but it is estimated the decreased use of hydro potential (2%).

Environmental considerations related to the production and consumption of electricity are also problematic. There are large greenhouse gas emissions in the energy sector (about 75%). The Republic of Serbia made commitment on sustainable development, efficient energy production and use as the energy policy of the country, defined energy sector development strategy at national level, as well as energy sector development strategy completely based on energy efficiency and increased use of renewable energy sources in energy production and transportation.

ACKNOWLEDGMENT

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The Electrical Voltage Quality's Influence to Small Hydro Power Plant's Operating – Case Study

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Abstract—**This paper presents main indicators of electrical energy's quality that are in relation to the electrical voltage. Supply voltage quality requirements for medium voltage systems according to standard EN 50160 are also presented. Finally, electrical parameters at one small hydro power plant were monitored and the voltage quality's influence to its operating was analyzed.**

Keywords- electrical voltage's quality, small hydro power plant, phase voltage asymmetry, total harmonic distortion, voltage interruptions

I. INTRODUCTION

In the last few decades electrical energy quality became one of most important subjects in the area of electrical power engineering. Constant development of electrical appliances that consist of a large number of electronic devices is followed by increased need for high-quality electrical energy. The term "electrical energy quality" has several aspects, such as:

- frequency quality, that is related to the frequency control at the prescribed value,
- voltage quality, that is related to the deviation of voltage magnitude and voltage signal from rated values and ideal references,
- current quality, that is complementary to the term voltage quality and it is measured by the deviation of current signal from ideal references, but current quality also characterizes consumer's performance in relation to the system,
- power (energy) quality that represents combination of voltage and current qualities;
- supplying quality that includes all technical and commercial aspects of voltage and frequency qualities that have influence to the customer;
- customer's quality that includes all technical and commercial aspects of voltage, current and energy qualities that can have impact to the supplier [1,2].

In this paper the emphasis is placed on voltage quality's influence and its importance to the proper operation of small hydro power plants connected to the electrical energy system.

II. THEORETICAL BACKGROUND

A. Electrical Energy Quality Indicators Related to the Electrical Voltage

Electrical energy quality related to the electrical voltage is measured by the deviation of voltage's magnitude and waveform from ideal references. According to this fact, basic forms of disorder are defined:

- voltage dips represent reducing of voltage magnitudes that last in the range of 0.01 second to 1 minute and which typical values are from 10% to 90% of rated voltage value,
- voltage interruptions represent total voltage loss – voltage value is lower than 10% of its rated value and they can be classified as: momentary interruptions that last from 0.01 to 3

seconds, short duration interruptions that last from 3 to 60 seconds, and sustained interruption that last more than one minute;

- voltage swells which are defined as voltage increases for 10 % or more than rated value which last from 0.01 to 60 seconds;
- transients which are characterized by voltage sinus impulse irregularity that are repeated in short time intervals that can be caused by a lot of different unpredictable situations;
- over voltages and under voltages that represent deviations more than ±10% from the rated voltage value;
- harmonics that represent sinus waveforms which frequencies are multiples of basic voltage frequency and that are added to the basic harmonic making its distortion;
- frequency deviation that is manifested in changing of voltage waveform periods;
- phase voltage asymetry that is characterized by a difference in the phase voltage amplitude or argument in comparison with two other phases [1].

All those voltage disturbances can have high impact to electrical energy quality that is delivered to the customer.

B. *Main Requirements of Standard EN 50160*

One of most important documents that defines and describes voltage quality in relation to frequency, magnitude, waveform, and phase symmetry in electrical power systems is European Standard EN 50160. It was created by CENELEC (European Committee for Electro technical Standardization) in 1994. [3-4]. EN50160 standard gives general limits, which are technically and economically possible for the supplier to maintain in public distribution systems. This standard is used for all European power systems. Some of supply voltage requirements that are going to be used for voltage quality analyses at the connection point of small hydropower plant to electric power system (example from practice used for case study and described in next Section) for medium voltage electrical systems according to EN50160 are shown in Table 1.

TABLE I. CEATINES SUPPLY VOLTAGE CHARACTERISTICS ACCORDING TO EN 50160 FOR MEDIUM VOLTAGE SYSTEM

Parameters	**Averaging time**	**Limit values for 95% of week (160 hours)**
Voltage magnitude variations	10 minutes	±10%
Short interruptions of supply voltage (up to 3 minutes)	10 ms	10-100/ year
Long interruptions of supply voltage (longer than 3 minutes)	10 ms	10-50/ year
Phase voltage asymmetry	10 minutes	<2%
THD	10 minutes	<8%
Temporary, power frequency overvoltages	-	1.7 $U_C{}^a$ – for solid or impedance grounded systems 2 U_C - for ungrounded or reactance grounded systems

One of voltage quality parameters presented in Table 1 was THD (total harmonic distortion, usually for first 40 higher harmonics). It is determined by Eq. (1), where U_N is rated voltage of the system (fundamental harmonic), and U_h is value of harmonic with ordinal number *h*.

$$THD_u = \sqrt{\sum_{h=2}^{40} (U_h)^2} \cdot \frac{100\%}{U_N} \qquad (1)$$

According to EN 50160 THD in medium voltage electrical systems should be lower than 8% of fundamental voltage harmonic. Furthermore, EN 50160 defines allowed values separately for first 25 higher harmonics in percents of fundamental harmonic, but because they will not be used for voltage quality

TABLE I.

[a] U_c is declared voltage for electric power system. It is usually rated voltage, but it can have other values if there is agreement between supplier and customer.

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analysis in this case study separately, but only with THD as voltage quality parameter, it is not necessary to show their values here. Higher harmonics are usually not considered because their values are really low and they don't have significant part in THD calculating, so they are usually negligible.

It is important to note that standard EN 50160 defines more voltage quality parameters, such as frequency, rapid voltage changes (flickers) etc., but they are not described in this chapter because they will not be subjects of voltage quality analyses made at the example from practice.

III. EXAMPLE FROM THE PRACTICE

The voltage quality influence was analyzed at the example of one small hydro power plant's operating. The need for this power plant's monitoring was appeared because during periods of high waters a lot of outages occurred and facility couldn't operate. This represents a great problem because during those periods best conditions for electrical power producing are created and in this manner the owner of the plant has significant financial losses. Total generator installed capacity of this power plant is 630 kVA and it is connected to electrical energy system via distribution transformer 10/0.4 kV.

Electrical parameters at the place of small power plant's connection to the electrical energy system were monitored for a period of one month – February 2016. This month was chosen because for this facility it represents period of high waters and during this period it could operate with the rated power.

For electrical parameters measuring and data storing, smart measuring electrical device - MIS-1U was used. This measuring device was invented by Research and Development Center "ALFATEC" and it is presented in the Fig. 1. It has four inputs for voltage measuring circuit for three-phase AC voltage 400/231 V – three phase plus neutral conduit that are carried out through the unique connector, as well as three inputs for AC current measuring which effective values are 5 A or smaller. Measuring range of device MIS-1U can be extended by additional connecting of voltage and current measuring transformers with appropriate characteristics. Electrical parameters that can be measured by MIS-1U are effective values of phase and line voltages and currents; active, reactive, apparent power and power factor in all three phases and in total; frequency, total harmonic distortion (THD) of phase currents and voltages, active, reactive and apparent energy [4]. All measured data are storage at inserted microSD memory card. Time interval of data storage can be adjustable in a range 1-15 seconds and for concrete case, time interval of 5 seconds was chosen, because it was also time interval that owner of the plant used for data storage by his measuring device at the point of power plant's connection to the electrical energy system. Stored data can be analyzed by a different software packages and for this analyses specially created software IPC-AS was chosen according to its possibility to make monthly analyses of electrical parameters.

For this hydro power plant's electrical parameters monitoring MIS-1U was connected in the secondary circuits of measuring current and voltage transformers that were installed in transformer substation at the electrical facility at voltage of 10 kV. MIS-1U connection was realized at available connection points of electrical power network analyzer that has been placed by the owner of the plant in order to perform control measurements. In this way smart measuring device was monitoring total electrical power producing, as well as voltage characteristics at the medium voltage side of 10/0.4 kV distribution transformer used for power plants connection to electrical energy system.

Figure 1. Measuring information system - MIS-1U

IV. RESULTS AND DISCUSSION

After one month of electrical parameters monitoring, analysis of obtained results was made. It is determined that during the period of measuring (February 2016) 52 power plant forced outages were occurred. All those outages were analyzed separately and it was concluded that 29 from them were caused by

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low voltage quality in electrical energy system at the point of power plant's connection. Other 23 outages are not in relation with voltage conditions in the system, since they are products of some other protective systems reactions. Monitoring results are presented through monthly diagrams of phase and line voltages, phase voltage asymmetry and phase voltage total harmonic distortion (THD), shown in Figs. 2 – 5, as well as in the Table II that represents the review of all forced outages caused by voltage conditions in the system.

In Fig. 2 monthly diagrams of line voltages are presented and it is obvious that during the period of monitoring there were a lot of voltage interruptions. Actually, some of these interruptions didn't cause forced outages, because in moments of their appearances power plant had already stopped its operating. Therefore, 12 forced outages were caused by voltage interruptions: 3 by short duration interruptions (lasted less than one minute) and 9 by sustained interruptions (lasted more than one minute). Voltage interruptions which caused forced outages are classified by days of month and its duration in Table II. It is also necessary to say that if there were momentary voltage interruptions, they couldn't be recorded, because they last less than 3 seconds and time interval of data storage was 5 seconds.

If those voltages interruptions are analyzed in relation with requirements of voltage quality standard EN 50160, it is important to count all interruptions (those that caused forced outages, but also those that didn't cause). According to EN 50160, limit value for short duration voltage interruptions (less than 3 minutes in EN 50160) is 10-100 per year, and limit value for long duration voltage interruptions (more than 3 minutes in EN 50160) is 10-50 per year. Diagram from Fig. 2 was analyzed day by day and following results were obtained: during the period of one month 20 short duration and 21 long duration voltage interruptions were occurred. If these results are compared with limit values it can be concluded that those values are lower than limit values. However, if it is known that period of measuring was only one month, it is necessary to extend measuring to a period of a whole year, because with these results is only possible to make an assumption that there will probably be more interruptions than it is allowed by EN 50160 standard.

By analyzing line voltage diagrams it is also possible to determine that there weren't voltage deviations and magnitude variations higher than the allowed value of ±10% for medium voltage (10 kV), as well as temporary over voltages higher than 1.7 U_c, so limit values determined by EN 50160, regarding these parameters haven't been exceeded.

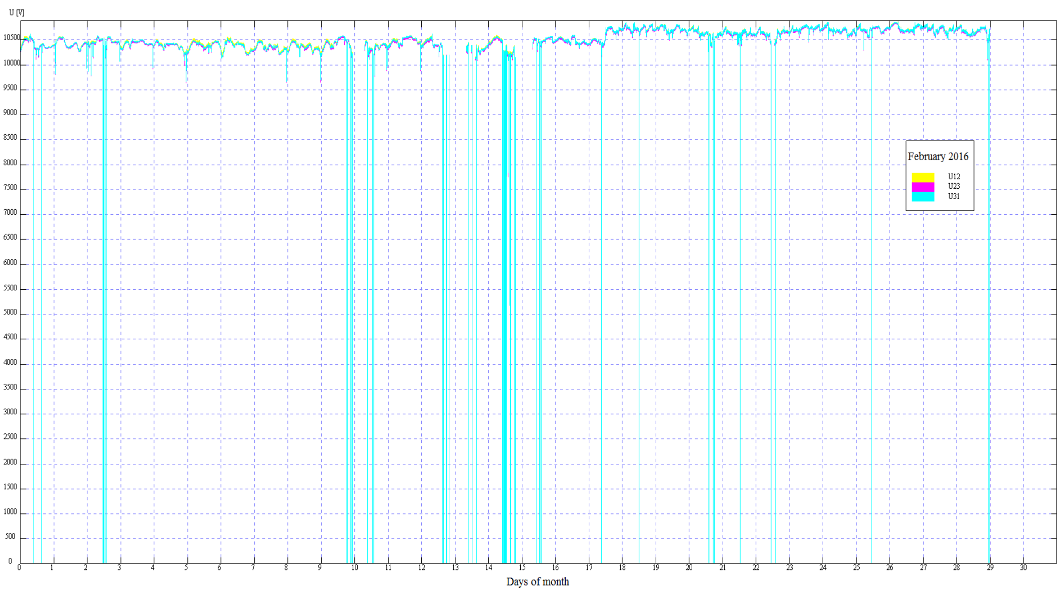

Figure 2. Line voltages diagrams at 10 kV side of transformer at the place of hydro power plant's connection to electrical energy system

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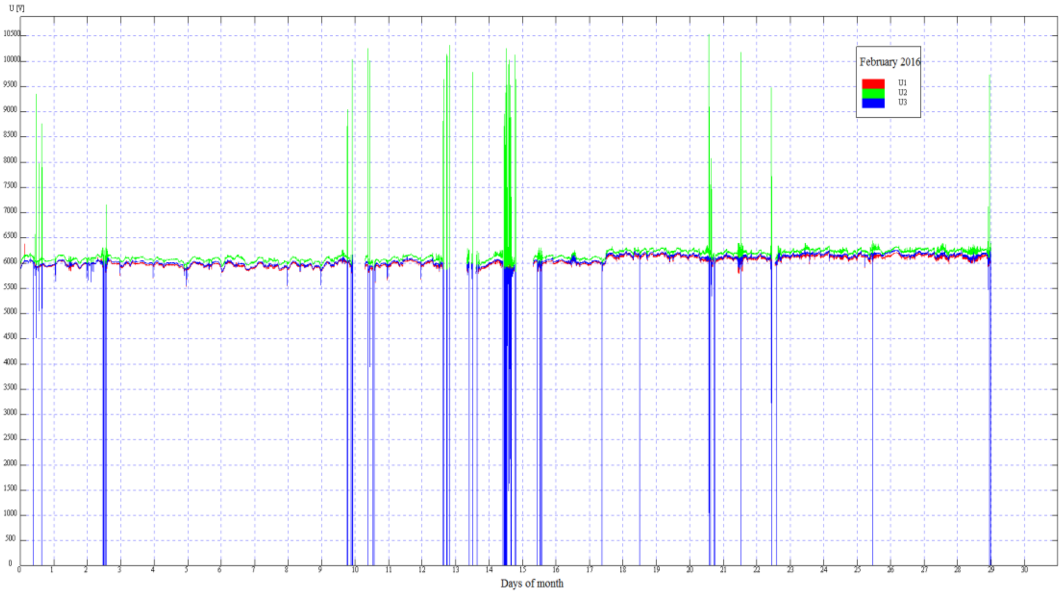

Figure 3. Phase voltages diagrams at 10 kV side of transformer at the place of hydro power plant's connection to electrical energy system

In Fig. 3 monthly diagrams of phase voltages are presented. Observing these diagrams it can be noticed that there is a high phase asymmetry during the whole period of monitoring. From 29 forced outages caused by low voltage quality, 17 were caused by phase asymmetry in the electrical system (Table II). From diagram shown in Fig. 3 it can also be noted that phase asymmetry here has model of its appearance: phase voltage U2 (green) usually increases, while phase voltage U3 (blue) simultaneously decreases. Phase voltage U1 (red) that is not easy visible in the picture, because its diagram is for the most part covered by phase voltage U2 increases in the same manner as U2, but it doesn't reach same values as U2. It is necessary to say that in all moments when phase asymmetries were detected, there were no line voltage asymmetries. In general, this is typical for single-line ground faults in ungrounded electrical systems. It is obvious that single-line ground faults were taking places in phase 3 as well as that phase voltage U3 hasn't reached value 0 at all these situations. Furthermore, phase voltages U1 and U3 didn't have same increases at those moments, which indicates that those ground-faults were realized through some impedances.

If it is determined that asymmetry has its model of appearance and it if is clear that it is caused by single-line ground faults in electrical energy system, it can be assumed that those situations are not accidental. Probably, there are some points at distribution line where, during bad weather conditions such as wind or humidity, vegetation can cause this kind of situations. This assumption can be checked by detail observation of distribution line and if it is correct, it is necessary to remove that vegetation and reduce number of single-line ground faults as well as number of forced outages of the plant.

This phase voltage asymmetry can also be considered in relation with EN 50160 requirements. In Fig. 4 its monthly diagram is presented. From this diagram it can be noticed that for the largest part of the month phase asymmetry was less than 2%, what is limit value for 95% of week defined in standard EN 50160. But there are also many peaks that in some moments reach values higher than 90%. This is typical for periods when single-line ground faults have been occurred. The "worst day" regarding the voltage asymmetry was 15th of February when phase asymmetry was higher than rated value for almost 8 hours. This indicates that voltage quality in relation with phase asymmetry at the point of power plant's connection to the system is not in accordance with the standard EN 50160.

This low voltage quality resulted in situation that hydro power plant had many forced outages and many nonworking hours.

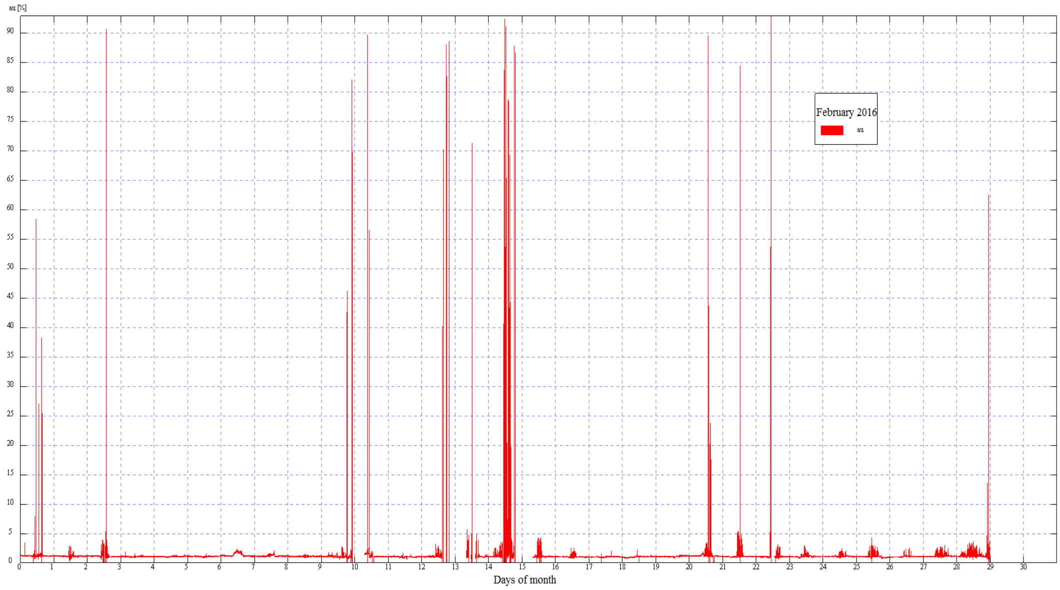

Figure 4. Phase voltages asymmetry diagram at 10 kV side of transformer at the place of hydro power plant's connection to electrical energy system

Actually, number of forced outages was consciously reduced, because the owner of the plant decided to stop operating during periods of highest asymmetries in order to reduce damaging of switching equipment of the plant.

One of really important voltage quality parameters according to EN 5060 is certainly voltage THD (total harmonic distortion). In Fig. 5 phase voltages THD diagrams at the place of power plant's connection are shown. Limit value of voltage THD, declared by EN 50160 for 95% of week is 8%. From diagrams presented in Fig. 5 it can be noticed that this requirement is satisfied for the most part of the monitoring period (phase voltage THD is about 4%).

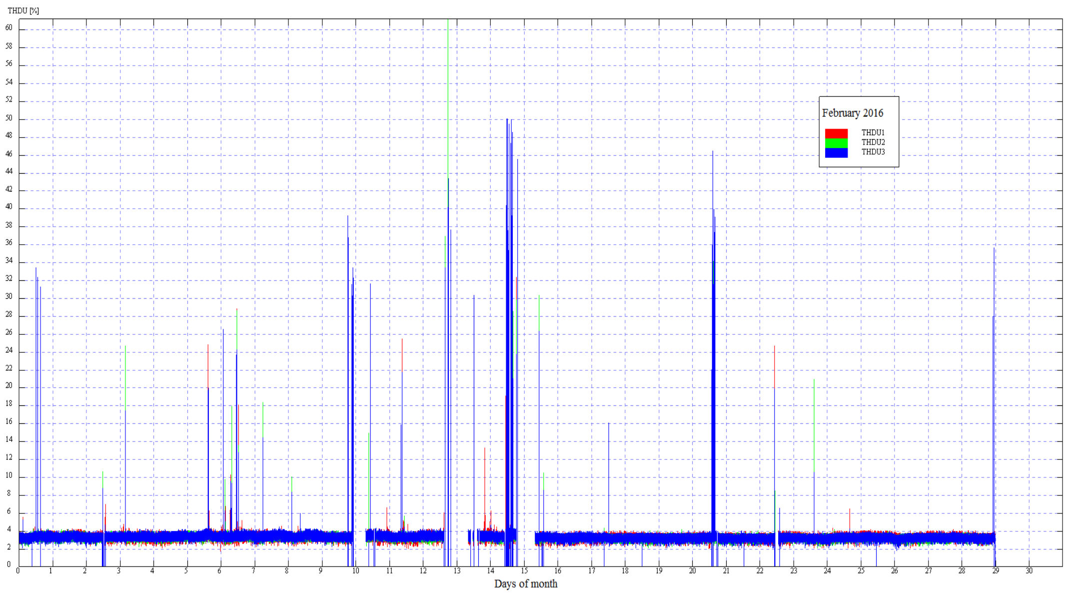

Figure 5. Phase voltages THD diagrams at 10 kV side of transformer at the place of hydro power plant's connection to electrical energy system

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However, as it was case with phase asymmetry, here are also visible a lot of peak values that are in some moments higher than 50%. Those situations are specified for moments of transformer connection or disconnection from electrical energy system and if diagrams from Figs. 4 and 5 are compared it can be seen that a lot of peak values of THD are at same moments as peak values of phase asymmetry.

TABLE II. REVIEW OF POWER PLANT'S FORCED OUTAGES CAUSED BY VOLTAGE QUALITY

Date	Number of power plant's forced outages caused by short duration voltage interruptions	Number of power plant's forced outages caused by sustained voltage interruptions	Number of power plant's forced outages caused by phase asymmetry	**Total number of power plant's forced outages caused by low voltage quality**
01.02.2016.	1	0	2	3
02.02.2016.	0	0	0	0
03.02.2016.	0	1	1	2
04.02.2016.	0	0	0	0
05.02.2016.	0	0	0	0
06.02.2016.	0	0	0	0
07.02.2016.	0	0	0	0
08.02.2016	0	0	0	0
09.02.2016	0	0	0	0
10.02.2016	0	1	1	2
11.02.2016	0	1	1	2
12.02.2016	0	0	0	0
13.02.2016	0	0	0	0
14.02.2016	0	2	1	3
15.02.2016	0	1	1	2
16.02.2016	0	1	0	1
17.02.2016	0	0	0	0
18.02.2016	1	0	0	1
19.02.2016	1	0	0	1
20.02.2016	0	0	0	0
21.02.2016	0	1	2	3
22.02.2016	0	1	5	6
23.02.2016	0	0	1	1
24.02.2016	0	0	0	0
25.02.2016	0	0	0	0
26.02.2016	0	0	0	0
27.02.2016	0	0	0	0
28.02.2016.	0	0	0	0
29.02.2016.	0	0	2	2
Total month	**3**	**9**	**17**	**29**

Critical day in regarding with THD was also 15th of February, especially during the period in which the largest number of single-line ground faults occurred and power plant was out of system. In general, this day can be described as typical example for low voltage quality in the system: long period with phase asymmetries, a lot of ground faults, high value of THD and 11 voltage interruptions. One of them caused a forced outage of the plant (Table II).

V. CONCLUSION

Regarding all these voltage quality parameters it can be concluded that at the point of considered small hydro power plant's connection to the electrical system, its voltage quality is not satisfied for normal hydro power plant's operation. It is necessary to check all assumptions made in this study about bad conditions in distribution line and try to remove principal causes of events such as single-line ground faults, phase voltage asymmetries or THD and in that way reduce number of forced outages of the plant.

Further researches in this area can include analyses of voltage quality for another kind of customers, such as industrial facilities or important public buildings (hospitals, water supply systems etc.). That research can also include other voltage quality parameters that haven't been analyzed in this paper: voltage flickers, power frequency or analysis of individual voltage harmonics. In addition, future investigation can be based on requirements of other voltage quality standards: IEEE 1159 or IEC 60038.

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Hybrid Spatial Mathematical Model for the Selection of the Most Sutiable Wind Farm Locations

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Abstract— **The main objective of this paper is to develop a reliable model for the identification of locations for the installation of wind farms which will provide significant support to planners in the strategy for the development and management of renewable energy. The proposed model is based on the combined application of Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) using the multi-criteria technique of Decision Making Trial and Evaluation Laboratory (DEMATEL), the Analytic Network Process (ANP) and Multi-Attributive Border Approximation area Comparison (MABAC). The DEMATEL-ANP (DANP) method is used to determine the weight coefficients of the evaluation criteria, and the MABAC method is used to rank the selected viable locations. The final map of benefits is presented using raster cells (alternatives) which are evaluated in the range of 1 (least suitable) to 7 (most suitable). A sensitivity analysis, carried out by changing the input weights of the clusters, indicates that the model is useful for identifying suitable locations for the development of wind farm projects, as well as for assessing the suitability of already licensed renewable energy projects for the construction of wind farms. The proposed method can be used for spatial development policy at all levels of public administration related to renewable energy resources.**

Keywords - GIS; DEMATEL; ANP; MABAC; renewable energy.

I. Introduction

Energy is a key element necessary for the sustainable development and prosperity of a society [1]. Over 80% of the world's energy production is based on fossil fuels - coal, oil and natural gas. However, the global oil reserves are limited and unevenly distributed, which could in the near future lead to serious political and economic conflicts [2]. The increasing demand for energy and the depletion of fossil fuels inevitably causes a rise in their price. This is why most countries have started to develop new energy security policies in order to reduce energy costs and increase energy independence. At the same time, increasing awareness of environmental pollution has also led to an increasing use of renewable energy sources (RES) [3]. Besides RES being inexhaustible and reducing the energy dependence of society on fossil fuels, they are also the most acceptable sources of energy from an environmental point of view and from the aspect of the fight against global climate change [4]. In order to increase energy independence, the European Union (EU) states determined a strategy that by 2020 they would increase the share of renewable sources to 20% of their total energy consumption [5].

The development of RES, together with measures aimed at more efficient use of energy are priorities at a national and European level, as both the basis of environmental protection and of energy policy. According to Directive 2009/28/EZ [6] and the Decision of the Ministerial Council of the Energy Community [7] a binding target was determined that by 2020, renewable energy would make up 27% of the gross share of energy consumption in the Republic of Serbia. In order to achieve this level and to encourage use of RES, the Republic of Serbia has adopted a number of bylaws in the field of renewable energy which define the conditions for using renewable energy sources [8], and it has developed a National action plan for the use of sources of renewable energy [9].

In recent years, wind energy has become one of the most popular sources of renewable energy [10]. Use of wind energy has a relatively small impact on the environment (visual effects, the loss of birds colliding with wind turbines, the negative effects of noise on animals, loss or damage to the habitat of certain species, etc. compared to the more serious effects of conventional electricity production, which contribute to climate change and disrupt the natural balance [11]. Wind energy is renewable and clean: it does not pollute the air, it does not emit CO_2, and it does not cause acid rain or destroy the ozone layer. For these reasons, many countries have developed projects in recent years and invested in the construction of wind farms; other reasons for wind farm projects are their quick and relatively simple installation [12,13]. Wind energy has proven to be a serious source of renewable energy that is developing globally and that has an installed capacity that significantly increases each year [14].

The choice of suitable locations for wind farms is a complex issue that requires the careful and combined analysis of numerous criteria. On a global level, a large number of wind farms follow mainly economic criteria, ignoring any negative effects on the environment [13]. The optimal selection of locations for wind farms requires the resolution of mutually conflicting factors of an economic and technological nature, with ecological and social limitations, while also respecting public opinion [15]. In other words, spatial planners are faced with a double challenge, since they must answer for the wind farm projects they work on, which must be able to generate economic benefit on the one hand, while minimizing risks to the environment and the interests of stakeholders on the other [16]. In order to achieve this, it is essential to establish certain rules that will evaluate different locations on the basis of a range of environmental, economic and social criteria and constraints [17].

Geoinformation technologies are suitable for this type of study because they can efficiently manage large amounts of spatial and attribute data collected from various sources. Geoinformation systems also have certain shortcomings, seen in their inability to make multicriteria decisions and to propose optimal locations. In order to facilitate multicriteria decision making and to present the spatial results using a GIS, it is essential to combine the tools of MCDA with GIS. The combination of GIS and MCDA is a concept that is widely used in solving problems in many areas, such as the environment, ecology, transportation, urban and regional planning, waste management, hydrology, agriculture, forestry, geology, and site selection [17].

This paper presents a new model for identifying the best locations for wind farms. The model considers 11 constraints and 11 evaluation criteria grouped into economic, social and environmental clusters. In the hybrid GIS-MCDA model, the fuzzy DEMATEL method [18] is implemented to determine connections in the network structure based on the criteria. Pair-wise comparisons of the criteria/clusters from the DEMATEL method are the input parameters for the mathematical apparatus of the ANP method. Weight coefficients of the criteria/clusters are obtained as the output values from the ANP method, which are then used in the GIS for obtaining the final map of most suitable locations for wind farms. After determining the most suitable locations, the MABAC method is used to select the most suitable location from them. Application of the model is presented as a case study of the region of Vojvodina in Serbia.

The paper is organised in three sections. The introductory section presents the importance of renewable sources of energy. The second section of the paper presents and describes the phases of the proposed GIS-MCDA model. In the third and final section are the concluding considerations and suggestions for future research in this area.

II. Architecture of the model

The model presented in this paper is based on the spatial structure of MCDA. Spatial multicriteria decision analysis (SMCDA) consists of procedures which include the use of both geographic data and preferences of the decision maker (DM), and the manipulation of data and preferences according to specified decision rules [19]. This approach exploits the capabilities of GIS in the management of spatial data, and the flexibility of MCDA to combine real spatial information (e.g. slope, communication, use of the land) with value-based information (e.g. expert opinion, standards, surveys) [20]. The main advantage of integrating GIS and MCDA can be seen in their specific capabilities supplementing each other. GIS has great possibilities for the manipulation, storage, management, analysis and visualization of geospatial data, while MCDA provides a collection of procedures, techniques and algorithms for structuring decision problems, and designing, evaluating and prioritizing decision alternatives [19].

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Because of the complexity of the problem of determining a location, the GIS-MCDA model is proposed as a relevant option for systematic analysis and rational decision making when selecting locations for wind farms. From a methodological point of view, the proposed model for identifying suitable locations for wind farms includes the stages presented in Fig. 1.

After defining the problem and establishing the model, the constraints and evaluation criteria are identified. The constraints are based on criteria which limit (dismiss) possible alternatives and which are based on the Boolean relation (true/false), while the evaluation criteria can be quantified according to their degree of suitability for all feasible alternatives [21]. The identification of criteria involves a systematic analysis of factors that may impact installation of the wind farms [17]. This is achieved through questionnaires, workshops organized with stakeholders, or based on some expert knowledge or a combination of all of these.

By investigating GIS-MCDA studies [11,15,17] it can be noted that in the decision making process for the selection of locations for wind farms, the most commonly used clusters are those of an environmental, spatial, social and technical nature, which are proposed in this model.

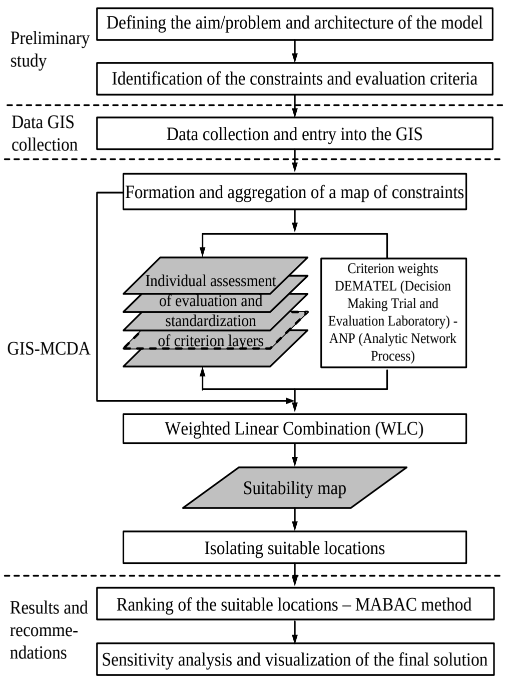

Figure 1. The GIS-MCDA model

III. GIS-MCDA EVALUATION

MCDA includes aggregation of the constraints, standardization, weighting, a summary analysis of all the criteria to be considered in the decision-making process andselection of the best alternatives. At the step of forming and aggregating the map of constraints, all of the layers of constraints on the thematic maps are obtained using Boolean (logical) algebra, and the raster cells (alternatives) of the dismissed areas are assigned a value of zero (0), while the alternatives for the remaining areas are given a value of one (1). The final constraints of the area are obtained by the aggregation of all of the layers of constraints. On the final map of constraints, only the locations characterized as suitable (value 1) on all of the layers of constraints are considered as potential locations for constructing wind farms and are the subject of the analysis [16].

After this, individual assessment of the evaluation criteria and standardization of the clusters/criteria takes place. The criteria on the maps are presented in the form of GIS layers in different ways and in different forms. Use of the method of weighted linear combination (WLC) requires that all data sets be standardized [21] or transformed into units that can be compared. Use of the WLC method requires normalization of the weights. When determining the weight coefficients of the clusters/criteria, the hybrid DANP model is used for calculating the normalized weight criteria and for the final application of the WLC method.

A. DEAMTEL method

The original DEMATEL method is modified by some researchers so as to make it comply with their problems. The modified fuzzy DEMATEL method used in this paper is adapted from a study by Dalalah et al. [18]. Based on Dalalah et al. [18], the procedure for carrying out the fuzzy DEMATEL method is described in the following section:

Step 1. Gather experts' opinion and calculate the average matrix *Z*. A group of *m* experts and *n* factors are used in this step. Each expert is asked to view the degree of direct influence between two factors based on pair-wise comparison. The modified fuzzy DEMATEL method is built first, creating the direct-relation fuzzy matrix *Z* where *Z* is the (*nxn*) matrix, *n* represents the number of criteria. The direct relation matrices are all obtained by holding a pair-wise comparison

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among the criteria themselves in which Z indicates the degree to which criterion C_i affects criterion C_j therefore the relationships between the criteria can be held within a matrix. For each expert, an $\left[z_{ij}\right]_{nxn}$ non-negative matrix is constructed (n represents the number of criteria) as $Z^e = \left[\tilde{z}_{ij}^e\right]$, where e is the number of experts participating in the evaluation process with $1 \le e \le m$. Thus, $Z^1, Z^2, ..., Z^m$ are the matrices from m experts. In this method, the effects of the criteria on each other are expressed in terms of linguistic expressions. Pair-wise comparison of the criteria of the experts is carried out using a fuzzified scale in which linguistic expressions are represented by means of triangular fuzzy numbers $\tilde{z}_{ij}^e = \left(z_{ij,e}^{(l)}, z_{ij,e}^{(m)}, z_{ij,e}^{(r)}\right)$, where e denotes an expert, and m is the total number of experts. The final matrix Z is obtained by aggregating the expert opinions. The elements of matrix Z are obtained using expression (1)

$$\tilde{z}_{ij} = \left(z_{ij}^{(l)}, z_{ij}^{(s)}, z_{ij}^{(r)}\right) = \begin{cases} z_{ij}^{(l)} = \min\left(z_{ij,e}^{(l)}\right) \\ z_{ij}^{(s)} = \dfrac{1}{m}\sum_{i=1}^{m} z_{ij}^{(s)} \\ z_{ij}^{(r)} = \max\left(z_{ij,e}^{(r)}\right) \end{cases}, \quad (1)$$

where $z_{ij,e}^{(l)}, z_{ij,e}^{(s)}$ and $z_{ij,e}^{(r)}$ are the preferences of the e-th expert, M is the set of experts involved in the investigation, e denotes an expert, and m is the total number of experts.

Step 2. Calculate the normalized initial direct-relation matrix D. In this step, the elements of the normalized initial direct-relation matrix $D = \left[d_{ij}\right]$ are calculated. The elements of matrix D are obtained by summing the elements of the average matrix Z by rows. Following this, using equation (3), the maximum element R is found among the summed elements. By using simple normalization, equation (2), each element of matrix Z is divided by the value we obtain using expression (3).

$$d_{ij} = \frac{\tilde{z}_{ij}}{R} = \left(\frac{z_{ij}^{(l)}}{r^{(l)}}, \frac{z_{ij}^{(s)}}{r^{(m)}}, \frac{z_{ij}^{(r)}}{r^{(r)}}\right), \quad (2)$$

$$R = \max\left(\sum_{j=1}^{n} \tilde{z}_{ij}\right) = \left(r^{(l)}, r^{(s)}, r^{(r)}\right), \quad (3)$$

where n is the total number of criteria.

Based on Markov chain theory, D^m are powers of matrix D, e.g. $D^1, D^2, ..., D^\infty$ guarantees the convergent solutions to the matrix inversion as shown below:

$$\lim_{m\to\infty} D^m = [0]_{nxn}, \quad (4)$$

Step 3. In this step, the elements of the total relation matrix T are calculated. The total-influence matrix T is obtained by utilizing equation (4), in which, I is an nxn identity matrix. The element of $\tilde{t}_{ij}$ represents the indirect effects that factor i has on factor j, then the matrix T reflects the total relationship between each pair of system factors. The initial normalized direct-relation fuzzy matrix can be separated into separate sub matrices i.e., (D_1, D_2, D_3). It was proven that $\lim_{w\to\infty}\left(D_s\right)^w = 0$ and $\lim\left(I + D + ... + D + ... + D\right) = \left(I - D\right)$, where *0* is the null matrix and I is the identity matrix. Therefore, the total-relation fuzzy matrix T can be acquired by calculating the following equation [18]:

$$T = \lim_{w\to\infty}\left(D + D^2 + ... + D^w\right) = D\left(I - D\right)^{-1}, \quad (5)$$

Step 4. Summing elements ($\tilde{t}$) of matrix T by rows and columns. In this step, the DEMATEL method is used to carry out summing of the elements of matrix T by columns and rows. The sum of rows and sum of columns of the sub-matrices T_1, T_2 and T_3 denoted by the fuzzy numbers D_i and R_j, respectively, can be obtained through equations (6) and (7) respectively:

$$D_i = \sum_{i=1}^{n} \tilde{t}_{ij}, \quad i = 1, 2, ..., n, \quad (6)$$

$$R_i = \sum_{j=1}^{n} \tilde{t}_{ij}, \quad j = 1, 2, ..., n, \quad (7)$$

where n is the number of criteria. Let D_i be the sum of the i^{th} row in matrix T. The value of D_i indicates the total of both the direct and indirect effects that factor i has on the other factors. Let R_j be the sum of the j^{th} column in matrix T. The value of R_j shows the total of both the direct and indirect effects that all other factors have on factor j. If $j = i$, the value of ($D_i + R_j$) represents the total effects both given and received by factor i. In contrast, the value of ($D_i - R_j$) shows the net contribution by factor i to the system. Moreover, when ($D_i - R_j$) is positive, factor i is a net cause.

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When $(D_i - R_j)$ is negative, factor i is a net receiver.

Step 5. Determining the threshold value α. The threshold value α is used to construct a cause and effect relationship diagram. The threshold value α is calculated as the mean value of the elements of matrix T, according to equation (8). This calculation is aimed at eliminating some minor effects of the elements in matrix T [23].

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\tilde{t}_{ij}}{N}, \qquad (8)$$

where N is the total number of elements in matrix T.

Step 6. Constructing a cause and effect relationship diagram. The cause and effect diagram is constructed by mapping all coordinate sets of $(D_i + R_j, D_i - R_j)$. The factors for which t_{ij} is greater than α, are selected and shown in a cause and effect diagram [23].

B. *Hybrid DANP method*

After constructing the cause and effect relationship diagram, in the next phase the weight coefficients are calculated for the clusters/criteria using the ANP method. The hybrid DANP method, that is, the integration of the DEMATEL and ANP methods, is carried out in five steps, which are implemented after constructing the effect relationship diagram (ERD). The DANP method can be described in the following steps [22]:

Step 1. Determining the unweighted supermatrix. Before determining the unweighted supermatrix it is necessary to define the network model for the ANP method. The network model is determined on the basis of the total relation matrix and ERD. The first step is based on the network model and the total-influence matrix T to construct the network hierarchical structure of the system to the defined objectives. The matrix T will be obtained from DEMATEL. Formation of the network model creates the conditions for determining the unweighted supermatrix. Normalize each level with the total degree of influence from the total relation matrix T for criteria by DEMATEL.

$$T_c = \begin{array}{cc} & \begin{array}{cccc} D_1 & D_1 & & D_1 \\ c_{11}c_{12}\cdots c_{1m1} & c_{21}c_{22}\cdots c_{2m2} & \cdots & c_{n1}c_{n2}\cdots c_{nmn} \end{array} \\ \begin{array}{c} D_1\ \begin{array}{c} c_{11}\\ c_{12}\\ \vdots \\ c_{1m1}\end{array} \\ D_2\ \begin{array}{c} c_{21}\\ c_{22}\\ \vdots\\ c_{2m2}\end{array} \\ D_3\ \begin{array}{c} c_{n1}\\ c_{n2}\\ \vdots\\ c_{nmn}\end{array}\end{array} & \begin{bmatrix} T_c^{11} & T_c^{12} & \cdots & T_c^{1n} \\ T_c^{21} & T_c^{22} & \cdots & T_c^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ T_c^{n1} & T_c^{n2} & \cdots & T_c^{nn} \end{bmatrix} \end{array}, \qquad (9)$$

Where matrix T_c^{11} contains the factors from group D_1 and their influences in relation to the factors from group D_1. In matrix T_c^{21} are the factors from group (cluster) D_2 and their influences in relation to the factors from group D_2 and so on.

Step 2. The normalized total influence matrix for criteria T_c^{α}. After obtaining matrix T_c, it is then normalized. During the process of normalization, the criteria total-influence matrix T_c yields T_c^{α}. Normalized matrix T_c^{α} is shown by equation (10):

$$T_c^{\alpha} = \begin{array}{cc} & \begin{array}{cccc} D_1 & D_1 & & D_1 \\ c_{11}c_{12}\cdots c_{1m1} & c_{21}c_{22}\cdots c_{2m2} & \cdots & c_{n1}c_{n2}\cdots c_{nmn} \end{array} \\ \begin{array}{c} D_1\ \begin{array}{c} c_{11}\\ c_{12}\\ \vdots \\ c_{1m1}\end{array} \\ D_2\ \begin{array}{c} c_{21}\\ c_{22}\\ \vdots\\ c_{2m2}\end{array} \\ D_3\ \begin{array}{c} c_{n1}\\ c_{n2}\\ \vdots\\ c_{nmn}\end{array}\end{array} & \begin{bmatrix} T_c^{\alpha 11} & T_c^{\alpha 212} & \cdots & T_c^{\alpha 1n} \\ T_c^{\alpha 21} & T_c^{\alpha 22} & \cdots & T_c^{\alpha 2n} \\ \vdots & \vdots & \ddots & \vdots \\ T_c^{\alpha n1} & T_c^{\alpha n2} & \cdots & T_c^{\alpha nn} \end{bmatrix} \end{array} \qquad (10)$$

Step 3. Calculating the elements of the unweighted supermatrix W. Because the total influence matrix T_c fills the interdependence among the dimensions and criteria, we can transpose the normalized total influence matrix T_c^{α} by the dimensions based on the basic concept of ANP resulting in the unweighted supermatrix $W = (T_c^{\alpha})'$, equation (11)

$$W = (T_c^{\alpha})^T = \begin{array}{cc} & \begin{array}{cccc} D_1 & D_1 & & D_1 \\ c_{11}c_{12}\cdots c_{1m1} & c_{21}c_{22}\cdots c_{2m2} & \cdots & c_{n1}c_{n2}\cdots c_{nmn} \end{array} \\ \begin{array}{c} D_1\ \begin{array}{c} c_{11}\\ c_{12}\\ \vdots \\ c_{1m1}\end{array} \\ D_2\ \begin{array}{c} c_{21}\\ c_{22}\\ \vdots\\ c_{2m2}\end{array} \\ D_3\ \begin{array}{c} c_{n1}\\ c_{n2}\\ \vdots\\ c_{nmn}\end{array}\end{array} & \begin{bmatrix} W^{11} & W^{12} & \cdots & W^{1n} \\ W^{21} & W^{22} & \cdots & W^{2n} \\ \vdots & \vdots & \ddots & \vdots \\ W^{n1} & W^{n1} & \cdots & W^{nn} \end{bmatrix} \end{array} \qquad (11)$$

Step 4. Calculating the elements of the weighted normalized supermatrix W^{α}. The elements of the weighted normalized supermatrix W^{α} are obtained by multiplying the elements of the unweighted supermatrix W with corresponding elements from the normalized total influence matrix T_D^{α}. The elements from the normalized total influence matrice T_D^{α} are obtained by normalizing the matrix T:

$$T_D^{\alpha} = \begin{bmatrix} t_D^{11}/d_1 & \dots & t_D^{1j}/d_1 & \dots & t_{c^{1m1}}^{11}/d_1 \\ \vdots & & \vdots & \dots & \vdots \\ t_D^{i1}/d_i & \dots & t_D^{ij}/d_i & \dots & t_D^{in}/d_i \\ \vdots & & \vdots & & \vdots \\ t_D^{n1}/d_n & \dots & t_D^{nj}/d_n & \dots & t_D^{nn}/d_n \end{bmatrix}, \quad (12)$$

where $t_D^{\alpha j} = t_D^{\alpha}/d_i$, and the value of d_i is obtained as $d_i = \sum_{j=1}^{n} t_D^{ij}$.

Step 5. Find the limit of the weighted supermatrix W^{α}. The two stages of this step are to get the limit supermatrix. Multiplying the weighted supermatrix by itself multiple times results in the limit supermatrix; then the weight of each evaluation criterion is obtained. The weighted supermatrix can be raised to the limiting powers until the supermatrix has converged and become a long-term stable supermatrix to obtain the global priority vectors, called DANP influence weights, such as $\lim_{k \to \infty} = W^k$, where W is the limit supermatix, while k is any number.

C. Aggregation of the criteria

After determining the weight coefficients of the clusters/criteria, it is necessary to carry out aggregation of the criteria. WLC is used in the process of aggregating the criteria. The WLC aggregation method multiplies each standardized factor map (i.e., each raster cell within each map) by its factor weight and then sums the results. The following mathematical expression was used to combine the evaluation criteria (factors) according to the WLC method:

$$S = \sum w_i x_i \,, \quad (13)$$

where S is suitability, w_i is the normalized value of the weight of factor i, and x_i is the criterion score of factor i.

All GIS software systems provide the basic tools for evaluation of such a model [21]. WLC is relatively easy to understand and can be applied in many different situations. In addition, it is compensatory, meaning that low scores in one criterion can be compensated for by high scores in another one, which is desired for this particular decision problem. For these reasons, WLC was selected as the method of aggregation. As the final result of applying WLC and the aggregation of criteria maps, a Suitability map is obtained.

In the next step it is necessary to separate the suitable locations, by separating the cells with the highest values from the suitability map, which represent alternatives for the location of wind farms. The cells are filtered by combining the application of the GIS arithmetic operations and questions, by means of which feasible locations for installing wind farms are defined.

D. Results and recommendations

The final decisions or recommendations should be based on the ranking of the feasible locations. Ranking is performed in order to assess each location in relation to the targets set for the analysis. In this model, use of the MABAC method is proposed for selecting the best location. The MABAC method was developed by Dragan Pamučar at the Centre for research in the area of logistics defence at the University of Defence in Belgrade [24]. The results of the research by Pamučar and Ćirović [24] demonstrate that the MABAC method gives stable (consistent) results when compared to other methods of multicriteria decision making (SAW, COPRAS, MOORA, TOPSIS and VIKOR) and is a reliable tool for rational decision making.

Forming the initial decision matrix (X). The first step is an evaluation of m alternatives according to n criteria. We present the alternatives with vectors $A = (x, x, \dots, x)$, where x_{ij} is the value of the i-th alternative according to the j-th criterion (i=1,2,...,m; j=1,2,...,n).

$$X = \begin{array}{c} \\ A_1 \\ A_2 \\ \dots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \end{array}, \quad (14)$$

Normalization of the elements in the initial matrix (X). The elements of the normalized

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matrix ($N = [t_{ij}]$) are determined according to the equation:

- for *Benefit* type criteria (higher criteria values are preferable):

$$t_{ij} = \frac{x_{ij} - x_i^-}{x_i^+ - x_i^-}, \tag{15}$$

- for *Cost* type criteria (lower criteria values are preferable):

$$t_{ij} = \frac{x_{ij} - x_i^+}{x_i^- - x_i^+}, \tag{16}$$

where x_{ij}, x_j^+ and x_j^- are the elements of initial decision matrix (X), for which x_j^+ and x_j^- are defined as:

$x = \max(x, x, ..., x)$ and represents the maximum values of the observed criterion for each alternative.

$x = \min(x, x, ..., x)$ and represents the minimum values of the observed criterion for each alternative.

Calculation of the elements of weighted matrix (V). The elements of weighted matrix (V) are calculated on the basis of equation (17):

$$v_{ij} = w_i \cdot t_{ij} + w_i, \tag{17}$$

By using equation (17) we obtain weighted matrix V:

$$V = \begin{bmatrix} v_{11} & v_{12} & \dots & v_{1n} \\ v_{21} & v_{22} & & v_{2n} \\ \dots & \dots & \dots & \dots \\ v_{m1} & v_{m2} & \dots & v_{mn} \end{bmatrix}, \tag{18}$$

where n is the total number of criteria, m is the total number of alternatives.

Determining the matrix of border approximation areas (G). The border approximate area for each criterion is determined by equation (19):

$$g_i = \left(\prod_{j=1}^{m} v_{ij} \right)^{1/m}, \tag{19}$$

where v_{ij} represent the elements of weighted matrix (V), m is the total number of alternatives. After calculating the value of g_i for the criteria, a matrix of border approximation values G (19) is formed with the format *nx1* (n is the total number of criteria according to which the selection is made from the alternatives offered):

$$\begin{array}{cccc} & C_1 & C_2 & \dots & C_n \\ G = & [g_1 & g_2 & \dots & g_n], \end{array} \tag{20}$$

Calculation of the distance of the alternatives from the border approximation area (Q). The distance of the alternatives from the border approximation area (q_{ij}) is determined as the difference between the elements in the weighted matrix (V) and the values of the border approximation areas (G):

$$Q = \begin{bmatrix} v_{11} - g_1 & v_{12} - g_2 & \dots & v_{1n} - g_n \\ v_{21} - g_1 & v_{22} - g_2 & \dots & v_{2n} - g_n \\ \dots & \dots & \dots & \dots \\ v_{m1} - g_1 & v_{m2} - g_2 & \dots & v_{mn} - g_n \end{bmatrix}, \tag{21}$$

where g_i is the border approximation area for criterion C_i, v_{ij} is the elements of weighted matrix (V), n is the number of criteria, m is the number of alternatives. Alternative A_i could belong to the border approximation area (G), upper approximation area (G^+) or lower approximation area (G^-), that is $A_i \in \{G \vee G^+ \vee G^-\}$. The upper approximation area (G^+) is the area which contains the ideal alternative (A^+), while the lower approximation area (G^-) is the area which contains the anti-ideal alternative (A^-).

Ranking the alternatives. A calculation of the values of the criterion functions for the alternatives (22) is obtained as the sum of the distance of the alternatives from the border approximation areas (q_i). By summing the elements of matrix Q by rows we obtain the final values of the criterion functions of the alternatives:

$$S_i = \sum_{j=1}^{n} q_{ij},\ j = 1, 2, ..., n,\ i = 1, 2, ..., m, \tag{22}$$

where n is the number of criteria, m is the number of alternatives.

E. Sensitivity analysis and visualization of the final solution

The final step of the proposed GIS-MCDA model involves a sensitivity analysis and visualization of the final results. A sensitivity analysis is a study of the stability of the solution (the alternative selected and the rank of the alternatives) to changes in the input data. The aim of such an analysis is to identify the effects of changes in the input data (geographic data and preferences of the DM) on the output values (rank of the alternatives). An unavoidable process in a sensitivity analysis is an analysis of the stability of the solution to changes in the relative weight of the clusters and criteria, as a representative of subjectivism in multicriteria decision analysis. Visualization of the choice of location is carried out in the form of a GIS cartographic representation, charts, tables and others [19].

IV. CONCLUSIONS

A combination of the DEMATEL-ANP (DANP) hybrid model and MABAC method with a GIS was implemented here for the first time for selecting the optimal locations for wind farms. The DANP technique was used in the section for determining the weights, that is, the significance of each criterion, and the WLC technique was used for summing the weights and for the final identification of the suitable locations for building wind farms. The connection of the tools was possible in the ArcGis software environment using the ArcGIS Advanced 10.2 software firm ESRI. Finally, after defining the suitable locations, the most suitable alternative was selected using the MABAC technique.

This model broadens the theoretical framework of knowledge in the field of location problems. The existing problem is considered using new methodology, which creates the basis for further theoretical and practical improvement. This is primarily related to the requirements of investors, municipal and non-governmental agencies and environmentalists, as well as limitations in terms of their visibility in relation to settlements and facilities for sport and recreation. The practical significance of this model is the possibility of its application in solving location problems in various fields, including the environment, transport, risk and others.

The main recommendations for the further use of this model are its accessible mathematical apparatus and the stability (consistency) of its solution, as well as the possibility of combining it with other methods, especially in the section related to determining the weight criteria. Directions for future improvement of the GIS-MCDA model should be based on the application of classical fuzzy sets and the intervals of fuzzy numbers in the process of determining the parameters of the criteria/clusters. Fuzzification makes it possible to exploit the uncertainty that arises when defining the parameters of the criteria/clusters. In addition, another possible future application can be seen in the implementation of individual phases of the MABAC method in phases of the VIKOR, TOPSIS or PROMETHEE methods, which would exploit the strengths of these methods.

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The Importance of Carbon Capture and Storage

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Abstract— **In the era of climate changes and continuous concern about rapid global warming, the main objective is to find a way to reduce the greenhouse gases (GHG) emission. One solution is the introduction of carbon dioxide capture and storage (CCS). Considering the current reliance on fossil fuels for the power generation and industry, the CCS may serve as a span technology on the way to sustainable energy.**

Keywords - climate change, carbon dioxide, capture, transport and storage.

I. INTRODUCTION

Carbon dioxide (CO_2) is the primary greenhouse gas (GHG) that is contributing to recent climate change. Before the humans, changes in climate resulted entirely from natural causes such as changes in Earth’s orbit, in solar activity or volcanic eruptions. CO_2 is naturally absorbed and emitted as part of the carbon cycle, through plant and animal respiration, volcanic eruptions, and ocean-atmosphere exchange. Also, human activities, such as the burning of fossil fuels and land use changes, release large amounts of CO_2 increasing its concentration in the atmosphere. The human activities after the Industrial Revolution (18. century), especially trough burning of fossil fuels significantly contributed to climate change by adding CO_2 and other heat-trapping gases to the atmosphere, causing the rising of Earth’s surface temperature [1].

About 85 percent of all commercial energy is derived from fossil carbon resources. If cutting down the use of fossil fuels for producing energy would be the measure of mitigation of climate change, the consequences in the sense of energy crisis would be drastic. The main problem of using fossil fuels lies in the emission of CO_2, so, the way out of this would be finding a way to prevent its release into the atmosphere. Carbon capture and storage (CCS) provides the solution to this problem [2]. CCS presents a set of technologies aimed at capturing CO_2 emitted from large emission sources, or directly from the open atmosphere, than at transporting and storing it, usually by burying it in suitable deep underground geological formation. Considering the fact that significant amount of power generation and industry will continue to rely on fossil fuels in the future, capturing and storing CO_2 safely and permanently eliminate the most critical environmental impact of the use of fossil fuels [3].

CO_2 can be captured from large point sources such as fossil fuel or biomass electricity power plants, industrial facilities with major CO_2 emissions, natural gas processing, synthetic fuel and fossil fuel-based hydrogen production plants [4]. In this paper, the implementation of CCS in two major industries that release high amounts of CO_2, electric power and natural gas processing plants will be discussed.

II. CSS INTEGRATION IN ELECTRIC POWER AND NATURAL GASPROCESSING PLANTS

The CCS introduction in an electric power or natural gas processing plant requires three basic steps: removal of CO_2 from the process, transportation of CO_2 to an adequate site and its storage in the long-term storage sites [4,5] (Fig. 1).

A. *Removal of CO_2*

CCS was introduced in electric power plant as a method which would enable continuation of fossil fuels (gas, coal and biomass) use for producing electric power while at the same time preventing CO_2 emission to the atmosphere [6]. For example, a modern conventional power plant equipped with CCS releases 80-90% less CO_2 emissions to the atmosphere in compare to a plant without CCS. It is estimated that introduction of CCS in power plant could

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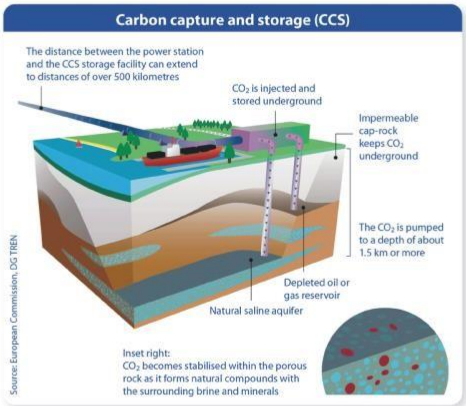

Figure 1. Carbon capture and storage

provide up to 55% of the total worldwide carbon mitigation effort until year 2100. With this purpose, the first pilot-scale CCS power plant was put in operation within Schwarze Pumpe in the eastern German in 2008 [4].

Natural gas processing plants extract gas that contains large quantities of corrosive impurities so called “acid gases”, typically CO_2 and H2S, which have to be removed or reduced to required level in order to meet costumer’s specifications. For example, the natural gas produced at the Sleipner Field in the North Sea contains unusually high levels (about 9%) of CO_2, but customers that are buying the gas request CO_2 levels below 2.5 %, so, a special processing platform, Sleipner-T, has been built to separate CO_2 from the natural gas [4].

The removal of CO_2 from electric power production and natural gas processing plants can be carried out through three technics: post-, pre- and oxyfuel combustion [4,5], and the applied system depends on the concentration of CO_2 in the gas stream, the pressure of the gas stream and the fuel type (solid or gas) [8].

1) Post-combustion involves capturing the CO_2 from the fuel after combustion in the air stream, either by scrubbing it or trough chemical absorption process. This technique can be applied to conventional steam turbine cycle power plants and natural gas processing plants.

2) Pre-combustion, which means that CO_2 is first removed from the fuel before burning it, the process during which the fuel is directly converted to CO_2 and carbon free combustible gas such as H_2, CH_4 etc. This technique is usually applied in fertilizer manufacturing and in hydrogen production and in the Integrated Gasification Combined Cycle (IGCC) power plants, where the fossil fuel is partially oxidized in air in a “gasifier” to form synthetic gas or “syngas” which primarily consists of carbon monoxide (CO), CO_2, and hydrogen (H_2). CO_2 can be captured from this relatively pure exhaust stream before combustion, while H_2 can also be separated and used as fuel. From this point of view, IGCC technology seems like best suited for integrating CO_2 capture in the power plant process.

3) Oxyfuel combustion process occurs in an oxygen-enriched (i.e., nitrogen depleted) environment, producing a flue gas which consists mainly of CO_2 (up to 89 vol%) and water [2]. After removing the water through condensation process, almost pure CO_2 stream is obtained. Sometimes the electric power plant processes based on oxyfuel combustion are referred to as “zero emission”, considering that the CO_2 stored is not a fraction which is removed from the flue gas, like in the case of pre-or post-combustion, but the entire flue gas stream itself [4].

B. Transport of CO_2

Weather it was captured from electric power or natural gas processing plant, CO_2 must be transported to suitable storage sites. CO_2 can be transported in three states: gas, liquid and solid, where gaseous and liquid CO_2 can be pumped though pipelines or transported by tank wagons and ships. Transport trough pipelines is the cheapest form of transport, and well known and reliable technology.

A transportation network of pipelines (Fig. 2) that carry CO_2 in large enough quantities to make a significant contribution to climate change mitigation would be demanding, particularly in highly populated zones that produce large amounts of CO_2 [8].

Figure 2. CO2 transport trough pipelines

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With the increased number and carrying capacity of pipelines that a large-scale CCS industry would require, the pipeline safety would need to be studied more carefully, especially in heavily populated areas, or areas of high seismicity where earthquakes may cause damage to the pipes. If leakage occurred from a pipeline in open, windy areas of country, the escaping CO_2 would mix with the surrounding air and disperse rapidly, so it would probably not be a treat to people, livestock or crops. However, the leakage in localized low-lying areas where is little wind or in buildings which have basements or underground rooms could be a problem due to accumulation of CO_2 in such places, since it is heavier than air [4].

C. CO_2 storage

Once captured, CO_2 is transported and stored in geological sinks such as oil and gas reservoirs, deep saline formations, and unminable coal seams, which together have the capacity for holding hundreds to thousands of gigatons of carbon. The mechanisms used for trapping CO_2 depends on the formation type [7].

Depleted oil and gas reservoirs could store CO_2 for a long time, but storing CO_2 in active oil reservoirs trough enhanced oil recovery (EOR) operations has attracted more attention, since it offers twofold benefit, i.e storing CO_2 by injecting it in oil reservoirs increases the mobility of the oil and the productivity of the reservoir [7]. Abandoned or uneconomic coal can also be used for storing CO_2 trough the physical adsorption of CO_2 into the pore structure of coal.

However, it is believed that deep saline formations, both subterranean and sub-seabed, may have the greatest CO_2 storage potential.

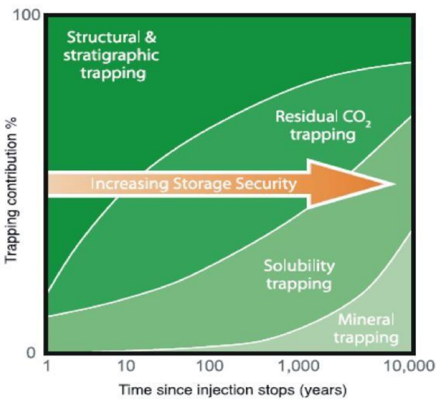

Figure 3. Storage security

The most effective storage sites are those where CO_2 is immobile because it is permanently trapped under a thick, low-permeability seal of the reservoir or has interacted with or incorporated into solid minerals or is adsorbed on the surfaces of coal micropores or through a combination of physical and chemical trapping mechanisms [8]. Storage security depends on a combination of physical and geochemical trapping mechanisms: structural and stratigraphic, residual, solubility and mineral CO_2 trapping, and it increases over time, meaning that longer the CO_2 stays underground, the chance of its leakage decreases (Fig. 3).

a) Structural and stratigraphic trapping

First, when CO_2 is injected into a permeable reservoir, it pushes out the brine from the pores. The pressure of CO_2 is rising and must be controlled so it does not exceed the pressure limit which would cause the rock fracture. Since the specific gravity of CO_2 injected below 800 m is lower than that of the ambient aquifer brine, the CO_2 will be buoyant and thus keep rising to the top of the reservoir, where will be trapped by an impermeable cap rock of the formation.

b) Residual CO_2 trapping

Some of the CO_2 gets incorporated into the soil matrix as it flows through the reservoir, and becomes immobile and permanently stored.

c) Solubility trapping

Over very long timescales of decades to centuries, depends on reservoir, some of the CO_2 will dissolve in the brine, decreasing the probability of leakage. The only way to release CO_2 would be with the brine that would leave the reservoir. However, this usually occurs on very long timescales.

d) Mineral trapping

Over centuries to millennia the injected CO_2 may react with the minerals in the reservoir, or it can get incorporated into the solid rocks and minerals in the reservoir and be permanently stored.

III. Combining CCS with Natural Gas and Electricity Production

The use of natural gas instead of coal as a fuel for generating electricity reduces the carbon emissions that contribute to climate change to about half [9]. Natural gas industries that are already leaders in the use of CCS are making great effort to apply the CCS technology to natural gas power generation. According to National Research Council, natural gas with CCS produces electricity at costs that are usually less than other fuels with CCS, and uses less fuel and less water than other fossil fuel CCS applications [10]. In United Kingdom, the international oil company Shell and British utility Scottish and Southern Energy Company are teaming up to retrofit the first full-scale (385 MW) commercial natural gas power plant to capture post-combustion CO_2 as a part of Peterhead CCS project (Fig. 4). The project is expected to come online in 2018 and it is estimated to be able to capture and store 1 million tons of CO_2 each year for 10 years [9].

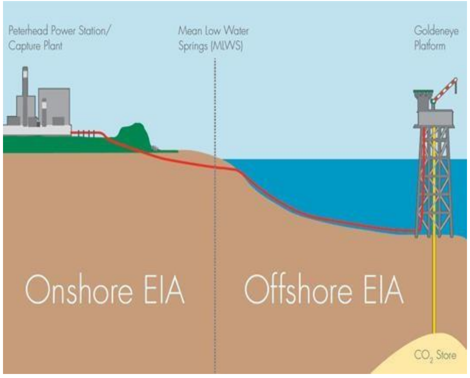

Figure 4. Peterhead CCS project

IV. Conclusions

As energy consumption continues to raise, extensive effort if required to cut GHG emissions, especially CO_2, very fast. Carbon capture and storage offers a solution to this problem and enables continuous use of fossil fuels while reducing the CO_2 emissions, thus serving as a bridge technology to sustainable energy. Introducing CCS in conventional power plant releases 80-90% less CO_2 to the atmosphere, while replacing coal with natural gas in a CSS power plant would reduce the CO_2 emission to zero. Unfortunately, CCS is relatively expensive, and its introduction would need more private and public research to cut down costs and government incentives to help commercialize the technology.

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Miscanthus *x* Giganteus - Solution for Degraded Land and Energy

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Abstract— **Biomass is considered a renewable source of energy as long as it is based on sustainable use. This energy source is renewable and environmentally acceptable, especially taking into account the different types of plants that have a high energy potential, such as Miscanthus x giganteus. Miscanthus is a perennial plant that has a good quality of combustion and which is suitable for briquetting. Miscanthus represents a plant species suitable for intensive cultivation, which should allow the substitution of existing energy sources with new renewable energy sources that will reduce carbon dioxide emissions. Growing these plants as bio-fuels in the Republic of Serbia is still in the research phase.**

Keywords - energy crop, biomass, Miscanthus

I. INTRODUCTION

In the recent decades, the focus of environmental protection did the demand for alternative energy sources, as well as rehabilitation of degraded areas. Researches for species that are tolerant to various abiotic and biotic conditions and which require a minimum investment are increased [1].

A large number of different technologies and types of bioenergy is used to obtain alternative forms of energy, and the trend of growth, development and innovations continues. Many countries due to the securing of energy security, have taken into account the environmental protection and the use of alternative energy sources for the production of biofuels and biomass [2]. The growth rate of the use of alternative fuels is constantly rising at about 15% annually [3].

The main stimulus for the use of alternative energy sources the implementation of the Kyoto Protocol in 1997, which is administered since 2005. The document was adopted as a supplement to the international agreement on climate change in Rio 1992, with the aim of reduce carbon dioxide (CO_2) and other gases that cause the greenhouse effect [3]. Serbia is a signatory of the Protocol of 2007.

Conventional bio-energy crops, such as corn, sugar cane and other require a greater investment in the land cultivation, while the new generations especially some types of grass, do not require greater investment, and can be grown on degraded lands [4].

The advantage of Miscanthus plants is that they can be grown in areas that are not suitable for food production with regard to safety. Many countries use Miscanthus as energy source and cultivate it for commercial purposes [5]. Lands in R. Serbia are suitable for the cultivation of these plants, which can be used as a fuel in power plants, as well as the reclamation of degraded lands, as shown by performed studies.

II. BIOMASS AS FUEL

Biomass as fuel is a renewable and environmentally friendly source of energy, which is easily accessible and technically acceptable. In addition to all the benefits, there are also some disadvantages (collection, packaging, storage, investment costs, etc.). Most of these disadvantages can be solved if the biomass is compressed in the form of pellets and briquettes. Although this requires extra energy for grinding, drying, pressing, cooling, but the end result is very positive [6].

Miscanthus (fam. *Poaceae*) is a highly productive perennial rhizomatic grass type, with a the very large annual yield. Originates from East Asia. The most cultivated and used grass is the hybrid type is *Miscanthus x giganteus* created by crossing species *Miscanthus sinensis* and *Miscanthus sacchariflorus* [4].

The fast-growing hybrid type *Miscanthus x giganteus*, also known as China reed, Chinese grass or Elephant grass, thanks to strong growth

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rates with minimal engagement and significant expenditures of nutrients belong to the C4 type of photosynthesis (C4-plant)[i] [5]. The stalk of the plant reaches a height of over 3m. The energy value of 20t dry miscanthus is equivalent to 12t of coal [7]. Besides the use as an alternative energy source, miscanthus also have other purposes. From this cane quality insulations, roofs and plastics are made [6], there are also used for making paper pulp [2]. Miscanthus hybrid, created by crossing sugar cane and so-called Chinese cane is an exceptional source of energy and has a very high energy value and is an excellent feedstock for biodiesel production [6].

This plant is persistent and perennial (15-20 years), and is reaped every year and is characterized by a large potential yield of biomass [7]. For the experiment, which was carried out in the Republic of Serbia in two locations (North Sumadija and flatlands Srem) were obtained different results. The experiment was carried out on two soil types chernozem and eutric kambisol. The highest yield is in Shumadija during September, while in Srem it is in early October [8]. In this period the moisture content is high and the miscanthus can be used to produce biogas. By returning the harvest the quality of biomass combustion improves because there is a decrease of moisture content and certain substances (nitrogen - N). Also, with the postpone of the harvest in early spring there is a reduction in the amount of biomass [5]. The date of the harvest is therefore determined in accordance with the interests and represents a compromise between yield and quality. In addition, the time of the harvest depends on the region and weather conditions.

The maximum biomass yield is achieved between the second and fifth year, depending on climatic conditions. In this essay, the maximum yield was in the third year. The average yield on chernozem in the period from the third to the fifth year of the harvest in February was 23.45 t/h, while for the same period and the time of the harvest on kambisol the yield was 15.22 t/h [8].

A. Energy characteristics of miscanthus

The thermal power and the dry matter yield of crops are the most important characteristics that are taken into account in determining the energy as a raw material for biofuels. In addition to these two factors the content of water and ash were taken into account. Dry matter yield depends primarily on the characteristics of soil and climate conditions, while the water content of the ash depends on the time of the harvest.

Biomass from the Miscanthus is suitable for combustion because of the low water content and ash content compared to other energy crops, shown in Table I [6].

TABLE I. CHARACTERISTICS OF ENERGY CROPS[6]

Crop	Dry matter yield t/h	Calorific power MJ/kg	Moisture content %	Ash content %
Straw	2-4	17	14.5	5
Poplar	9-16	18.7	53	2.0
Red canary grass	6-12	16.3	13	4
Giant red	15-35	16.3	50	5
Miscanthus	8-32	17.5	15	3.7

The plant miscanthus is characterized by high efficiency and high rate photosynthesis and CO_2 fixation. In the autumn period, the plant performs translocations of nitrogen and other compounds in the rhizomes and in this way the Miscanthus may give higher yields without adding fertilizer, for about 15 years [6]. This is also important from an economic and ecological point of view because there are no major invests during the yield period, and also there is no pollution of the environmental caused by adding fertilizers.

Miscanthus as an energy source, emits 0.131 kg CO_2 equivalents kW^{-1} of power produced, compared with 0.990 kg CO_2-equivalents 1 kW^{-1} of electricity produced by burning coal [9].

The world is increasingly using co-combustion process which burn two fuels in the same time. Co-combustion is actually the process of replacing a specific part of the fossil fuel which is burning in power plants caldrons, with fuels which are mainly biomass, who have low content of CO_2, as a renewable alternative [10].

Reduced annual combustion of coal (coal replace with solid renewable fuels), about 3 million tons, induces reducing overall emissions of pollutants. For example, CO_2 reduction of 1.900 kt/year would be obtained in relation to the total emission of CO_2 of 30.330 kt from coal-fired power plants [11].

[ii] C4 plants bind CO_2 for PEP acid, and thus they form a malic acid containing four carbon atoms, thus increasing the CO_2 concentration and the plants have a "stronger" and "faster" in terms of the photosynthesis high temperature

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The advantage of this power schemes production method are the energy savings of the primary source of energy, lower fuel costs, avoidance of ash and slag, the reduction of sulfur and nitrogen oxides and the reduction of greenhouse gases, primarily CO_2 [10].

III. BIOMASS AND DEGRADED LAND

In the Republic of Serbia there are a large number of coal mines, quarries, clay deposits and similar surfaces that are left after the exploitation of natural re-cultivation - a process which is very slow, lasting for decades, while in some locations it is not even possible. In order to speed up the process, it is necessary to apply the technical, bio-technical and biological measures.

Technical measures contributing to the improvement of resistant and deformable characteristics of landfills, which directly affect the increase of erosion stability of slopes. Bio-technical measures, along with technical measures, contributing to faster achieve and maintain lasting stability of the landfill. Biological measures include the use of agricultural and forest land reclamation, which contribute to the stability and maintenance of reclaimed land, but they are much more important from the aspect of revitalizing the area and the establishment of natural biocenoses [12].

Thermal power plants, surface mines, ash and slag dumps and other accompanying contamination are leading to disorders in the environment and to human illnesses.

Open pit mine "Drmno" was opened in 1987. and today is the only supplier of coal branch "Thermal Power Plants and Mines Kostolac", which is part of the Electric Power Industry of Serbia. Development digs led to the degradation of about 890 hectares of arable land. When land acquisition led to the emergence of a new composition of land - tailings, which belongs to the sandy-clay loam. Agrochemical characteristics of the mullock are given in the Table II [12].

Mullock are initially deposited on the outer surface of the landfill 180 hectares outside the boundaries of the mine, while today tailings disposed inside the mine. By the end of its service life bathed in the plan is the degradation of another 1.740 hectares of arable land. Re-cultivation was carried out on 30 hectares, and the rest is left to natural re-cultivation and time [12].

TABLE II. AGROCHEMICAL PROPERTIES OF SOIL IN SERBIA[12]

Profile depth (cm)	pH in KCl	Chemical composition		
		Humus	$CaCO_3$ (%)	
0-20	7.50	1.67	4.99	
20-40	7.50	1.67	6.30	
Profile depth (cm)	pH in KCl	Chemical composition		
		N (%)	P_2O_5 mg/100g	K_2O mg/100g
0-20	7.50	0.2	5.40	27.90
20-40	7.50	0.2	5.20	30.00

In Bosnia and Herzegovina a experiment was carried out on degraded land to see where deposols planted with *Miscanthus x giganteus* [13]. Agro-technical features of this area are given in the Table III.

TABLE III. AGROCHEMICAL PROPERTIES OF SOIL IN BOSNIA AND HERZEGOVINA[13]

Parametar	pH		Organic m. (%)	
	H_2O	KCl		
Value	5.8	4.6	1.60	
Parametar	Humus (%)	N (%)	P_2O_5 mg/100g	K_2O mg/100g
Value	0.01	0.0	0.38	1.94

On degraded land such characteristics of miscanthus biomass yield was satisfactory. Weighted average yield for the three-year research period amounted to 5.78 t/h. The highest yield was in the third year with a mean of 8.73 t/h [13].

IV. DISCUSSION OF RESULTS OF DIFFERENT STUDIES

The main function of miscanthus on degraded lands is the production of biomass. As an energy source, miscanthus contributes to the reduction of CO_2 emissions compared to using the fossil fuels.

Previous studies show that miscanthus should be planted on soils that need rehabilitation and less fertile soils [7]. Miscanthus also reduces the risk of soil erosion and increases soil carbon content and enhances biodiversity. The plant itself has a positive impact on the ecosystem because it allows translation of degraded land into land that can be used for commercial purposes.

Investments in cultivating the land are minimal and it can be performed with standard agricultural machinery. The plant itself yields about 20 years, a cheap investment and large yields make this a popular plant bio-fuels [4].

Production of energy from renewable energy sources in the Republic of Serbia is still in the initial stage. The potential of the country for the production of renewable energy are favorable, where the production of biomass, is one of the highest priorities [3].

The Republic of Serbia is estimated that biomass accounts for 63% of total renewable energy sources. Of the total 2.4 million tons of biomass per year, 1 million tons of wood waste generated during the primary processing and industrial production, and 1.4 million tons of biomass from crops. The energy generated from the rectangular bales by 28%, from a round straw bales to 34% cheaper than that of coal [1].

Using agricultural crops for the production of bioenergy is growing globally by 20 - 30% per year, despite the economic crisis. Due to the high productivity, production of bioenergy is increasingly shifting from degraded fertile land [3].

Serbian energy system is depend ending on the exploitation of lignite, which represents the largest source of pollution. R. Serbia in 2014 suffered extensive damages on the energy system due the emergency and floods which hit power plants and mines [14].

The study, which was conducted in Bosnia and Herzegovina shows that the yield of miscanthus on poorer soil with agrochemical characteristics of land use and tailings pit mine "Drmno" is satisfactory. On this basis, it can be concluded that planting miscanthus in this area yielded very good results.

V. Conclusion

Due to the use of fossil fuels, carbon dioxide is considered one of the most important factors that lead to global warming. Furthermore, reserves of fossil fuels are reduced, and the current trend of growth and development is increasing, leading to imbalances that will lead to future shortages of energy. Accordingly, the energy obtained from alternative sources is one of the solutions to this problem. Energy crops including miscanthus, represent a new type of field crops that have been developed with the aim of reducing carbon dioxide emissions and high energy power.

The main limitations of miscanthus is the high cost of establishing, poor overwintering on certain lands and insufficient supply with water in some regions (rainfall of 800mm is required for high yields)

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Using Optimization Tools for Solving Demand Side Management Problems

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Abstract—**Both customers and utilities use the opportunities given by Smart grid technologies to manage power systems, to make decisions on time schedule of energy consumption and to control the expenses. This ability is made through various Demand Side Management (DSM) programs. The solutions to the DSM problems are obtained by using the optimization techniques. Load shifting and peak clipping techniques are applied to the problem presented in this paper.**

Keywords - demand side management, objective function, load factor, optimal formulation

I. INTRODUCTION

Demand Side Management (DSM) is done by planning, implementation and development of activities in order to influence on customer's use of electricity, so as to produce the desired daily or seasonal load shapes [1,2]. For utility companies, DSM means avoiding or delaying the need to construct new generating capacities, reducing capital investments, improving the power quality and ensuring efficient operation in generation, transmission and distribution [3]. For residential consumers, DSM means reduced bills and taking advantage of financial incentive provided by utilities. For commercial and for industrial customers, DSM means lower costs and also more competitive products. DSM is a set of interactive programs which give customer a greater role in shifting the demands to off-peak periods, reducing the total energy bills, while providing lower costs per kWh to utilities.

The main principle activities and measures are: demand response programs or load shifting, at one side, energy efficiency and conservation programs, at the other [4]. These programs are different from one utility to another, depending on number of customers, nature of the load type (commercial, industrial or residential), the revenue from programs, the level of customers' reaction or satisfaction with the applied programs, etc. However, benefits from applying are mutual (for both the customers and utility), so that DSM activities have grown fast over the past few decades. Many utilities are either implementing DSM programs or considering it as a part of their planning processes.

II. DSM TECHNIQUES

Valley filling is one of the possible ways to change the load curve (Fig. 1), so to have the load factor closer to unit, and also in the predefined margins. In this way the utility can maximize the profit and minimize its costs per kWh of energy. Increased demand in off-peak hours is achieved by encouraging customers to spend electrical energy with paying the lower tariff.

Load shifting is the best solution from the point of view of utility companies. With this DSM technique the part of demand is shifted from peak to off-peak hours (Fig. 2). Customers are encouraged for this by cheaper tariff in off-peak periods.

Peak clipping is also aimed at decreasing the demand during peak (Fig. 3), especially if the installed capacity is not enough to cover the peak demand.

Energy conservation is very important in power systems. When it is required to decrease the overall energy consumption (Fig. 4), it may be achieved by using more efficient devices and appliances.

If the utility has surplus capacity or energy available to sell with lower costs per kWh, the increase of the overall energy consumption (Fig. 5) is required with the load building technique.

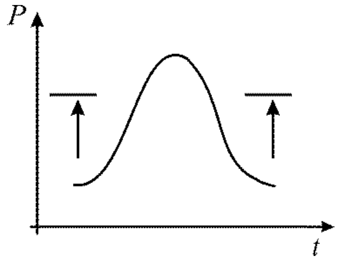

Figure 1. Valley filling.

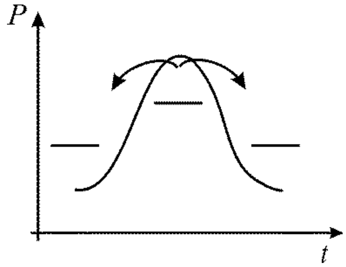

Figure 2. Load shifting.

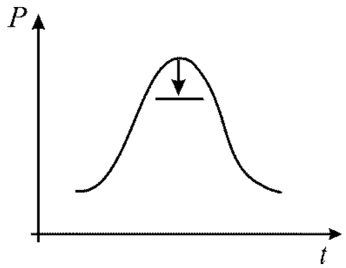

Figure 3. Peak clipping.

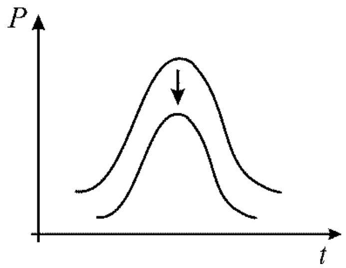

Figure 4. Energy conservation.

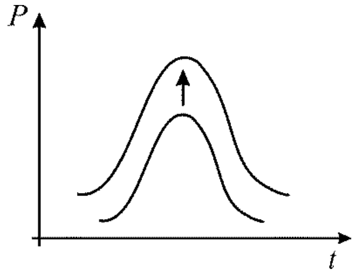

Figure 5. Load building.

For all of the five mentioned DSM techniques, some of the objective functions, either maximum of the load factor for the utility, defined by (1) or (2), or minimum of the total cost for customers, defined by (3), are optimized using the corresponding constraints for that technique.

The objective functions are defined as the following:

$$LF_{\max} = \left[\left[\sum_{i=1}^{N} \sum_{j=1}^{J} P_{(i,j)} t_{(j)} \right] / \sum_{j=1}^{J} t_{(j)} \right] / \sum_{i=1}^{N} P_{(i,k)} \;, \quad (1)$$

$$LF_{\max} = \left[\left[\sum_{j=1}^{J} P_{tot(j)} t_{(j)} \right] / \sum_{j=1}^{J} t_{(j)} \right] / P_{tot(k)} \;, \quad (2)$$

$$C_{\min} = \left[\sum_{i=1}^{N} \sum_{j=1}^{J} P_{(i,j)} t_{(j)} c_{e(i,j)} \right] + + \left[\sum_{i=1}^{N} \sum_{j=1}^{J} P_{(i,j)} c_{d(i,j)} \right] \;, \quad (3)$$

where:

$LF_{\max}$ – is the maximum load factor,

$P_{(i,j)}$ – is the power demand of load type *i* at the time interval number *j*, for $i = 1,..., N$, where N is the total number of load types, and $j = 1,..., J$, where J is the total number of time intervals,

$P_{tot(j)}$ – is the total demand power for all types of loads, where *j* denotes time interval number,

k – is the time interval number at which occurs the maximum demand for all the load types numbers $i = 1,..., N$, over all time interval numbers $j = 1,..., J$,

C – is the total cost of the electrical demand and energy consumption,

$c_{e(i,j)}$ – is the cost of energy for load type *i* at the time interval number *j*,

$c_{d(i,j)}$ – is the cost of demand for load type *i* at the time interval number *j*.

The imposed constraints depend on the chosen DSM technique, on the particular load specifications and the power system [6].

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For the valley filling technique (Fig. 6), the effect is obtained by building loads in off-peak periods.

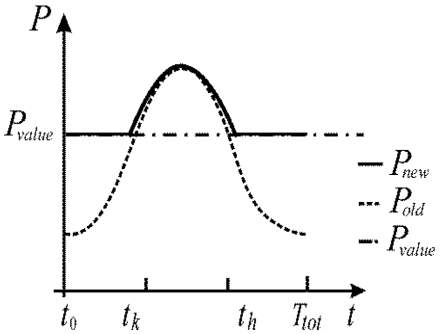

Figure 6. DSM valley filling technique.

Either (1) or (2) is optimized by applying equality constraint:

$$P_{new(i,j)} = P_{old(i,j)}, \ \forall t \in \{t_k, t_h\}, \tag{4}$$

and inequality constraints:

$$P_{new(i,j)} \geq P_{old(i,j)}, \forall t \in \{t_0, t_k\} \cup \{t_h, T_{tot}\}, \tag{5}$$

$$P_{new(i,j)} \leq P_{value}, \forall t \in \{t_0, t_k\} \cup \{t_h, T_{tot}\}, \tag{6}$$

where:

$P_{new(i,j)}$ – is the demand of load type *i* at time interval *j* after applying DSM technique,

$P_{old(i,j)}$ – is the demand of load type *i* at time interval *j* before applying DSM technique,

P_{value} - is the limiting value given by the planner of the system.

k – is the time interval at which the total demand of all load types $P_{tot(k)}$ is of the maximum value, so that

$$P_{tot(k)} > P_{tot(j)} \forall j = 1,..., J; j \neq k, \tag{7}$$

and the sum of all time intervals is:

$$T_{tot} = \sum_{j=1}^{J} t_{(j)}. \tag{8}$$

For the load shifting technique (Fig. 7), there is no change of the total energy consumption, but there is a decrease in peak demand.

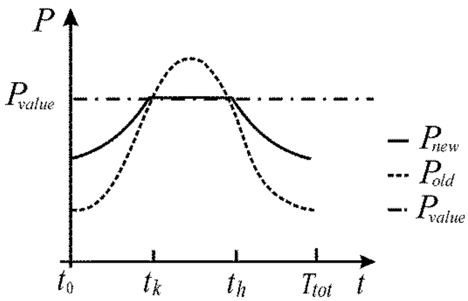

Figure 7. DSM load shifting technique.

Eqs. (2) and (3) are optimized by applying equality constraints:

$$\sum_{i=1}^{N}\sum_{j=1}^{J} P_{new(i,j)} t_{(j)} = \sum_{i=1}^{N}\sum_{j=1}^{J} P_{old(i,j)} t_{(j)}, \tag{9}$$

$$P_{new(i,j)} = P_{value}, \ \ \forall t \in \{t_k, t_h\}, \tag{10}$$

and inequality constraints:

$$P_{new(i,j)} \geq P_{old(i,j)}, \forall t \in \{t_0, t_k\} \cup \{t_h, T_{tot}\}, \tag{11}$$

$$P_{new(i,j)} \leq P_{value}, \forall t \in \{t_0, t_k\} \cup \{t_h, T_{tot}\}, \tag{12}$$

For the peak clipping technique, the effect is reduction of load demand during peak period from t_k to t_h and reduction of the total energy consumption up to T_{tot} (Fig. 8).

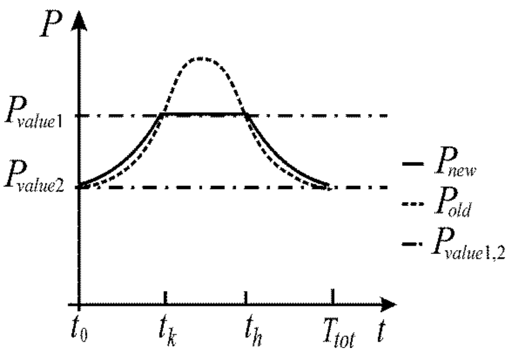

Figure 8. DSM peak clipping technique.

Eq. (2) is optimized by applying equality constraint:

$$P_{new(i,j)} = P_{old(i,j)}, \ \forall t \in \{t_0, t_k\} \cup \{t_h, T_{tot}\}, \tag{13}$$

and inequality constraints:

$$P_{new(i,j)} \le P_{value\,1}, \;\; \forall t \in \{t_k, t_h\}, \qquad (14)$$

$$P_{new(i,j)} \ge P_{value\,2}, \;\; \forall t \in \{t_k, t_h\}, \qquad (15)$$

$$P_{value\,2} \le P_{value\,1}\;, \qquad (16)$$

where $P_{value\,1}$ and $P_{value\,2}$ are the limiting values given by the planner of the system.

For the energy conservation technique, the peak demand and total energy consumption are reduced over the whole period of interest (as given in Fig. 9).

Eq. (3) is optimized, as it is representing the minimum cost of the electrical demand and energy consumption, by applying inequality constraint:

$$P_{new(i,j)} \le P_{old(i,j)}, \;\; \forall t \in \{t_0, T_{tot}\}., \qquad (17)$$

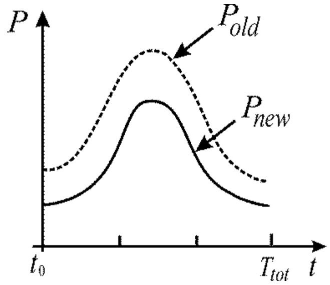

Figure 9. DSM energy conservation technique.

For the load building technique (Fig. 10), the effect is that peak demand and total energy consumption are increased over the whole period of interest.

Eq. (3) is optimized, as it is representing the maximum revenue, by applying inequality constraint:

$$P_{new(i,j)} \ge P_{old(i,j)}, \;\; \forall t \in \{t_0, T_{tot}\}., \qquad (18)$$

DSM techniques may be implemented through direct or indirect load control. In the direct load control, utilities can modify customers load pattern by switching-off the power supply to specific category of customers at specified time intervals or for specified types of electric loads.

Indirect control is an optimal way of control by utility, which may use special methods as:

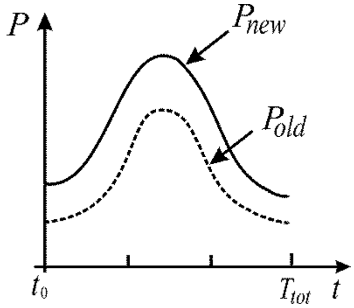

Figure 10. DSM load building technique.

loads time schedule, thermal energy storage, efficient end-use technologies, tariff system and electrification technologies (Fig. 11).

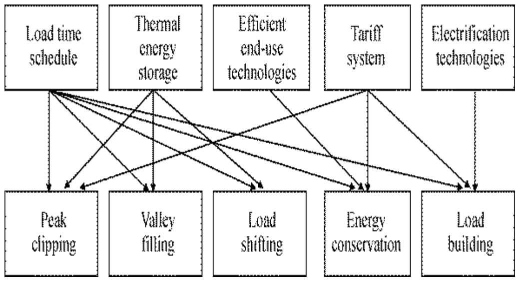

Figure 11. Scheme of load shape objectives.

III. Optimization Problem

For the given daily load curve and the demand P_{old} for the three loads as given in the second column of Table I and in Fig. 12, there should be found new time schedule for the loads, so to obtain the optimum load curve P_{new}. Loads are electrical boilers each of P=20kW, which should work for 4 hours continuously to achieve the desired temperature. As they may be turned on at any time, the possibility to change the demand time should be exploited.

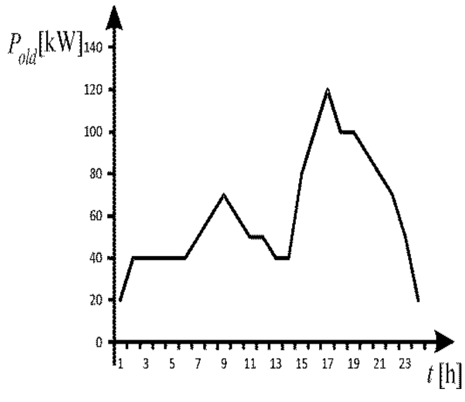

Figure 12. Daily load curve P_{old}.

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After applying load shifting and peak clipping DSM techniques, the new load curve and load time schedule as given in Table I are obtained by using Solver. It is MS Excel based tool for solving optimization problems (Fig. 13).

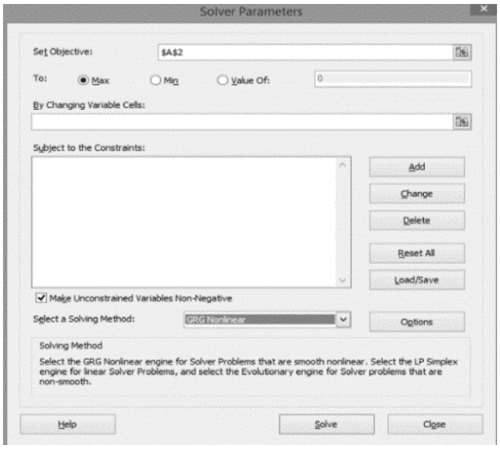

Figure 13. MS Excel tool Solver.

The objective function is written in the target cell, and constraints and variables in the changing cells. Results of the optimization are given in Fig. 14 and in Table I.

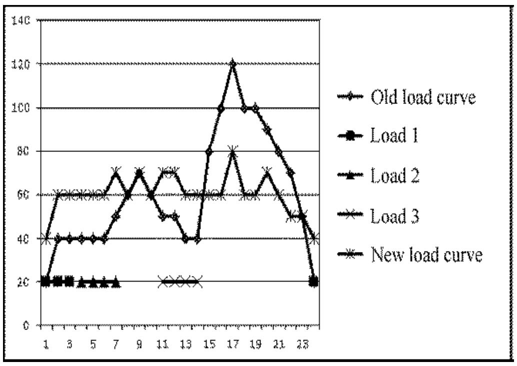

Figure 14. Load shifting and peak clipping DSM techniques applied.

The maximum value from the old daily load curve is $P_{\max old} = 120\,\mathrm{kW}$ and the minimum value is $P_{\min old} = 20\,\mathrm{kW}$. Their ratio value is $P_{\max old} / P_{\min old} = 6$. After applying two of the DSM techniques, the obtained limiting values are $P_{\max new} = 80\,\mathrm{kW}$ and $P_{\min new} = 40\,\mathrm{kW}$, as may be also noticed from Fig. 15, so that the ratio value is $P_{\max old} / P_{\min old} = 2$.

In Table II are given the results for some important parameters, $P_{av} = \sum_{j=1}^{J} P_{(j)} t_{(j)} / \sum_{j=1}^{J} t_{(j)}$, $P_{\max}$, $LF = P_{av} / P_{\max}$, and savings per year in percentages, after the applied DSM techniques.

TABLE I. LOADS TIME SCHEDULE BEFORE AND AFTER THE APPLIED DSM TECHNIQUES

Time interval	P_{old}	*Load*1	*Load* 2	*Load* 3	P_{new}
1	20	1	0	0	40
2	40	1	0	0	60
3	40	1	0	0	60
4	40	0	1	0	60
5	40	0	1	0	60
6	40	0	1	0	60
7	50	0	1	0	70
8	60	0	0	0	60
9	70	0	0	0	70
10	60	0	0	0	60
11	50	0	0	1	70
12	50	0	0	1	70
13	40	0	0	1	60
14	40	0	0	1	60
15	80	0	0	0	60
16	100	0	0	0	60
17	120	0	0	0	80
18	100	0	0	0	60
19	100	0	0	0	60
20	90	0	0	0	70
21	80	0	0	0	60
22	70	0	0	0	50
23	50	0	0	0	50
24	20	1	0	0	40

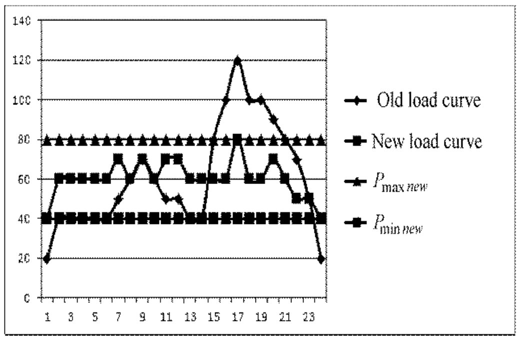

Figure 15. Load shifting and peak clipping DSM techniques applied.

TABLE II. SOME IMPORTANT PARAMETERS BEFORE AND AFTER THE APPLIED DSM TECHNIQUES

Parameter	Before applied DSM techniques	After applied DSM techniques
$P_{\max}$ [kW]	120	80
Energy per year [kWh/year]	529250	529250
P_{av} [kW]	60.4167	60.4167
$L.F.=P_{av}/P_{\max}$	0.5035	0.7552
Savings per year %	–	3.818995

Other optimization tools may be also used, such as LINGO [7], which is an optimization modeling software for linear, nonlinear and integer programming, suitable for this kind of problems solving.

IV. CONCLUSION

In this paper the procedures for optimizing of load curve using valley filling, load shifting, peak clipping, energy conservation and load building as DSM techniques are given.

Mathematical formulations of the DSM techniques are also presented, and Solver, as an MS Excel tool, is used to optimize the load curve for the given example. For this case, load shifting and peak clipping techniques are used, so that load factor is increased for 50%.

Optimization is done in this paper for the simple case, but the same DSM technique may be used for the complex power system case. Savings per year in percentages may be much greater, depending on the power system specifications, on number, type and demand of the loads.

The aims of DSM programs are fulfilled through their implementation and improvements.

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Risk Management in Coal Mining

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Abstract—**This paper presents a short review of the state of the art in risk management in coal mining. The main topics include coal risk mining identification and classification, analysis of references regarding workers' health and safety risks and project and business risks of coal mining. The paper concludes with suggestions for empowering a comprehensive and integrated approach in risk management for coal mining.**

Keywords - coal mining, risks identification, risks management.

I. INTRODUCTION

The concept of risk is clearly a multi-dimensional one [1]. A certain degree of probability is always present when the outcomes of business project are considered thus making risks of all types inseparable from the business process. There are many different definitions and classifications of risks, depending on consideration (e.g. project risks, environmental risks, risks related to health and safety of workers, political risks, etc.). In mining, risks are most often classified as *external* and *internal,* according to their origin [2]. This classification is significant since it covers the most important aspects of risk identification, analysis and management. Moreover, it is operational since it separates more predictable risks (thus more manageable) from the less predictable ones.

The risks with immediate relation to technical and technological activities within the mining field are considered internal. These are the risks for which the mining company is able to make informed and adequate assessment and to adaptively manage almost all of them [2]. In fact, the extent of adaptive management is one of the more important performance indicators for the said mining company. The external risks are the risks for which the mining company has little or no influence on their occurrence, intensity and probability, namely the geopolitical, market, legislative, financial (Fig. 1). In addition, there is a temporal or progress component related to risks in mining, meaning that risks in mining evolve and change during the lifetime of mine (see timeline in Fig. 1).

Classification of risks to external and internal in mining persists in the literature on risks in coal mining as well. Being an energy resource among other uses, coal is, in some cases, considered strategic or critical material, particularly when discussing coking coal [3], but also when discussing coal as the energy resource. For example, coal used for firing in the power plant can be considered strategic at the local, regional or even country level, depending on its contribution in the overall production of electric power. Therefore, Milutinovic et al., for example, classified mines with respect to risk assessment on: Mines of national importance (strategic or critical), Mines of economic importance, Mines of regional importance and Mines of local importance [2].

The general schematic of risks in coal mining (Fig. 1) is evidently complex, but it can be useful as a source point for various checklists and other aiding tools in checklists

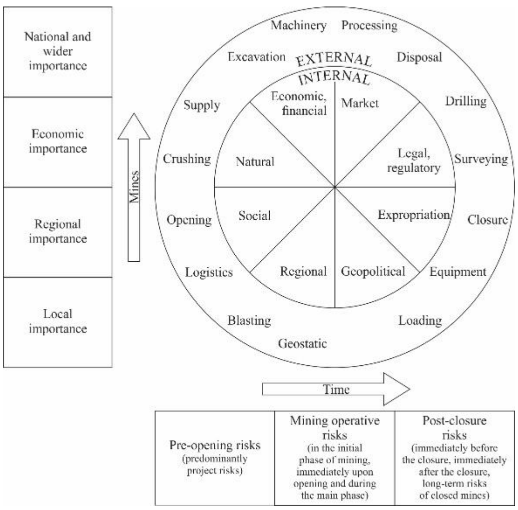

Figure 1. Coal mining risk classification.

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and other aiding tools in conducting the comprehensive approach to risk management in coal mining.

It is natural that some of these risks belonging to the two of groups are overlapped, entwined even, but the classification of risk in this manner is elaborating risks in terms of being "predominantly under the control" and "predominantly beyond the control" of a mining company.

Despite the classification, representation of risks in the professional literature is uneven. While there is an abundance of material related to some issues, many points remain uncovered. Coal mining related literature is at present coherently clustered into two distinct areas: literature related to workers' health and operational safety, and project and business risks.

II. WORKERS HEALTH AND SAFETY RISKS

Much professional and scientific work is dedicated to internal risks in mining. However, the majority of these are related to health and operational safety risks. [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18], with environmental risks also frequently present [19, 20, 21, 22, 23, 24, 25, 26, 27, 28 29, 30, 31, 32, 33, 34, 35, 36, 37].

In the field of health and safety risk management, it is noticeable that countries that produce the highest amounts of coal (according to Yang A, Cui Y, 2012 those are China, India, United States, Australia, Indonesia, Russia, South Africa, Germany, Poland and Kazakhstan) beside legal documents, have developed guidelines or workbooks as aiding tools. These guidelines are almost exclusively related to health, safety and environmental concerns regarding mining. We give below the list of most accessible documents.

National minerals industry safety and health risk assessment guideline, Minerals Council of Australia; Sub-sectoral Environmental and Social Guidelines: Mining Open Cast, European Bank for reconstruction and development, Mining Underground Sub Sector Environmental & Social Guidelines; Best Practice Guideline A1: Small-Scale Mining, Department of Water Affairs and Forestry, 2006. Best Practice Guideline A1: Small-Scale Mining (Standard Format); Open pit mining through underground working: Guideline, Department of Industry and Resources, Government of Western Australia; Guidance for carrying out risk assessment at surface mining operations, Safety and health commission for the mining and other extractive industries, Dublin, Ireland: Health and Safety Authority, Committee on Surface Workings; Overview of Best Practice Environmental Management in Mining, Environment Australia; A Guide to leading practice sustainable development in mining, Australian Government, Department of Resources, Energy and Tourism; Risk management handbook for the mining industry: How to conduct a risk assessment of mine operation and equipment and how to manage the risks; Risk assessment workbook for mines, New South Wales Government; Guidebook for Evaluating Mining Project EIAs, Environmental Law Alliance Worldwide.

Upon checking this list and the majority of written material in this field, it can be stated that Australia is the leading country regarding mining related risk management. Fifteen years ago, the Australian coal mining industry started to investigate the use of more systematic safety engineering to reduce the highly unacceptable injury and fatality rates occurring in the industry. This initial interest occurred simultaneously within the regulatory agencies and the coal mining industry with the regulators presenting information on safety and risk management while the industry established a research project to investigate and trial the approaches [31].

A major project was initiated in Australia in 2010, by the Australian Coal Association Research Program. The aim of the RISKGATE project is to build, capture and deliver a national body of knowledge for managing risk in coal mining [14, 15]. It is intended that RISKGATE as the web-based tool provides clear, up-to-date and practical checklists for controlling risks across 17 specific high-priority unwanted events (or hazards, called topics in RISKGATE). RISKGATE accounts basically for the first attempt to create the comprehensive system for risk identification, analysis and management in mining, with implications on its application outside this field of expertise. However, RISKGATE presently deals only with risks or hazards immediately connected with production process in mines and consequences of these related to the health and safety in mines.

RISKGATE also presents substantive and leading edge controls to assist industry stakeholders in the design, management and

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reporting of organizational and regulatory compliance requirements

For the purpose of defining the methods and procedure of the external risk assessment, it is necessary to:

- Recognize risks and qualify the risks according to the geopolitical, social and business economical factors;
- Qualify mines with opencast mining according to the mineral resource type and the importance of the mineral resource from the national, economical, regional and local focus of interest;
- Determine and quantify risks according to mines qualified according to the certain criteria.

Risk management handbook for the mining industry describe [32] the modes and procedures for use of regular risk assessment methods such as FMEA, FTA, HAZOP and others in mining industry. In addition, essential contents of risk assessment report are defined.

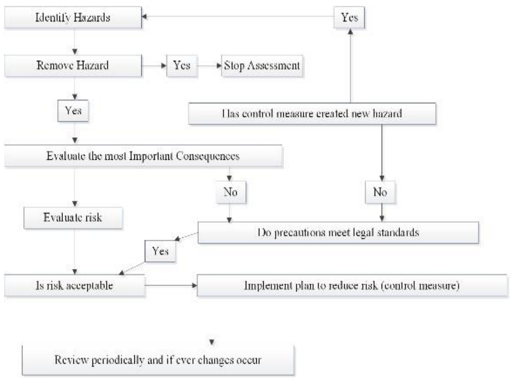

Figure 2. Model for risk assessment [5].

Step-by-step approach to identify hazards, assess risks are presented in the Risk assessment workbook for mines, identifying likelihood and consequence of harm that could occur in and around the mine. It also records specific hazards, possible problems and risk levels [33].

According to Nie B et al., safety management in mines has experienced three stages, which are experience management, system management and control counter management. As the highest level of safety management, the control counter management uses safety management method and various technical means to found the hazards and prioritizes of these hazards in order to manage them and to realize the purpose of controlling accidents [11].

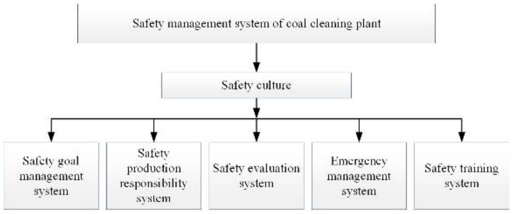

Figure 3. Overall structure of the safety management system [11].

According to Paithankar R., risk assessments will help the mine operators to identify high, medium and low risk levels. Risk assessments will help to prioritize risks and provide information on the probability of harm arising and severity of harm by understanding the hazard, combine assessments of probability and severity to produce an assessment of risk and it is used in the assessment of risk as an aid to decision making [8]. In this way, mine owners and operators will be able to implement safety improvements. Different types of approaches for the safety in mines various tools and appropriate steps have to be taken to make mining workplace better and safer. Paithankar R. also identified 7 groups of risks in coal mines regarding health and safety of working environment, namely: Dust, Chemical & Hazardous substances; Electrical energies; Explosives; Gravitational energies; Mechanical energies; Pressure (fluid/gases) and other risks related to the working environment.

While much has been written regarding safety of workers and operations and workers' health, it can be noted that, despite some progress regarding the systematic and comprehensive, there is still an overwhelmingly ad hoc approach in treating these hazards and risks. Similar to the state from the previous decades, apart from evident progress made in the field of documentation, guidelines and handbooks there is still room for improvement and multiobjective and multidisciplinary strategy in battling day-to-day risk and hazards in mine operations.

III. PROJECT AND BUSINESS RISKS

Business risks, in particular those related to mining production, planning and scheduling are also a subject of a number of research and professional papers and other documents. While health and operational safety related risks and environmental risks deal with immediate and long-term outcomes of mining operations, business related risks are those dealing with feasibility of mining project throughout its life. It can be argued that business related risks in mining are not much different from “regular” business risks but depending on the size of operations and their importance for the local, regional or country level, the economics of single mine can be very different even in similar conditions.

Project and business risk in coal mining are also the subject of a number of references [38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 52, 53, 54, 55, 56, 61, 62, 77, 78, 79, 80]

According to Ernst & Young reports [57, 58], the top 10 business risks in mining and metals industries are depicted in Figs. 3 and 4, presenting shifts in business environment worldwide, with risks being more extreme and more complex. Two significant contributing factors identified are:

1. Softening commodity prices which have seen mining and metals companies taking on more risk relative to the short term returns

2. Capacity changes in terms of skills and infrastructure which have affected organizations’ short term commitment to capital projects with life of mine of at least 10 years

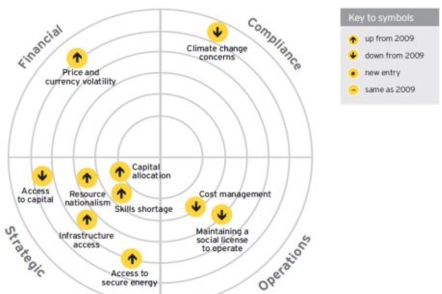

Figure 5. The top 10 business risks in mining and metals in 2010 [57].

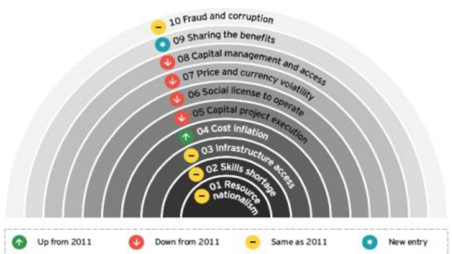

Figure 6. The top 10 business risks in mining and metals in 2012 [58].

Macfarlane stated that Mineral Resource Management relies in terms of deliverables on optimizing the value extracted from the Mineral Resource, and minimizing the risk that is associated with its extraction, and that the two are synonymous [59].

Macfarlane suggested the graph presented in Fig. 4 as the proportion between the technical and financial risks during the lifetime of a mining project.

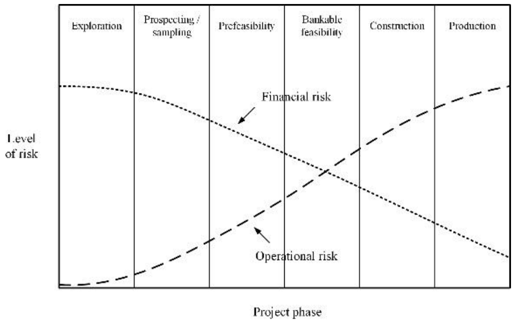

Figure 4. Financial versus operational (technical) risk during the life of a mining venture [59].

Macfarlane stated that scenario techniques such as best case/worst case scenarios are useful at a high level of decision making, but that more rigorous probabilistic risk assessment is necessary, using simulation techniques. Sensitivity analysis is useful mainly in terms of identifying the key value drivers, but both these techniques have significant limitations. Similarly, simulation is only as useful as the inputs to the analysis, and the correct distributions must be identified for the critical input variables that have been identified through the sensitivity analysis. Furthermore, simulation only adds value if the outputs are analyzed, and the results engineered so that risk is reduced to acceptable levels, and value is increased to meet free cash flow targets, within confidence limits [59].

According to Simonsen and Perry, both economic and financial analyses rest upon a number of assumptions and predictions such as costs, prices and demand [60]. The need for increasingly scientific approaches to the estimation of risk comes from the accelerating rate and quantum of investments in projects.

The uncertainties in a planned mining operation include:

- Commodity market characteristics, particularly price

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- Ore reserves and mineralogical composition
- Mining method
- Process performance
- Capital and operating costs
- Schedule duration
- Economic environment effects [60].

An interesting approach was presented by Badri et al., [75]. In this paper, a novel practical approach to risk management applicable to mining projects was presented. The approach is an attempt to devise a method of managing practically all risks in mining projects and involved adapting new concepts developed in the context of open pit gold mining to the underground context. The simultaneous evaluation of practically of types of risks in mining project was accomplished using the new concept of “hazard concentration” and multi-criteria analysis – AHP [75].

A number of standard risk procedures has been employed in the risk analysis and management of mines, including FTA [73], FMEA, HAZOP, ALARP concept [76], or their modifications, for example Fuzzy FTA [10], but there is a trend of inflow for the utilization of contemporary mathematical methods in this field of work. There are some study cases employing such methods [62, 63, 64, 65, 66, 67, 68, 74, 80].

For example, Frimpong et al., developed a stochastic-optimization model to examine the economics and risks exposure, concluding that the cyclical spot coal prices and their effects on contractual arrangements require thorough and rigorous optimization modeling of the extraction and transportation processes. Stochastic-optimization modeling provides coal companies with relevant information to make decisions under uncertainty and to assist in risk mitigation and control [69].

According to Ordin and Ordin, mine investment projects are often evaluated by using integral criteria of efficiency, such as current net cost or discounted net profit, a profitability index, or an internal norm of profitability [68]. These criteria are based on the discounting of projected costs and profits over future years. Thus, the integral value of a given mineral deposit includes annual discounted cash flows, which depend mainly on the rate of the mine's development or the capacity of the mine. The latter is one of the main technical-economic indices that determine the efficiency with which a mineral deposit as a whole is exploited. The authors have proposed a new approach to solving the problem of optimizing the design capacity of a mine. The solution of this problem is based economic principles which we have found to govern the optimization of the capacity of a mine. The optimization is done by determining the maxima of integral criteria of optimality with the use of logging data [70].

According to Runge [71], the economics of the resources industry are unique. All mining is subject to uncertainties not applicable to other industries. Every mine is different. Industry economics are difficult to quantify and categorize. Information is very costly. In major mining countries, there is now a real dichotomy [71]. The products of the minerals industry are essential primary ingredients in almost everything used in an advanced society, yet their availability is often taken for granted. In the developed world, the value of mining is increasingly being called into question. The difficulty in making profits is compounded by political uncertainties and environmental restrictions on top of the uncertainties created by nature [71].

Against this backdrop, however, actual production in many developed countries has increased. Despite declining prices, as well as profitability that frequently falls short of expectations, more capital continues to be injected into the industry. Many of the factors that lead to profits or losses escape recognition if conventional tools of analysis are used [71].

There are a few of study cases related to social impacts. For example, Lockie S., et al., stated that in 2003, many of the social impacts evident at that stage of the resource community cycle related to a failure by the community to capture positive benefits (in particular, economic development) despite increasing dependence on mining for employment and income. At the same time, while mining was responsible for only a small increase in population, demographic and social changes undermined the likely ability of the community to generate alternative economic and cultural futures [72].

Business and project related risks in mining are not so often a subject of research papers, handbooks and other publishing material. While it is true that the number of references is significant, the substance is more often related to market considerations. Legal issues, geopolitical issues, expropriation issues, etc. are disregarded and only scarcely mentioned. In the profit oriented industry world, with companies withholding many pieces of information, this is no wonder.

IV. Conclusions

The literature on mining risks is distinctively clustered into two major areas: workers' health with operational safety and environmental issues and business and project related risks. Regarding the first area, there is general orientation toward the comprehensive approach. There are efforts towards the systemic approach in identification, qualification and quantification of risks, contributing to overall improvement in risk management. However, there are two important areas rarely covered or not covered at all, the impact of so called human factor and the area of multiobjective multidisciplinary approach, most likely bound to produce adequate results.

Regarding the business and project related risks, the major obstacle in more research are most likely the mining companies. It would be beneficial to learn which methods are used in day-to-day operation of single mine, what steps are taken in particular cases, etc. For example, older all-around methods such as FTA, FMEA or HAZOP are suggested in the literature, but there is little or no evidence of their use. There is off course room for the analysis of the approach that is each company taking toward this issue, but this is, in a nutshell, a black spot for the researchers, since the research results are used but no appropriate feedback is given.

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Construction of Thermal Power Plants in the Countrys in Transition – Truth or Political Manipulation

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Abstract— **In B&H there has been an intense activity for the construction of new power plants. For many years, serious energy facility has not been built in the public sector. Since 2008 in B&H, Elektroprivreda carried out activities of the choice of strategic partners to build a replacement of unit 7- 450MW in Tuzla. The whole state influenced "couch time interval" for the realization of the investment. WB and EIB and other financial institutions do not finance these projects because of the negative impact on the environment. The paper gives a brief overview of the activities in EPB&H from 2008 until today.**

Keywords – power plants, the environment, construction of energy facilities.

I. INTRODUCTION

A. *The EU Situation, Global Trends*

Until 2020, the yearly increase of electric power consumption in EU is cca 1.6%. Coal will be avaliable cca for about 250 years, and, if wide-spread equally, it will represent the way to make the usage of new technologies for the production of electric power possible. The new powering objects need to fulfill requirements in terms of environment, supply security and the economy of production. It has never been harder to predict the future of energetics!

This question deals with: the economic growth, energy products price, energetic policies, climate changes, renewing sources of energy, coal (CSS) and nuclear reactors.

The question remains: Should the governments play a bigger role in energetics?

The EU trends regarding new generations of reactors in the following 10-20 years are:

1. The steam TE fueled with hard coal; the steam parameters of 700°C and the degree of useful effect up to 54% (built in 2014)

2. TE fueled with brown coal with pre – drying of the coal

3. TE coal - fueled with the integrated gasification of the coal

Highly efficient TE with the steam parameters of about 700°C will be part and parcel of the technology's separation and storage of CO2 (CCS technology), which' s commercialization is expected to occur in 2022.

B. *Technical – Economic Situation in Electrical power industry (BiH)*

Because of the existing blocks' age in TE Tuzla and Kakanj, the construction of replacing capacities is necessary (all the blocks in TE Tuzla are coming out of the manufacturing plant until 2027). The obligation for the EU legislation imply the increase of share production from the renewing energy sources. Additionally, there is a sufficiency regarding private financial sources for the new investing cycle.

The estimated value for investing in new energy objects which can be accomplished in a 10 – year period is 1.92 billion €, referring to:

- 448.72 mill € intended for 9 projects related to renewing sources

- 1.3. billion € for the 2 replacing blocks in Tuzla and Kakanj

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- 171.79 million € for the mining capacities

Still, there is a need for investing in the existing productional, distributive and mining capacities which will raise the investments' price on more than 2.564 billion € in the following 10 years.

Electrical power industry B&H disposes with amortizations for the investments cca of about 51.28 million €, and is incapable of financing the new investing cycle on its own.

In order for the financing construction to be closed, it is necessary to establish construction models, such as:

- Increase of bank indebtedness
- Collaborative constructing with a strategic partner

It is commonsensical that Electrical power industry BH can afford cca 15% of the needed means for the new TE. According to that, the FBH government has defined the principles regarding partnership for constructing the TE.

C. Constructing Models Comparison

Financing through the formation of a shared company for the construction and usage of a new object – JV

- Advantages:

The risks regarding the construction and usage of the powerhouse in all segments (financing, deadlines, achieving of the projects' parameters and so on..) between partners are allocated. If a partner is good, the transmission of knowledge and technology during the construction and usage of an object can be done.

- Disadvantages:

A partners' ownership question regarding a newly – built object, providing larger private involvement in constructing of the object, cca 50%, the quantification of the more complex contracts regarding collaborative construction and usage of the object, and, adjusting the preceding involvement of EP B&H with the one it applies in the shared company (the existing infrastructure, coal security and the legal valorization for the CO2 emission..).

Financing through a contract regarding a long – term takeover of the electrical energy or by amortizing loan, without the formation of a shared company – JV

- Advantages:

The partners' ownership over a newly- built object is not questionable, project financing, a self – financing project, a private involvement relatively low (cca 10 – 20%), financial risks when it comes to the market are on behalf of the partner, the partner provides a financial guarantee for a loan.

- Disadvantages:

All the risks regarding construction (deadlines, contracting and achieving projects' parameters and a planned budget are on behalf of Project Company, the risk on behalf of EP B&H is the compilation of a contract for a long – term delivery of electrical energy and a satisfying cartelization of the powerhouse under the EPC system (employing a good consultant is obligatory).

The construction of a new TE is financially and technically complex project throughout which the preparations last 5 and the actual construction 4 years.

II. CONSTRUCTION OF THE BLOCK 7 – 450MW IN TE TUZLA

The replacing block is being built at the TE Tuzla location, there is an infrastructure, and the input resources are coal, water, a port on the EES, a "continuity" cadre in TE Tuzla, an infrastructure for district heating in Tuzla and Lukavac in order for the blocks to work in cogeneration.

A. Economic indicators

The investments regarding the construction of the block 7 are cca 766.5 mil. € (722 mil. €), and the average electrical energy consuming price (along with the buying price of coal 2.43 €/GJ) 42.29 €/MWh.

The investments in the block 7 construction together with the mine are 842 mil. €. The average price – expense of the electrical energy (along with the price – expense of coal and the mine – investment) is cca 38.19 €/MWh. (NPV: 173.7 mil. €; IRR: 7.5%; Money refund period: 17 years)

The official pre – qualification call for the election of a project partner regarding shared investing in the construction – project block 7 in TE Tuzla has been announced 31.7.2012, corrected 4.9.2012, being also published in the Financial Times 8.8.2012. The contract

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regarding compilation of the investing and environmental documentation has been signed 1.12.2008 along with the Consortium of designers: Esotech d.d. Velenje (the Consortium leader); CEE d.o.o. Ljubljana; ERICO Velenje, and RI Tuzla. The nostrification of the project has been done by Energoinvest d.d. Sarajevo. The additional control of the imagined project has been done by the Japanese Hitachi, and the same company also financed compilation of the Study with the help of NEDO organization and employing of the Japanese consultants.

B. Received Permissions and Agreements

On the basis of finished, revised and nostrified investment and environmental documentation, the needed agreements necessary for making an investment decision about the block 7 construction have been received. The Energy permission is remained to be provided. The requirements for the environment protection are adjusted with the IED EU directive. In comparison with the existing blocks in TE Tuzla, the emissions will be lowered up to 20 times.

III. A BIDDING DOCUMENT

Throughout the tender, the principles for the project partnership have been established. They are agreeable with the government FBH decision regarding the preparation and construction of the 7 – 450MW block in TE Tuzla. Also, they are unchangeable, not a matter of negotiations, widespread and, according to which, the distinct partnership models by the interested candidates can be offered. Furthermore, candidates are required to fulfill much of the actual qualificational criteria.

A. A Bidding Procedure – The Activities with the ALPIQ

According to the international public application, lasting from 4.5.2010, Alpiq AG was announced in 9.7.2010 as the only qualified candidate that applied in the pre – qualificational process for the election of the strategic partner regarding shared investment in TE Tuzla.

The second electing phase for the shared partner regarding collaborative investing in the block 7 – 450MW project in TE Tuzla has been accomplished according to the tender delivered to the pre – qualificational candidate Alpiq Ag in 19.8.2010. The delivered bid to Alpiq AG containing an Agreement Draft about the cooperation relating to the block 7 – 450MW construction has been opened in 1. 10.2010.

After the bid – evaluation and meetings with the Alpiq's representatives, a part of the questions required in the tender were agreed upon, in contrast to questions related to the electrical energy delivery price until the time of putting the block 7 to work, the ways and requirements related to securing and closure of the financial construction.

The extension for the optional bid wasn't asked for and there were no further contacts after 30.9.2011, it has passed without a bank guarantee, there were no bidders' appeals, the negotiations were closed and the Electrical power industry B&H governance board made a decision on postponing the electing process for a strategic partner in 22.6.2012

B. The First Phase – List of the Pre – qualificational Candidates

A new public call for pre – qualification has been announced in 31.7.2012. 12 candidates applied. The decision regarding the pre – qualification of candidates that satisfied the established criteria was made in 29.10.2012.:

1.	China Machinery Engineering Corporation, Kina;
2.	Harbin Electric International Co. Ltd., Kina;
3.	Consortium - Gezhouba Group Company Limited, Kina (lider) i GEDI - Guandong Electric Power Design Institute, Kina;
4.	SEPCO Electric Power Construction Corporation, Kina;
5.	MVM OVIT National Power Line Company Ltd., Mađarska;
6.	Consortium - SEPCO III Electric Power Construction Corporation, Kina (lider), HTG Development Group Co. Ltd., Kina, Shandong Electric Power Engineering Consulting Institute Corp. Ltd.;
7.	COBRA Instalatciones y Servicios S.A. Madrid, Španija;
8.	SIEMENS A.G., Njemačka;
9.	Cengiz Enerji Sanayii ve Ticaret A.S., Turska;
10.	Consortium - TOSHIBA Corporation, Japan (lider), RAFAKO S.A., Poljska, Hrvatska elektroprivreda d.d.-HEP, Hrvatska;
11.	HITACHI Ltd., Japan;

C. The Second Phase: Short – listed Elections

Most of the qualified candidates have visited TE Tuzla, had access to the projects documentation and the requirements for the block 7. The bidding document have left out the possibility for the candidates to put forward a partnership model they prefer and for which they can find a financial institution that is able to secure financing of the project.

In terms of Technical bid, the technical data, the block's performances and the description of the offered resolution were required. In terms of the financial one, a delivery of the partnership agreement draft, a letter of support from the financial institution, a guarantee for the offer validity, an overestimated – informative value of the investment and the estimation of the projects' financial effectiveness was required. In terms of informative (non-final), a decision was made to leave a possibility so that through negotiations and optimization of the technical solution, the more acceptable resolution would appear.

The second phase bidding document regarding the election of the project partner for a shared investment, has been delivered to the qualified candidates in 2.4.2013. The bid – delivery deadline was 24.6.2013, and at the same date they were publicly opened.

The three bids were received (two consortiums and one individual bid)

In 27.8.2013, Electrical power industry decides to announce the short-listed bidders that satisfied the criteria: Hitachi Ltd. Japan and Consortium: China Gezhouba group Co Ltd. – leader GEDI – Guandong Eletric Power Design Institute, China.

D. The Third Phase – The Final and most suitable price – The preferred bidder

After the short – listed bidders' verification, a competing dialogue have occurred, involving special bidders dealing with the explanations and equalizing of the specific elements from the bid. The goal of such a dialogue is to approach an optimal solution which needs to entail three basic factors: price, reliability and efficiency.

The second aspect deals with clarification of the partnership model, expectance from the partner to accomplish the partnership and durance of partnership's contract. In terms of reconciliation of the financial backgrounds, the meetings were held in BH, Japan and China, involving technical experts. The dialogue was directed to the financial institutions: the Export – Import Bank of China, in China and the Agency JICA in Japan, which expressed the will to finance the block 7.

The competing dialogue was fruitful with the results according to which the Bidding Document was prepared for the final and most suitable solution. This final Document was delivered to the short – listed bidders (17.1.2014) containing a defined delivery deadline of the Final bid, which is until 17.4.2014. The final bids were publicly opened at 17.4.2014 involving the Consortium CGGC – GEDI representatives.

The two Bids were prepared:

- Mitsubishi Hitachi Powers System Ltd. Japan
- China Consortium Gezhouba Group CO Ltd – Leader and Guandong Electric Power Design Institute.

After the Mitsubishi Hitachi Power System Ltd. Japan Bid being opened, their jurist stated that the only thing delivered is the assertion explaining that they are not in the position to finance their bids and are incapable to deliver the Final bid because of the political situation in BH.

IV. THE CONSORTIUM CGGC – GEDI BID

The Bid characteristics of the Consortium China Gezhouba Group Ltd (CGGC) and Guandong Electric Power Design Institute (GEDI) are:

	PBC	BC
Shared debt	85%	85%
Shared capital JP EP B&H %	15%	15%
Interest rate	2%	5%
Commitment fee	0,25%	0,25%
Managing expenses	0,25%	0,25%
Accompanying expenses	0	7,7%
Grace period	5	5
Amortization (20 years)	20	15
Amortization period	15	10
Sovereign guarantee	Yes	No
Collateral	Escrow of the Tuzla 7 plant, escrow account for PPA, a guarantee from JP EP BiH, a government guarantee	Escrow of the Tuzla 7 plant, escrow account for PPA, a guarantee from JP EPIBH, a government guarantee, SINOSOURE assurance

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The Consortium Gezhouba – GEDI bid from 17.4.2014 confirms the following guaranteed values for the block 7:

The netto activity level (condensational work regime)..	42%
The netto activity level (the winter regime – heating)	45.9%
The netto activity level - average for the 7000 working hours	43.6%
Availability of the block 7 – first year of a guaranteed period	88%
Availability of the block 7 - second year of a guaranteed period	90%
SO_2 emission	<150mg/Nm3;
NO_x emission	<200 mg/Nm3;
Dust emission	<10mg/Nm3

A. Project Cooperation Agreement

The Project Cooperation Agreement draft is part and parcel of the CGGC – GEDI final bid which entails basic elements of the partnership Project and the Plan implementation Project for the 7 block construction:

- Partnership Project Basis

The financial construction is closed without formation of a shared JVC while using the beneficial money loan along with the money loan refund. In that case, the project partner appears as an EPC contractor and the Electrical power industry uses the building and disposes with the produced energy. Both sides are interested to start with the activities, negotiations and the Project realization. Also, they are willing to cooperatively develop the Tuzla Project block 7 as based on the EPC contract.

The Project will be developed and realized through a special Project company that will be established in the period of 60 days from the date of EP B&H's signature of the mentioned contract.

The CGGC – GEDI is an EPC contractor. After the Bank application according to the prescribed procedure, the Agreements' signature on project cooperation – PCA and the construction EPC contract, the loan will be approved. The China Gezhouba Group Co Ltd (CGGC) consortium and the Electric Power Design Institute (GEDI) gives the commitment account regarding the Block 7 preparation, construction and exploitation. The account is based on the following principles:

EPIBH secures the construction site, permissions, available TE resources, the Project company constructing registration with an emphasis on the EP B&H 100% ownership. Also, EPIBH develops the Project, financial concept and applies for a loan. Furthermore, it builds and manages TE, secures human resources and infrastructure for the Project company. It also deals with all the work the Project company does in the block 7 preparation and construction phase and secures the needed guarantees for the loan refund.

CGGC – GEDI assists in receiving the loan from the Chinese financial institutions and postpones the 100 mil. € loan negotiations for RU Kreka. The CGGC – GEDI powerhouse and equipment will fit the Final EPC Consortium Bid and the EP B&H technical requirements, taking care of the minimal Chinese involvement as demanded from the Chinese financial institutions.

The EPI BH shall 100% own the constructed block 7, a mortgage on the same block, the escrow account regarding the PPA income, the EP B&H and Sinosure insurance policy guarantee.

All the loan requirements mentioned in the bid serve for the orientation (reference). The bank, Sinosure (if needed) and negotiations between the creditor and borrower will define the final loan requirements after the Project estimation takes place.

- Project Guarantees

A guarantee for the loan refund should be acceptable for the Bank which gives the credit as is defined when it comes to the type of credit. A guarantee for the performance bond secures the Construction Consortium according to the EPC contract. The EP B&H has a 100% right on using the block 7 power and electrical energy while the construction model is the EPC contract. The deadline for the implementation plan is 56 months upon the date of the EPC contract efficiency entering into force.

- Project Organizational Structure

EP B&H as an investor through the Project company has the following obligations: To lead and coordinate the investments, to control and technically supervise the equipment delivery in all phases (materials, industrial testing, the equipment receipt in the factory and at the constructing place), supervision and the receipt of the construction work and assemblage,

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involvement in the probational plant of the block and the final block receipt.

The CGGC – GEDI as a general designer, the equipment deliverer and work – assemblage contractor has the following obligations: to compile the documentation (the building permit, production, building and assemblage and the upkeep guidelines), to form the company at the place of construction, to employ the required delivery experts, to receive the factory equipment, assemblage and the probational plant, to receive and store the equipment, to deal with the guarantee measurements, to control the project at the constructing place, to cooperate in planning and organizing the project with the investor, to supervise the transport, assemblage, testing, probational powerhouse plant, and the quality control.

B. Optional PBC Credit Netto Bid Price (Preferencial Buyer's Credit)

The bids are given tabularly along with the indicators:

in mil. of €	total investment 785	total investment 835	distinctions	„increase of 85“(%)	„decrease of 835“(%)
The site preparation work	9.39	9.98	0.59	6.3	5.9
constructio n work	151.9	161.4	9.54	6.3	5.9
mechanical equipment	415.6	441.7	26.1	6.3	5.9
electrical equipment	29.3	31.14	1.84	6.3	5.9
rest of the plant	3.81	4.05	0.24	6.3	5.9
the voltage testing and putting to work	169.3	180.0	10.6	6.3	5.9
capital equity	3.91	4.15	0.24	6.1	5.8
spare parts	2.26	2.4	0.14	6.2	5.8
total investment	785.6	834.9	49.3	6.3	5.9

The offered technical solutions in terms of main equipment like brazier, turbine and generator are manufactured by Alstom and Siemens, so the guarantee values which completely fulfill the bidding requirements are based on them.

V. Financial Bidding Elements Evaluation

In the cooperation with the financial consultant - the American Delphos International ltd. factory in Washington, the financial bid evaluation for the block 7 construction in TE Tuzla has been accomplished. The financial and technical bids are delivered in accordance with the bidding documentation requirements. The financial bid evaluation has been carried out according to the criteria given in the bidding document, as follows:

A. Internal Rate of Return (IRR)

The internal rate of return (IRR) is calculated according to the business plan and the financial modeling data delivered by the bidder as a part of the financial bid. In the business plan under the wire of the projectional money courses regarding the Project and according to the financial modeling data and private estimation, the bidder has carried out the calculation of the internal rate of return relating to the EPC contract value scenarios of about 785 and 835 million €, with the two loan requirement variants.

The financial consultant has carried out the calculation of the internal rate of return according to the financial modeling data, the private estimation and the subsequent explanations regarding the input data received from the bidder for the EPC contract value scenarios of about 785 and 835 million €, with the two loan requirement variants.

The calculations give the following overview of the Project financial maintenance:

Scenario	NPV u EUR mil	IRR
BC 835	-190	2,3%
PrefBC 785	46	10,9%

From the results calculated (IRR) by the bidders and financial consultants, it is obvious that the Project will be financially maintained only if EPC contract financed by the PBC and EPC contract value of about 785 mil €. The negative influence on IRR is the bidders' higher bid as the result of the SINOSURE insurance which is necessary when financing the Project

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using the buyer's credit (BC) which amounts 7.7% of credit and interest altogether.

VI. Financial position – methodology

The financial possibilities have also an influence on the new power houses entrance date besides the status of existing capacities and the mine position. The maintaining versions of the result accounts are the financial analyses showing the dynamics and building intensity being dependent on company's position and debt capabilities. The financial projections, which besides income – outcome analysis also contain an investing plan and the structure of those investments (a credit share and the participation of the designing partners) are needed in order to evaluate the investing capabilities.

The dynamics of withdrawal of loanable funds, interest calculation and amortization are necessary to be done for the credit – financed share. Attached to that plan is a plan for the existing credits which are in the amortization process. The amortization amount, because of the large investing and because of the new funds activation, is continually increasing. The credit – servicing expenses (interests and capital fund repayment) are increasing because the largest part of the new objects is credit – financed. It affects the quality of success, which, along with grants and credits, represents the funding source for investing.

When the funding sources face the totality of needed funds contained by the investing funds, the credit – servicing, taxation and the working – capital changes, the answer to the investing potential, maintenance of the definite investing plan and the funding sources structure appear. The plan unsustainability is perceived through a bad financial result, negative balance of needed funds and sources, decrease in cash or a negative amount of cash in the balance state. In order for a plan to be sustainable, the amount, investing dynamics and source structure can be influenced

VII. The way of realizing capital investments

It is impossible, in such a short period of time, to accomplish all the projects by the classical way of taking a corporation loan because of several reasons: the intensity and amount of investing, low business interest and the loan limit. Because of that, the combining financing models for the special thermal blocks along with the involvement of project partners have been chosen. The Gro investing is in the TE with mines, so it is crucial to find the way of financing them. On the other hand, the realization with the help of a project partner can be achieved only through project system or through the combination of project – corporative financing system.

For the Tuzla 7 project realization, a model of corporative credit financing has been established. It would be secured by the project partner who gave the bid for the project realization, but not for the owning share or the power and energy reservation.

The projected involvement of the partners for the other thermal blocks is 49%. The model is simplified for the compilation of these projections through observation of the EP B&H share in the investments, production and also the plant expenses and commitment servicing. The realization of HE and VE projects is imagined through a classical corporative financing, by combining the private funds and those borrowed from the international financial institutions. The reason for that is because it is all about the renewing energy projects for which it is easier to get a credit. The produces kWh will be additionally valued as renewable and there are smaller individual capacities and investment amounts.

All of this makes possible a more faster project realization start, because choosing the strategic partner and a conclusion of a file of contracts needed for the project financing requires much more time.

The final contract text regarding the block 7 construction – The Engineering, Procurement and Construction Agreement – has been signed and agreed upon on 27.8.2014, and the contract value has been estimated to be 785.65 mill €. The contract says that it itself can be changed on the demands of EP B&H Sarajevo, the FBH Government, the BH parliament and the EX1M Bank during the period from its signing until putting to work. Through the Project Cooperation Agreement and the EPC contract, it is imagined that in the expiration of the period case, which lasts for 365 days from the official delivery of the acceptable credit application, the credit remains unsigned. The partnership project contract and the project cooperation agreement becomes invalid just like all the previously concluded under – project agreements or contracts such as the EPC contract.

If the requirements for the EPC contract putting to work are not completed, neither one of the contracting sides will have any rights regarding any kind of claims, damage compensation or any other compensations. In other words, each side is responsible for its own created expenses up to that time.

By signing the EPC contract the requirements for the credit application have been accomplished. From the date of 27.8. up to 7.9.2014 and EP B&H delegation resided in PR of China and applied in the Export – Import Bank of China, Concessional department for the preferential credit and enclosed the necessary accompanying documentation. A memorandum about the understanding and financing of the block 7 in TE Tuzla has been signed between The Export – Import Bank of China (Eximbank China) – the lender, and the FBH government represented by the Ministry of Finance. The signing up of such a memorandum, the FBH government has confirmed the readiness for the "sovereign" guarantee disposing regarding the credit – security imagined for the construction of the block 7 in TE Tuzla.

VIII. Conclusion

In May 2016 B&H Council of Ministers and Federation B&H Government supported the idea of Chinese investors to construct Block 7 in TE Tuzla. Annex of the Contract has been signed, so the price of the Project is cca 722 Mill. EUR, out of this amount (15%) of the price EP will pay, 85% will be paid by Chinese Exim Bank. Payment by credit in 15 years' time, with grace period of 5 years (the construction period of Block 7). Interest rate is unknown, will be defined later on by the Chinese partner!?

It is also unknown how much electric energy will be produced by TE and by which price, how much coal will cost is also unknown.

Elektroprivreda B&H is obliged to pay an advance of 15% of the EPC contract value suppliers. It is not clear whether these payments have to be done as a single "off-advance" at the very beginning of the project, or can be spread over the construction phase of the "pro rata" with CGGC investing!

Starting decision and analyses are made with prices for electric energy cca 54 €/MWh, coal 2 €/GJ, but at the market at this moment cca 40 €/MWh.

None of existing blocks cannot operate efficiently except hydropower stations, especially it would be complicated to build a new block, energetic experts consider.

It would be possible to pay back a loan to Chinese only by these parameters. But price of the electric current at the market is cca 40 €/MWh, and coal between 2.5 and 3 €.

Regarding these starting data it is a question of competition and economic sustainability of Block 7.

On the other hand if price of coal is getting lower at the market, sustainability of domestic mines, especially Kreka, is under a big question.

All attempts made by Federation B&H Government, responsible Ministry, EP B&H company, between 2008. and now days, are totally unsuccessful. Definitely, it is today an irretrievable process, which in a long term, degrades economic stability of B&H. After all these years and processes, it is difficult to expect better economic situation in B&H, because it is generally known, mining needs double more time for "economic recovery" of the mine.

It is impossible today, in this constellation of relations in B&H, to have Prime minister, ministers, managers in EPB&H company who have knowledge, will strength and political mandate to make a needed steps forward in coal mines. Yes, impossible!

That is definitely, today, wasted time and continuation of further path into an abyss, which costs too much for B&H. The aims and methods are known and clear how the process can be made in a desired direction – first of all to sell members of EP B&H concern, companies (daughters): Eldis Tehnika, Iskra-Emeco, ETI Sarajevo and Hotel Elbih Makarska and rationalization of EP B&H and coal mines business, with completely new managements and personnel!

That is not "a core" activity of the company, significant resources are "poured of" through daughters companies, but, especially, investments in so called "enlarged capitalization" are suspicious, made by ruling company – Elektroprivreda B&H dd Sarajevo. The Government, responsible Ministry have to put big efforts for investments, new equipment, modernization.

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The most important aims are: to invest in production capacities to provide the cheapest coal with the lowest price k/s in Block 7 in long term business of coal mine, but it is very difficult achieve after 8 years!

Present situation in coal mine is best indicator for investments so far. Coal mines with poor equipment are not able to meet needs of TE. All experts agree “There is no new block without investment in coal mines and there are no coal mines without new block”, but it is just a vicious circle of suspicious, very suspicious public procurements.

Construction of Block 7, for some experts, is the only way that B&H sustain energy independence, and strategic projects risks always exist. None of western credit organizations didn’t want to finance the project, because it is forbidden to construct facilities on coal, due to pollution, although our authorities are seriously warned by number ecological associations.

EU members and Energy community permanently increase fines for those who pollute the environment, thermoelectric power plants, are of course, one of them. So, what is the “story about European equipment and Chinese credit”? Whether Block 7 is able to meet EU ecological standards in cooperation with Chinese companies, and whether we are able to obtain all the required performances for the new block, and approve it with “small China”!

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Green Roofs as an Example of Green Building Design

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Abstract— **The aim of this paper is to analyze the green roofs application in context of green building design as the possible model of human (as a part of civil engineering measures) adaptation to global climate change. The research is grounded on representing the types of green roofs which exist, as well as the manner in which they are held and applied with regard to climate characteristics, which can influence the way of maintaining the green roofs. The importance of green building designs is explained in solving problems of climate change impacts on human habitation and settlements. At the end of the presented research, the examples from the world are presented, which further confirm the importance of implementation of green building design in the world, as well as in our country. The conclusion summarizes the most important preventive activities to be undertaken in sense of climate change risk prevention and mitigation.**

Keywords – climate change, green building design, green roofs, environmental impact

I. Green Building Design

Green buildings appear during the energy crisis of the 1970's when the solar energy was transformed into electrical energy. According to US EPA (*United States Environmental Protection Agency*) green buildings are: *"…the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction*"[1]. Green buildings are reducing and ultimately eliminating the impacts of conventional buildings on the environment and human health. That is why this form of construction becomes increasingly popular both because of the benefits they provide, and because of their appearance. Green roofs, as a part of a green building represent one of the tools for adaptations to climate change.

II. Green Roofs as an Example of Green Building Design

Green roofs, as a part of a green infrastructure, in recent years increasingly gaining in importance as one of the possible adaptation measures to climate change.

Except that they increase the total area under vegetation, green roofs affect also on: reducing urban heat island effect, quality and quantity of storm water, air quality in a city, energy efficiency of buildings and energy consumption etc.

As the cities expand, and a man is increasingly moving away from the natural ability to take a walk in a park, especially when the skyscrapers started to build, there was a need to plant green areas on the terraces and roofs. Unlike traditional, green roofs represent partially or completely covered roofs of buildings with vegetation, which is located above waterproof layer of the membrane. They are also called "*roof garden*" or "*living roofs*". These types of roofs are viewed through the prisms of their economic, environmental and social benefits which were bring to urban environment, and their implementation provide sustainable living environment. The most important advantages of green roofs are:

- The impact on the urban heat island;
- The impact on control of storm water runoff;
- The impact on air quality in the city;
- The impact on biodiversity;
- The impact on energy consumption and energy efficiency of buildings;
- The impact on noise level reduction in the city;
- The possibility of food production in the city;
- Place for socialization and relaxation;
- The impact on prices of real estate;

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- The impact on sustainability of an installation;
- The possibility of creating new jobs;
- The impact on the image of the urban landscape.

Green roofs are usually represented as the only way of reducing heat island in cities, where space is one of the main scarce resources. Bass and colleagues tried to produce mathematical model with which they could predict the impact of green roofs on a heat island in Toronto, which predicted reduction of temperature for 2^0C [2].

When we talk about the control of stormwater runoff, we are witness of the frequent floods on the streets that occur in recent years due to heavy precipitation, especially in the central zones of the city. Many studies have quantitatively demonstrated that a green roof, which is properly designed, implemented and maintained, will absorb atmospheric residue and release it slowly over time, in contrast to conventional flat roof that instantly creates surface runoff. The amount of stormwater that green roofs can hold depends on several factors, such as: the thickness of the substrate and its water potential, the climate zone and the time of year, the characteristics of the vegetation cover, the frequency and intensity of precipitation, as well as the period of time that passes between the rainfall [3].

Aggravation of air quality is a global problem, and pollution reduction initiatives range from local to global strategies. Green roofs are just one of the possible ways to reduce urban air pollution by lowering air temperature, adoption and retention of solid particles and the absorption of pollutant gases. Numerous other studies have also shown that green roofs can be very important part of the strategy and they can influence the reduction of pollution in urban zones [4].

Research in the US and Europe have shown that green roofs may be substantially to improving biodiversity in urban areas, by providing habitat for different species of spiders, butterflies, invertebrates, etc., which many of them are endangered species that cannot survive in urban habitats. According to some results, green roofs have the potential of habitat and green spaces at ground level, and can have a role in connecting fragmented habitats if they are planning to be built in positions that are strategically determined [5].

Green roofs impact on energy consumption and energy efficiency of buildings, as seen from the economic point of view, perhaps attracted the most attention when opting for a green roof. The reason is that it is proven in practice that the installation of green roofs affect the energy balance of heating buildings by reducing heat losses in the winter, which increases the energy efficiency of the building. Firstly, reduction of the building temperature during the summer period is the result of evaporation of moisture retained in the substrate and transpiration by plants themselves. In addition, reduced heating occurs because, instead of heating the roof, the energy of sunlight is partially spent on the running of photosynthesis. The energy benefits of thermal behavior of buildings and roofs may vary depending on the climate zone, the time of year, type of green roof and the amount of moisture absorbed by the roof. The studies were conducted in different climate zones, and their results should be interpreted according to that, and should be taken as relevant only those who have obtained in the zone of moderate continental climate. Measurements were performed during 1984. in Berlin and they have shown that the installation of a green roof not only reduces heat roof surface, but also the temperature amplitude were halved [6].

Noise is one of the biggest challenges that occurs in urban areas, and it has a very negative impact on mental and physical health of the population. It has been shown that, for the urban population it occur different psychological disorders, cardiovascular diseases and other diseases, due to increased urban noise and prolonged exposure to it. Green roofs can reduce the intensity of urban whir, because the combination of soil, plants and other layers in the structure acts as a sound barrier. Part of the sound waves is reflected, part absorbed by the substrate and vegetation cover, and the other part dissipates [7].

The usage of green roofs in order to produce food in an urban environment is becoming trendier (i.e. urban agriculture). This is often the case with restaurants and hotels, which grow different plants for their own use. This type of intensive roofs actually represent a roof garden, and they require adequately prepared and reinforced roof structure. There are many examples, but one of them is the Hotel Fairmont in Vancouver, where is 195 m^2 of surface area of roof converted into a roof garden in which they

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grow herbs, vegetables and flower types to satisfy it needs of the hotel [8].

In addition to the previously mentioned impacts of green roofs, we cannot miss many other economic and social benefits that the implementation of these roofs offer. Green roofs offer the possibility of formation of open green spaces in places where there is enough space for them. These areas have multiple functions and potentials, and one of the most important feature is that they offer to urban populations the possibility of direct contact with the natural elements within the urban fabric. Therefore the green roofs are important spaces for relaxation and socializing. Green roofs are accessible spaces for social interaction, relaxation and recreation. In many cities companies are forming green roofs increasingly on their buildings, where employees can spend their free time. This venture proved to be very useful benefit, because people who are working in these companies recorded better concentration, productivity and creativity, and stress level was significantly reduced. If green roofs are constructed as part of the eco building, then the cost of heating and cooling, as well as one of the major items in the household budget, will be significantly less. This means that the initial expensive outlay for flat, leading to savings through a number of subsequent years i.e. makes an investment in the future, thus enabling an increase of prices of real estate, whit which buyers of apartments can agree [9]. What is also demonstrated through various examples is that green roofs have a longer lifetime than conventional roof structures, almost double. This is the result of functions and features of a green roof which protect roof surface from UV radiation, large temperature fluctuations, mechanical damage (e.g. from hail) [10].

III. CLIMATE CHANGE ADAPTATION, RISK PREVENTION AND MITIGATION

We are witnesses of the climate change on a global level and it is one of the biggest challenges that we are facing on daily basis. If measures for climate change adaptation are not implemented then it can be expected that many inhabitants of large cities will decrease quality of life. According to US EPA, climate change adaptation refers to: "*the adjustments that societies or ecosystems make to limit the negative effects of climate change or to take advantage of opportunities provided by a changing climate. Adaptation can range from a farmer planting more drought-resistant crops to a coastal community evaluating how best to protect its infrastructure from rising sea level*". According to same source, adaptation actions can be divided into two basic groups:

- reactive actions: which means responding to conditions that have already changed due to the climate change adverse effects, and
- anticipatory actions: which aims proactive and predictive planning for climate change before impacts are observed [11].

As climate change adverse effects is already impacting societies and ecosystems around the world, there are many actions focused to adaptation in place. The correct, and above all, anticipatory actions are to be selected on the basis of climate changes impacts risk assessment, as shown in Fig. 1 [12].

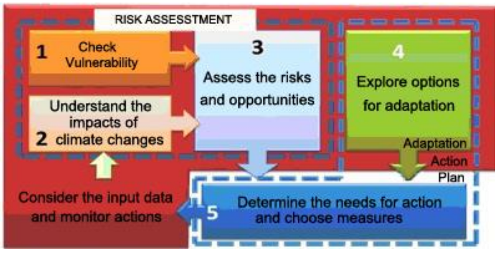

Figure 1. Illustrative stages in risk assessment regarding the impact of climate changes

Bearing in mind that an occurrence of climate change adverse impacts implies risks with potentially significant effect, in recent years there has been a growing interest among researchers in development of appropriate adaptation models, facing the climate change risk management [13]. In abovementioned context, the green roofs are to be seen as a instrument of climate change adaptation policy.

IV. CONCLUDING REMARKS

Within concluding remarks, we would like to emphasize another, sometimes neglected detail concerning the green roof. The needs of the modern materials used in constructing of green roofs, condition the opening of new firms which would be engaged in import and distribution, or expansion of existing activities of companies, which would create new jobs. In the area of production of planting materials, especially here, would open even one field of production, which has not yet been developed, which would employ more people. And finally, there would be an increased need for qualified personnel and specialized companies which carry out the construction of green roofs. All this would lead to the need for highly educated skilled personnel, creating new jobs for lower skilled workers, starting supportive industry and education system, as well as a general increase awareness of environmental protection and culture which could be also spread to other fields of human activity.

ACKNOWLEDGMENT

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Integrating Environmental, Occupational Health and Safety System Using FMEA Method

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Abstract - **Human activities for improving the conditions of life and work disrupted the ecological balance, i.e. correlation and harmonious interaction and interdependence of the human being and his natural environment. Modern society is often called "risk society", because the development of science and technology and its implementation has significantly increased the number of risks and hazards. While the ecological balance in today's planetary constellation results in such a condition that there is a threat to basic resources necessary for sustaining life and human functioning. By using FMEA analysis in the paper will be presented and developed a methodology for assessing the risks in order to achieve a system and procedure for implementing internationally recognized standards and compliance with the legislation in the field of occupational health and safety and environmental protection within a company.**

Keywords - FMEA analysis, occupational health and safety, environmental protection, ISO 14001, OHSAS 18001

I. INTRODUCTION

Through a well-designed, modern and efficient management system and many other efforts, activities and processes, society needs a systematic change in the perception of the importance of occupational health and safety and environmental protection as a basic prerequisite for sustainable development and all associated components. Shortly, the economic and social transformation and globalization should be integrated into the strategy for occupational health and safety and environmental protection of each enterprise, every social group, governmental and non-governmental organizations and the entire community. The intensive development and application of science and technology on the one hand and global processes on the other significantly changed the general picture of the modern society. New sophisticated technologies are facing with very fast and effective application and implementation in the generation of various weaknesses in all spheres of human activity.

Today occupational health and safety and environmental protection in production systems can no longer be seen as one of the functions which involves a relatively small number of qualified people, but these disciplines should be seen as particularly important internal or inherent feature of any company in whose realization should be no excluded employees [1]. It is realistic to expect in the future, sooner, and exponential growth of changes and achievements in science and technology and their wide application in various fields. It is certainly not just predictions but actual danger and threat that facing modern society in terms of finding a more complex, more efficient and more successful solutions to problems for occupational health and safety and environmental protection challenges.

II. NORMATIVE LAW REGULATION OF OCCUPATIONAL HEALTH & SAFETY IN MACEDONIA

The implementation and compliance of the legal law requirements is required for any business system and entitles. These legal requirements are contained into a number of regulations (national legislation, laws, regulations, strategies etc.). Their number and dynamics of change is particularly expressed in the field of occupational health and safety. The reason is that OHS is a broad area and requires

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monitoring of its development and continued compliance with international law, and thus tendency towards global legislature.

After the independence of the Republic of Macedonia has been adopted Law of Occupational Safety, which defines responsibilities of employers and the rights and obligations of workers („Official Journal of the Republic of Macedonia„ no. 92/07). The Macedonian OHS law is almost fully harmonized with the Framework Directive 89/391/EEC for introducing actions and activities aimed to continuous improving of the health and safety of employees.

Therefore the law determines preventive actions against occupational risks, elimination of risk factors, informing, consulting, training of workers and their representatives, and also provides participation of employees in planning and undertaking measures for continuous improvement of OHS system [2]. OHS law involves measures, resources and methods to create safe working conditions where safety at work is an integral part of the organization of work and working processes and it is organized, regulated and provided by the employer.

The basic principle in the Law is „the principle of prevention of workplace injuries, professional diseases and diseases related to work". The Law of Occupational Health & Safety introduces the category of "risk assessment", which entered a new approach to protect the health of workers.

Fig. 1 shows the model of process direction with legal requirements for health and safety in the production system.

III. ENVIRONMENTAL LEGISLATIVE IN REPUBLIC OF MACEDONIA LAW ON ENVIRONMENT

In the Republic of Macedonia according to the framework of environmental legislation of Council of Europe, in 2005 has been developed Macedonian law on environment. This Law regulates the rights and the responsibilities of the Republic of Macedonia, municipalities as well as the rights and the responsibilities of legal entities in the provision of conditions required to ensure protection and improvement of the environment, for the purpose of exercising the right of citizens to a healthy and clean environment. Legislation for the protection and improvement of the environment of the Republic of Macedonia incorporate the principles of European environmental policy, but also a lot of attention is dedicated to the principles of environmental protection with national, regional and local mark.

So the environmental law is structured according to environmental principles, including ecology, management, responsibility and sustainability and aims to promote sustainable development for present and future generations. The law is based on preventive action, the polluter-pays principle, elimination of environmental damage at source, shared responsibility and the integration of environmental protection into other EU policies. So, according to the law, the environment is defined as a space with all living organisms and natural resources, i.e. natural and man-made values, their interaction and the entire space in which people live and in which settlements, goods in general use, industrial and other facilities, including the media and the areas of the environment, are situated [3].

The primary purpose of the Law of environmental protection is improvement of the quality and condition of soil, water, air; the areas of the environment, biodiversity and other natural resources, and the protection of the ozone layer and prevention the negative human impact on global warming and climate system.

According to the law, the protection and promotion of the environment is a system of measures and activities (social, political, social, economic, technical, educational, etc.) that provide support and create conditions for reduction of the pollution, degradation and influence on areas and media environment (protection of ozone depletion, prevention of harmful noise and vibration, ionizing and non-ionizing radiation, use and disposal of wastes etc). The law regulates the issue of access to environmental information, public participation in decision-making, the procedure for assessment of environmental impact, plans for controls of industrial accidents and supervision mechanisms of the environmental inspectors.

Especially accented in the law are IPPC permits, which introduces a system of gradual adjustment to the required standards for integrated control and pollution prevention. Through the introduction of integrated permits for harmonization with operation plans that is a requirement for continuing operation of the existing installations in the country.

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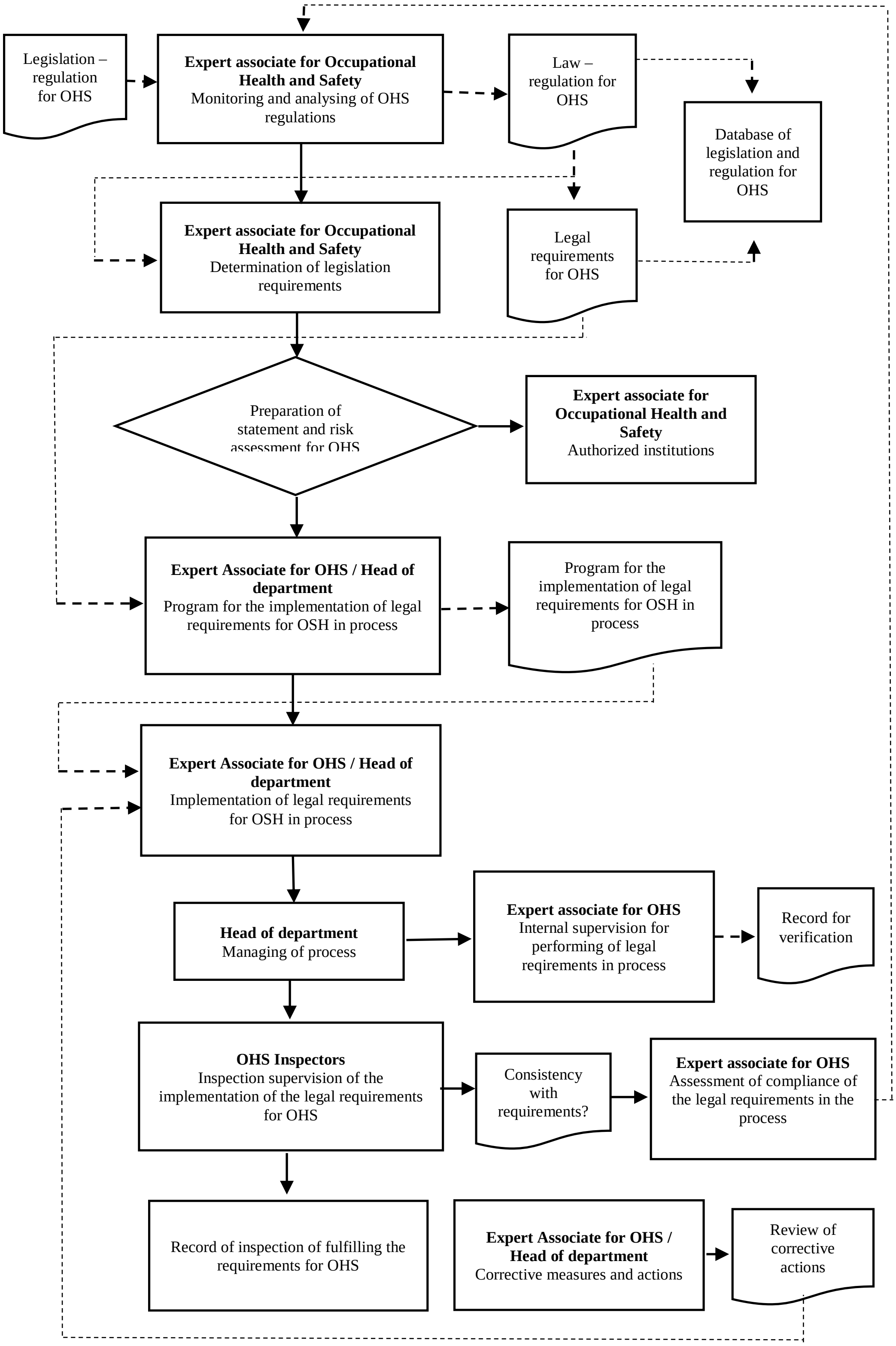

Figure 1 Model of managing with OHS legal requirements in production system

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IV. REQUIREMENTS OF OHSAS 18001

The organization shall establish, implement and maintain a procedure(s) for the ongoing hazard identification, risk assessment, and determination of necessary controls [4]. Besides for the identification and assesment of risks organizations should take into consideration following points:

- Routine and non-routine activities
- Activities of all persons having access to the workplace (including here sub contractors and visitors)
- Human habits, awareness, capabilities and other human factors
- Infrastructure, equipment, materials in the workplace regardless of whether they belong to the organization or owned by someone else
- Changes or proposed modifications in the organization and the scope of its activities or materials
- Any legal obligations relating to risk assessment and risk management
- Design of the workspace, processes, installations, machinery/equipment,operating procedures and organization, including their adaptation according capacity and capability of employees

Methodology of company for identification of hazards and risks should be defined in terms of the area of application in order to provide proactivity – not reactivity and also ensure the identification, prioritization and documentation of risk and implementation of appropriate actions.

V. REQUIREMENTS OF ISO 14001 STANDARD, POINT 4.3.1

The organization shall establish, implement and maintain a procedure(s) [5]:

- to identify and have access to the applicable legal requirements and other requirements to which the organization subscribes related to its environmental aspects, and
- to determine how these requirements apply to its environmental aspects.

The organization need to document and update this informations continuously. Significant environmental aspects should be taken into account in establishing, implementation and maintenance of EMS. In order to begin designing of the EMS it is needed to understand the interaction between the organization and its products and processes to the environment.

According to ISO 14001 Environmental aspect is an element of organizational activities, products or services that can interact with the environment.

As remark it is important to emphasize that a significant aspect of the environment is one that has or may have a harmful impact on the environment.

Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services – ISO 14001.

Overall environmental impacts can be divided into the following components, depending on the circumstances:

- Consumption of resources such as energy, materials, water, soil and so on
- Emissions of harmful substances into water and air
- Generation of waste and by-products
- Creation of noise and radiation
- Disruption of relief and cultural heritage

Harmful substances are substances that change the natural, physical, chemical, biological, bacteriological properties and composition, and radiological properties of the environment.

In order to determine the correlation of product and process environment it is necessary to do the following:

- To select the categories of products and services into the company
- To identify environmental aspects for each category of products, services and activities
- Evaluation (estimation) of the significance of the environmental impact of each identified aspect
- To define actions for eliminating, reducing and / or managing the risks and impacts of the environment

VI. FMEA – FAILURE MODE AND EFFECT ANALYSIS

Failure mode and effects analysis (FMEA) is commonly defined as “a systematic process for identifying potential design and process

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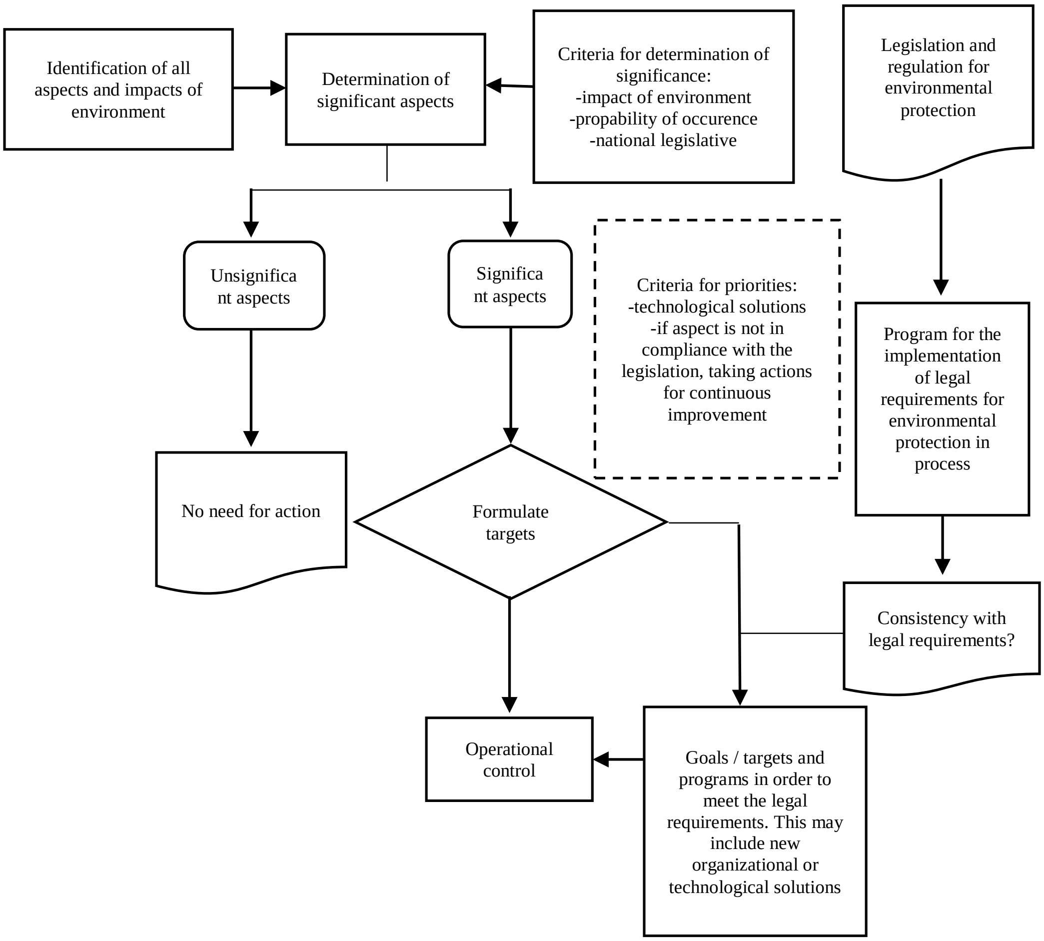

Figure 2. Model for identification and evaluation of environmental aspects

failures before they occur, with the intent to eliminate them or minimize the risk associated with them"[6]. FMEA is a method of reliability analysis intended to identify failures affecting the functioning of a system. It enables priorities for action to be set [7]. FMEA - method is a systematic procedure for analysis system in order to identify potential causes of failure and subsequent effects on system performance. The analysis is carried out at a relatively early stage of the system, so elimination or at least mitigating the potential failures is a very effective method, economically. The standard FMEA process evaluates failure modes for occurrence, severity, and detection [8]. FMEA method used Risk priority number RPN which is a mathematical product of the severity, the occurrence and the detection.

- Determination of the severity rate

Severity is a rating corresponding to the seriousness of an effect of a potential failure mode. Severity or seriousness of the risk is considered just in case of "the effect"; reducing the risk severity is possible only through changing the process and the manner of performing activities.

- Determination of the occurrence rate

Occurrence is ranked according to the failure probability, which represents the relative number of failures anticipated during the design life of the item.

Detection possibility is an assessment of the ability existing to identify a cause/mechanism of a risk occurrence. In other words, detection possibility is a rating corresponding to the likelihood that the detection methods or current controls will detect the potential failure mode. Assessing control process of standards, requirements and laws of labor and how to apply them to achieve this number are very useful.

These three criteria, receive grades from 1 (very small / negligible risk) - 10 (major / critical risk – shown into the tables below).

TABLE I. SEVERITY INDEX

Effect	Severity index
Dangerous without warning	10
Dangerous with warning	9
Very high	8
High	7
Moderate	6
Low	5
Very low	4
Slight	3
Very slight	2
None	1

TABLE II. OCCURENCE INDEX

Failure probability	Severity index
Dangerous without warning	10
Dangerous with warning	9
Very high	8
High	7
Moderate	6
Low	5
Very low	4
Slight	3
Very slight	2
None	1

TABLE III. INDEX DETECTION

Detection	Severity index
Uncertain	10
Very remote	9
Remote	8
Very low	7
Moderate	6
	5
High	4
	3
Almost certain	2
	1

Calculation of risk priority number - the risk priority number is calculated as a mathematical function that depends on: the likelihood of failure, the severity of failure and the probability of detection or monitoring of potential failure before it reached an undesirable effect. As a function that looks like this:

$$RPN = [S] \times [O] \times [D], \qquad (5)$$

The determination of the reasonable value of the Risk priority Number RPN is a specific difficulty and is associated with a subjective approach to the problem by the team for making FMEA. In any case there should be taken into account external conditions and the current state of the company. Working team determines acceptable values of RPN, so it is based on professional opinions of experts according to their previous education and experience in the field concerned.

If the value of RPN is higher than the critical value, it is necessary to propose further actions in order to reduce the potentional effects on the environment, and to minimize the risks and hazards to the health & safety of the employees. Than the RPN number is re-calculated and the revised RPN confirms the effectiveness of the corrective action undertaken.

The Risk priority number is a product of the three risk factors, and accordingly RPN factor to obtain the number of 1-1000. Based on that it is determined in which area of risk is necessary to take preventive and corrective actions.The following table shows the significance of the risk values in relataion with needed actions:

TABLE IV. GENERAL INDICATION OF THE LEVEL OF RISK

Risk Priority NumberRPN = [S]x[O]x[D]	
RPN < 50	Low risk
50 < RPN < 100	Medium risk
RPN > 100	High risk

Table 4: General indication of the level of risk

VII. FMEA ANALYSIS AS TOOL IN PROCESS OF IMPLEMENTING ENVIRONMENTAL AND OHS SYSTEM

Companies need to identify all the aspects, risks and hazards of their work related to the environment, occupational health and safety in order to assess and rank the environmental impact, evaluate the related risks and bring them to tolerable level on a continuous basis.

Practical application of FMEA analysis in function of risk assessment in the workplace, development, planning and manage with OHS

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Environmental FMEA											
	Aspects of Environment	Impacts on Environment	**S**	Potential Cause	Indicator	**O**	Prevention	Detection / Monitoring	**D**	**RPN**	Recommended Actions
USING OF NATURAL RECOURCES: ENERGY, WATER, etc.	Irrational use of energy;	Depletion of natural recourse	6	Production process; (machines,lighting, ventilation, air conditioning); Employees	kWh / per month	4	Plan for continuous reduction of energy consumptions; Investing in renewable sources of energy	Periodic - monthly review of the consumption of energy	5	**120**	Optimal use of all types of energy and reduce costs associated with power consumption.
										Risk:	S 4, O 4, D 5, RPN **80**
	Irrational use of water	Depletion of natural recourse	6	Production process; Characteristic of machinery and equipment; Employees	m^3/ per year	4	Plan for continuous reduction of drinking water consumption	Periodic - monthly review of the consumption of water	5	**120**	Closing the water cycle - cleaning of waste water and return to the process; Review the loss of water from the technological process Using groundwater for the requirements of the manufacturing process
										Risk:	S 4, O 4, D 5, RPN **80**
CONTAMINATED WATER	Discharge of contaminated water	Soil pollution; Pollution of local ground and underground waters	7	Production process; Technical characteristic of machinery and equipment	m^3/ per year	4	Monitoring of the quantity and quality of wastewater - authorized laboratories in accordance with legal regulations; Collection and treatment of wastewater and optimal use of water in accordance with the manufacturing process	Visual inspection of the nearest area for spills and leaks that could affect of soil, surface and groundwater quality; Periodic monitoring and laboratory examination of local soil and water	6	**168**	Installation / reconstruction of water treatment plant
										Risk:	S 7, O 2, D 6, RPN **84**

system is very realistic and achievable. In fact, FMEA analysis is tool for identifying potential hazards in the workplace, discovering the reason for their occurrence, risk assessment and propose actions for their elimination.

Importance of FMEA analysis in this area is actually a possibility for a systematic approach to identifying and analyzing risks and measures to be undertaken, i.e. implementation of preventive and corrective actions in order to eliminate and reduce potential hazards.

Environmetal fmea E-FMEA: The environmental application of FMEA takes into account the environmental impacts caused by technical problems, deficiencies or irregularity errors or processes. This analysis can be used to make constructional, process and system improvements [9].

Also, the purpose of E-FMEA is to identify and assess potential environmental impacts at all stages of the product life cycle by defined way (Life Cycle Assessment - LCA) - quantitative technique which takes into account the entire product life cycle from extraction of raw materials for its manufacture to recycling and disposal). E-FMEA enables a systematic review of potential environmental aspects associated with a product or process and eliminates them before occurrence of any irreversible consequences.

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FMEA Analysis for identification of occupational hazards and risks										
Risks and hazards	Potential failure	Potential effect	S	Potential cause	O	Prevention	Detection	D	RPN	Recommended actions
Mechanical hazards	Unprotected parts of work equipment / mechanical stroke	Injury / fractures	6	Machinery / Work equipment	4	Checking the equipment according to the legislation	Timely periodic testing of equipment / Visual detection - human factor	6	144	To train and educate workers for safe handling with the equipment, machines and tools; To provide protective devices and blocking devices; Continuous preventive and corrective maintenance of machinery and tools; To provide and use appropriate protective equipment.
								Risk:		S O D RPN 4 4 6 96
	Slippery floor	Injury / fractures	5	Slippery, unprotected areas	4	Preventive maintenance and cleaning of floors and slippery surfaces by appropriate detergent	Visual detection - human factor	6	120	Carefully selecting the floor, tidy and proper maintenance of floors and traffic routes, removing the cables, gaps, cracks and other obstacles on routes; If necessary, use appropriate methods of floor cleaning and chemical treatment of slippery surfaces.
								Risk:		S O D RPN 4 4 6 96
Physical and chemical hazards	Noise	Hearing disorders, headaches, nervous system disorder	4	High noise level – under legislative tolerance	4	Providing personal protective equipment (ear plugs)	Timely periodic measurements of noise in the working plants	6	96	To implement technical measures to reduce noise at source (isolation of machines);
								Risk:		S O D RPN 2 4 6 48

The objectives of the E-FMEA are:

- Preventive assessment of environmental impacts and elaboration of appropriate actions
- Identification of critical components and potentially sensitive areas
- Early detection and locating possible failures and their impacts on the environment
- Avoiding potential environmental disasters
- Improve systems, products and processes in terms of environmental protection

The main purpose of FMEA analysis as a tool of environmental protection is minimizing the excessive influence of production processes to the use of energy, water, raw materials, auxiliary materials and emissions and waste disposal. Comparative assessment of different impacts on the environment requires social consensus and that's why it is necessary to develop internal regulations (standards, specifications, principles).

These actions can be maintained regulations in tolerance, but every company should aim at continuous improvement and at least reduce the impact on the environment. Below is shown an example of FMEA analysis for OHS hazards and risks, and environmental aspects and impacts into production process. The FMEA example contains only several points, but illustrates declining of RPN number, accordingly with corrective actions.

FMEA document is a dynamic act and once the analysis is complete, it is reviewed, revised and updated in accordance with any change in the company and its environment, which may affect the environment and occupational health and safety (new or potential legal and other regulations, new technologies, new products, new facilities, new demands of stakeholders, new raw materials, deviations from standard operating processes, emergency etc.), thereby performing the identification, analysis and

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evaluation of new aspects and environmental impacts and new hazards and risks, determining measures to protect the environment, and removing and reducing ohs risks to minimum.

VIII. Conclusion

With some minor modifications of the standard FMEA format, this method provides increased value in the process of risk management in the field of occupational health and safety and environmental protection. FMEA method as a tool for identification of risks in the field of occupational health and safety and environmental protection broadens the concept of quantification of risk based on the likelihood and significance or effect of a particular event by adding attribute detection of risk. However, by adding value detection is enabled improved prioritization of risk. FMEA method is based on evaluation and assessment of risk and the value RPN enables identification of critical risks that require fast appropriate response.

The implementation of FMEA method gives a clear and transparent picture of the potential risk situations, as well as a clear indication of the justification of investments and education to protect the health and safety of employees and keep the environment clean, so preventive and corrective actions aimed to reduce the risk to an acceptable level.

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Mitigate Climate Change Through Minimazation of Building Sector Impact- A review

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Abstract—**This review paper deals with possibilities to mitigate climate change through energy consumption reductions but more importantly trough GHG emissions reduction in building sector, which is a huge contributor to global economy. This paper aims to incorporate all phases of possible energy and CO_2 emissions cutbacks.**

Keywords – sustainable development, low impact design, life cycle assesment

I. Introduction

Economic growth and progressive technology, especially in developing countries, are causing the increase of energy consumption at a pace that isn't environmentally sustainable. The climate change effects were first noted by the scientists in 1950s, when they discovered that the produced amount of CO_2 was more than the sea is able to absorb while the rest of it had to be compiled in the atmosphere [3]. The first World Climate Conference took place in 1979. The First UN Conference of the parties concerning climate change was held in Berlin in 1995, and the main topic was to negotiate reduction of greenhouse gases by developed countries [2].

Developing and countries withstanding economic transition are catching up to developed countries regarding the levels of CO_2 produced per capita.

In order to mitigate climate change and the effects of it that humanity is already facing, it is necessary to accelerate the pace of actions, including implementation of policies in place, as well as creating new ones that would support sustainable development.

Sustainable development is not a new concept, but it has many interpretations depending on the context in which the term is used. The most general explanation is given in the Report of the World Commission on Environment and Development [11]:

"Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs…

…sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs."

In order to achieve this an enormous effort has to be made, depending on the part of the world where the change needs to take place. One way is the *green design* or *low impact design.* Important category where reductions of CO_2 emissions (CO_2 e) is certainly building sector.

II. Energy consumption by building industry

According to predictions made by U.S. Energy Information Administration, residential energy use will be growing 1.4 % per year from 2012 to 2040 in the countries that are part of The Organization for Economic Co-operation and Development (OECD countries) and 2.1% in non-OECD countries. That is referring to overall energy consumption (except for transport) including cooling, heating, lighting, water heating and consumer product. Consequently, the emission of greenhouse gases (GHG) will increase. Estimations are that the emission of GHG will rise from 32.3 billion metric tons in 2012 to 35.6 billion metric tons in 2020, and to 43.2 billion metric tons in 2040 [6].

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Construction industry has an enormous environmental, social and economic impact. The building sector is the biggest contributor to the depletion of resources. It uses approximately 30-40 % of the worldwide energy consumption, and when the energy needed for construction and demolition of buildings is taken into account, the estimated number is 50 % of total energy usage [12]. In 2010 the amount of energy consumed by building sector was around 23.7 PetaWatt hour (PWh), and International Energy Agency (IEA) estimates that in 2040. the number would rise up to 38.4 PW h, due to increasing demand from non-OECD countries (IEA, 2013) [1]

III. ENERGY SAVINGS BY METICULOUS PLANING

A. *Background*

Architecture of the last century wasn't oriented towards energy preserving. It was rather characterized by fast and often low-cost construction, without proper consideration of energy efficiency. However, passive solar architecture is an example of good practice. Namely, there were studies done concerning the usage of active solar energy on MIT institute. One of the first case study houses was built in 1939, and afterwards there were a few solar houses made by the institute as a part of solar decathlon [4]. Some architects, including Frank Lloyd Wright were working on integrating passive solar principles into their design. After the Second World War, the most characteristic occurrence in less developed countries is migration from villages to newly industrialized cities. That migration entails fast construction of industrial buildings, but also residential and public buildings. Less attention was paid to energy efficiency whereas fossil fuels were rapidly used all around the globe. After the global energy crisis in the seventies, interest for renewable energy resources and their possible incorporation in the construction process and the buildings themselves has significantly increased [5].

B. *Passive solar systems*

Passive solar systems became very compelling in a short period of time and soon a lot of architects started implementing them in southwest America where the climate conditions were ideal. In early 80s those new trends are popularized in Europe, with the resurgence of Roman and Greek solar principles [5]. Basic principles of passive solar systems are based on the usage of energy gained from the sun for heating and cooling. In that manner various methods are used combined or separately, depending on the climate and the position of the building itself. Elements of passive solar design include managing of climatic and site conditions in order to provide heating in the winter and cooling during warmer months: *Window orientation, Thermal mass, Solar chimney, Sunspaces, etc.*

It is of utmost importance to use these elements properly if the goal is to achieve good results. The building should be elongated on the east-west axis, so that the south facade of the building can receive and absorb sunlight from 9 am to 3 pm during the heating season. Open floor plan optimizes the gain from passive systems. Spaces that don't need much light should be on the north side of the building. During the cooling season south-facing windows should have shading to prevent overheating. Passive solar heating could provide direct, indirect and isolated gain.

Direct gain approach means that the whole space is absorbing sun's radiation during the day. Thermal mass (floors, walls or other elements) should be made of masonry and shouldn't be covered during the day. Thermal mass would then radiate heat during the night into the living space.

In *the indirect gain* system thermal mass is located between the sun and the living space, and it is transferring the heat gained from sun by conduction. The indirect gain system will utilize 30 – 45% of the sun's energy striking the glass adjoining the thermal mass. There are two types of indirect thermal mass: thermal storage wall systems (Trombe wall) and roof pond systems. Thermal storage wall should be dark colored on the side that is oriented towards the sun and the vents should be closed during the night to avoid heat loss. Thickness of the brick wall should be 25-36 cm and for concrete wall 30-45cm. Roof pond systems should be from 15 to 30 cm thick. Water is usually stored in large plastic or fiberglass containers covered by glazing and the space below is warmed by radiant heat from the warm water above. The structure should be strong enough to withhold 320 kg/m^2 of dead weight and it should also have somewhat developed drainage systems and movable insulation to cover and uncover the water when needed.

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An *isolated gain* system has its integral parts separated from the living space. Most common are sunrooms or solar greenhouses. They employ a combination of direct gain and indirect gain system features. Sunlight entering the sunroom is retained in the thermal mass and air of the room. Sunlight is brought into the house by means of conduction through a shared mass wall in the rear of the sunroom, or by vents that permit the air between the sunroom and living space to be exchanged by convection. Convective air collectors are located lower than the storage area so that the heated air generated in the collector naturally rises into the storage area and is replaced by air returning from the lower cooler section of the storage area. Heat can be released from the storage area either by opening vents that access the storage by mechanical means (fans), or by conduction if the storage is built into the house.

Passive solar cooling is relying on natural ventilation without mechanical assistance, trough wing walls, solar chimneys and etc.

Wing walls are vertical solid panels placed alongside of windows perpendicular to the wall on the windward side of the house. They would accelerate the natural wind speed due to pressure difference created by the wall.

Solar chimneys employ convective currents to draw air out of a building. By creating a warm or hot zone with an exterior exhaust outlet, air can be drawn into the house ventilating the structure. This principle could be used to ventilate sunrooms or be incorporated into thermal mass walls, when it is necessary for wall to be insulated from the inside. Solar chimney can be constructed as a narrow configuration with an easily heated black metal absorber, which can reach high temperatures and be insulated from the house, on the inside, behind a glazed front. Performed numerical calculations show that for different values of ambient temperature (24- 36 ºC) and solar radiation (100-1000 W/m^2), a 4x4x4m room with a solar collector area of 2.55 m^2, has potential of generating 100-350 m^3/h ventilation rates [8]. The stairwell can also be transformed or made into a solar chimney, which is an esthetic and economic approach.

Green roofs and green walls are also very important for thermoregulation. The usage of green roofs can reduce the amount of possible flooding because of their absorbing properties. There is a great variety of widespread plants that could be used for this purpose. The concept of urban gardens appears as a logical step towards sustainable development.

C. Active solar systems

There are two types of *active solar systems*, based on the process of sun's radiation conversion, to be considered.

First type is related to direct transformation of the solar energy to electrical energy using photovoltaic panels (PV panels). Second type represents heat directly generated from solar collectors.

Solar cells produce small amounts of electrical energy. In order to generate more energy, solar cells are concentrated in solar modules, which then combined make a PV panel. PV panel's technology is progressing rapidly. Materials and technologies differ from opaque to transparent, crystalline (mono, poly or amorphous), thin film to organic PV panels [5], and have their advantages and disadvantages. According to their properties some of them are integrated into the buildings themselves, while others could be building attached PV systems.

Thermal collectors are rudimentary elements of active solar systems. System is consisted of an absorbent, collector cover, heat transferring fluid and insulation element. A*bsorbent* should be made of anticorrosive material. *Collector cover* is a transparent element usually made of PVC or glass because of their endurance properties and should have unreflective coating to minimize the heat loss. Because of the properties they have, *heat transferring fluids* are usually water, antifreeze or air and EPS foam is used for *thermal insulation* which directly affects the effectiveness of the collectors.

With careful analysis it can be decided which of afore mentioned elements are viable for which climate or if they could be merged in the design or redesign of a building.

That's where the concept of Life Cycle Assessment comes in place.

IV. LIFE CYCLE ASSESSMENT OF BUILDINGS

Life cycle assessment (LCA) first emerged from the packaging industry and it has steadily spread into many sectors, building included. LCA provide a holistic approach that is based on studying the whole industrial system behind a product, including production, usage and maintenance as well as the disassembling and recycling if that should be the case.

LCA tends to include a wide spectrum of environmental impacts throughout different stages of buildings lifecycle. Impacts can be classified by breaking them down into impacts of extraction, manufacture, onsite, operational impacts, demolition, recycling and impacts of disposal.

At present, there are various assessment applications on the market and they allow LCA studies to be carried out to various degrees of detail. Due to the large amount of data required to perform an LCA, it is recommended to use a software application that is the most adapted for the climate and materials used [7].

V. CONCLUSIONS

CO_2 emission studies show that buildings emit a great amount of CO_2 throughout their lifecycle. In different stages of lifecycle they contribute different amount, but the operating phase is maybe the most significant contributor because of the long lifespan of buildings [10]. Second contributor is the production stage, where in conventional buildings there is embodied energy in range from 2- 38% of total energy, while in low energy consumption buildings that percentage goes in range from 9-46%. Studies have shown that embodied energy isn't something that we should neglect while aiming to achieve sustainable development. Although the operating energy has more impact on the environment, because of a longer lifespan, both have to be considered. Demolition phase also has an impact on the environment that can be diverted by using recyclable, local materials and by reducing the raw materials percentage in the product as a whole. This stage can also sometimes be delayed by rebranding of sorts. There are various reasons to make such a decision: social, economic, political, but the only ones that matter are environmental. If the humanity would stop thinking as a consumer society it could mitigate climate change more efficiently and recreate a safe environment for future generations.

LCA methodology should be simplified into $LCCO_2$ [7] in order to avoid misleading energy efficiency certification, and the society should contribute to the environment by implementing following methods in designing or redesigning current and future buildings

- The usage of recyclable materials and reduction of raw material consumption as well as the use of local materials to reduce transport energy consumption
- Incorporation of passive and active solar design strategies where applicable. Appropriate redesign of residential and office buildings, mainly recognizing different amounts of energy used during the day and plan accordingly.
- Buildings that have lost their purpose or esthetic appeal should be redesigned, revitalized or rehabilitated in a way that lessens maintenance of the building, while at the same time avoids or significantly delays demolition. That way the CO_2 credits used in the product phase are not used in vain and there are considerable savings from demolition waste management.

The climate change is happening at this very moment. Mitigation of current climate change effects is slow and each year new disasters are affecting multiple regions of the world. It would be extremely beneficial if while repairing the damages, the society would start reimbursing what it took.

Renovation of existing building stock would be good way to start with reducing CO_2e now. Developing countries can embrace the existing knowledge on low impact and sustainable housing and direct development projects that way. That could also be said for countries withstanding transition that have a huge building stock with existing infrastructure and should start with reductions of GHG emissions.

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Industry and CO_2 emissions

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Abstract—**Numerous studies worldwide have shown that the concentration of carbon dioxide (CO_2) has significantly increased. A major cause of the increase of carbon dioxide in the atmosphere is an industry. Excessive air pollution can lead to the greenhouse effect, mostly as a result of increased emission of carbon dioxide. Today, one of the most important question is how to decrease the CO_2 emissions from industry sectors without major economic losses.**

Keywords- carbon dioxide, industry, global warming, emission.

I. INTRODUCTION

Gases that keep the heat in the atmosphere are known as greenhouse effect gases (GHG). The best known gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases. The carbon dioxide has the highest concentration in the atmosphere among these gases.

CO_2 is naturally present in the atmosphere as part of the natural carbon cycle between the atmosphere, ocean, soil, plants and animals. In this process of constant exchange, emissions and removal of CO_2 tend to balance. People with their activities affect this process in two ways: by increasing the amount of CO_2 in the atmosphere, and by making effort on reducing this gas in the atmosphere.

Human-related emissions of CO_2 and other GHG, along with the effort on reducing these gasses lead to a total increase of CO_2 in the atmosphere, which is particularly acute in the aftermath of the industrial revolution. The concentration of CO_2 in the atmosphere has been increased from 277 parts per million (ppm) in 1750. to 395.31 ppm in 2013 [1].

The most important emitters of CO_2 are users of fossil fuels (oil, coal and natural gas) for energy and transportation (Fig. 1). Many industrial processes use electricity, indirectly causing the emissions from the electricity production.

Besides that, there is a variety of industrial processes that emit CO_2 through fossil fuel combustion and chemical reactions. Total GHG emissions, especially CO_2 emissions, result in a distortion of the fractions in the composition of air and the atmosphere, which leads towards greenhouse effect [1].

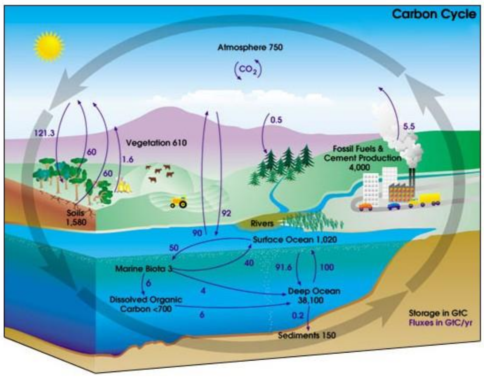

Figure 1. Carbon cycle diagram [2]

This paper describes the largest CO_2 emission industries and proposes the way of reducing these emissions, presenting the carbon capture and storage technology (CSS) as one possibility of these reduction.

II. INDUSTRIAL EMISSION OF CO_2

The industry uses nearly a third of total energy, and produces almost 40% of worldwide CO_2 emissions [3]. In the last decades there has been rapid development of industry, followed by increasing the CO_2 concentrations.

CO_2 emissions are often related to energy use. In the industry sector, the amount of CO_2 emission is not directly related to the amount of energy demand. In other words, if a particular

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industrial sector consumes more energy in its production process, it doesn't necessarily mean the higher CO_2 emission. For example – petrochemical products have large amounts of fossil carbon product stored inside them, some sectors have large emissions of CO_2which are not related to energy use and fossil fuel combustion. The amount of the emission depends on the type of the fuel used in the various industrial process [4].

The largest emitters of CO_2 among industries are: iron and steel, cement, chemicals and petrochemicals, pulp and paper and aluminum industries. These sectors comprise 75% of total CO_2 emissions from industry [3].

Fig. 2. indicates that the highest direct CO_2 emissions are produced in iron and steel industry (30%), followed by non-metallic minerals (mainly cement production) and chemicals industries. These three sectors are the largest producers of CO_2. Besides them, aluminum and pulp and paper industry are the next industrial sectors contributing the CO_2 emission. All other sectors participate with less than a quarter of total industrial CO_2 emission.

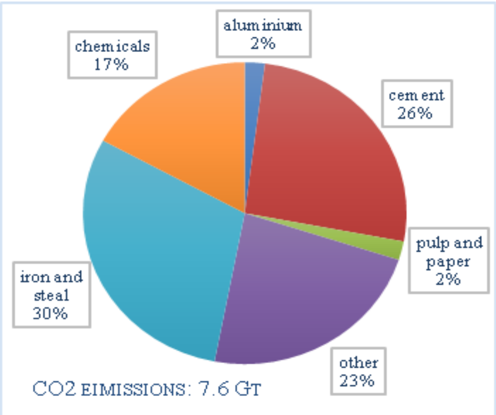

Figure 2. Industrial direct CO_2 emissions by sector in 2007 [6]

A. *Iron and Steel Industry*

The iron and steel industry is one of the largest industrial producers of CO_2 emissions accounting between 4% and 7% of all humans CO_2 emissions [5]. Fuel used to heat the coke ovens and the production process itself are direct sources of CO_2 emissions from steel industry. There are great differences in the amounts of CO_2 emitted in different countries. These differences are result of different energy production efficiency, fuel mix, production process used etc. For each produced steel there is CO_2 emission of 1.8 t on average [6]. Total amount of direct CO_2 emissions from iron and steel industry in 2007 was 2.3 Gt of CO_2 [6].

China is the largest crude steel producer in 2014 with 822.7 millions of tons which represents 49.4% of total world production for this year [7].

Industrial facilities could reduce indirect CO_2 emissions if they would use the energy generated from hydropower, nuclear power or using fossil fuels. Some of the measures to reduce direct CO_2 emissions are:

- switching to a fuel with a lower CO_2 emissions (natural gas and biomass);
- reduction of energy consumption using Best available technologies (BATs) and techniques;
- capturing the CO_2 and storing it underground or
- recycling the scrap steel [6].

B. *Cement Industry*

The cement industry is the largest energy user among the non-metallic mineral sector and also an important source of CO_2 emission. In the cement industry the biggest direct production of CO_2 emissions is achieved during the production of clinker. During production, the highest CO_2 emissions are realized through two processes: chemical decomposition of limestone and combustion of fossil fuels. Indirect CO_2 emissions are produced by burning fossil fuels (coal, natural gas or oil) to heat the furnaces. Also, the use of electricity power supply for the industrial installations, and the transportation of cement, represents indirect source of CO_2 emissions [8]. Total amount of direct CO_2 emissions from cement production in 2006 was 1.9 Gt of CO_2 [9].

China was the largest cement producer in 2015 with 2.350 millions of tons which represented more than half of the total world production for that year [9,10].

One of the most important issue is how to reduce the level of CO_2 emissions from cement industry. Indirect emissions can be reduced by using alternative fuels like natural gas, biomass and waste (sewage sludge, municipal solid wastes) instead of fossil fuels. Direct emissions from chemical decomposition of limestone can be reduced using other material instead of limestone, for example blended cement. Studies have shown that mixed cement can reduce CO_2

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emissions significantly, but its use should be restricted because it contains some toxic substances [8].

C. Chemical and Petrochemical Industry

The chemical and petrochemical sector is the biggest industrial energy user and also the third CO_2 emitter. The chemical industry produces three types of products: base, consumer and specialty chemicals. In chemical industry production of ammonia represents an important source of CO_2 emissions. According to International Fertilizers Association (IFA) for each produced ton of ammonia there is 1.5 to 3.1 tons CO_2 emissions on average [9]. Total amount of CO_2 emissions from chemical industry in 2005 was 3.3 Gt of CO_2 [11].

Petrochemical industry produces products such as plastics, synthetics, detergents etc. The basic raw materials for this industry are fossil fuels and coal. However, level of CO_2 is low because the largest part of the carbon is trapped into final products [3].

One way to reduce the CO_2 emissions in chemical industry is by using biotechnology in the production of basic raw materials, such as ethylene, butanol or acrylic acid as well as in the production process. In addition, using biomass energy would reduce the consumption of energy obtained by fossil fuel combustion [12].

D. Pulp and Paper Industry

The pulp and paper sector is the fourth-largest industrial energy user. The amount of CO_2 emission is the result of using fossil fuel in production processes.

United States, China, Japan, Germany and Canada produced 58% of total paper production in 2006. At the same time United States, Canada, China, Finland, Sweden and Brazil produced around 70% of total pulp production [9]. Therefore, these countries are the largest emitters of CO_2 produced in the pulp and paper industrial sector in 2006.

Pulp and paper industry could reduce its CO_2 emissions if the industrial sector began to use modern technologies (like black liquor gasification, biorefineries etc.) in the large scale, along with improving drying technologies.

E. Aluminum Industry

Aluminum industry is a large consumer of electricity. Primary aluminum production consumes more than a half of the energy used for the processing of ferrous metals. Aluminum can be produced from bauxite or from the recycling of scarp. Important source of CO_2 emissions in aluminum industry is smelting process [9]. According to International Aluminium Institute (IAI) for each produced aluminum ton in 2008 there are 0.70 tons of CO_2 emissions [13].

The largest aluminum producer in 2014 was China with 23.300 thousands of tons which represents more than half of total world production for 2014 [14].

Carbon capture and storage proposes solution to reduce CO_2 emissions from aluminum smelting and also from aluminum refining. One way to remove CO_2 emissions from refinery flue gases is post-combustion capture [9].

III. Carbon Capture and Storage Technologies

Carbon capture and storage (CCS) technologies have the greatest potential for CO_2 emissions savings and they are critical in reducing CO_2 emissions from industry sectors. However, this CCS technologies are facing many problems and they’re not given the necessary attention:

- insufficient investment in the development of these technologies;
- serious projects on development of these technologies are advancing very slowly;
- around 50% of new industrial plants are using old and inefficient technology.

CCS technologies must have the greater role in reducing CO_2 emissions in the future – otherwise achieving that goal is going to be difficult [15].

IV. Conclusion

Table 1 provides a breakdown of industrial CO_2 emissions by different sectors and states for 2005. The top 5 largest industrial emitters of CO_2 were China, USA, Japan, India and Russia. These five countries were providing around 57% of the world industrial CO_2 emission. Among them China was providing the 1/3 of the world’s industrial CO_2 emissions by itself. If the total emission broke down by sectors, iron and steel industry (including

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TABLE I. INDUSTRIAL DIRECT ENEREGY AND PROCESS CO_2 EMISSIONS IN 2005. [5].

	China	USA	Japan	India	Russia	World
Chemical and petrochemical	183	209	70	39	75	1086
Iron and steal	835	91	178	120	124	1992
Non-metallic minerals	791	115	56	111	45	1770
Paper, pulp and print	40	66	13	6	1	189
Food and tobacco	57	60	9	25	4	243
Non-ferrous metals	42	15	2	3	0	110
Machinery	55	27	7	2	2	129
Textile and leather	46	10	0	5	0	96
Mining and quarrying	20	0	1	3	7	98
Construction	28	5	12	0	3	96
Transport equipment	19	14	0	0	2	49
Wood and wood products	9	11	0	0	1	27
Non-specified	38	37	42	34	3	775
Total	2163	660	390	348	267	6660

emissions from coke ovens and blast furnaces) would have the largest direct CO_2 emissions (1992 Mt), followed by non-metallic minerals (mostly cement) and chemical and petrochemical industry. These three sectors were responsible for nearly 73% of total world CO_2 direct industrial emission. CCS technologies are going to be critical in reducing CO_2 emissions. In accordance with that, more attention has to be paid to developing and implementing these technologies into industry sectors [5, 15].

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Using Social Networks to Promote Energy Efficiency

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Abstract—**This paper deals with the contribution of ICTs to energy efficiency, more precisely, with the use of goal-driven social networks that may accelerate reaching the aim of raising collective awareness on energy consumption, and enhance citizen participation in decision-making, thus creating a sustainable community/society. Industry, end-users and household consumers, should, at their own levels, engage in adoption and diffusion of new technologies in the energy sector. The focus of this paper is on citizens' involvement and what motivates them to use social networks in this evolving context, as well as on tools available to promote energy efficient actions and knowledge.**

Keywords - energy efficiency, social networks, citizens' motivation, tools

I. INTRODUCTION

Energy efficiency continues to be a key priority worldwide. Many governments have recognized the ICT potential in smart energy management and started funding energy efficient initiatives and projects that include building and adoption of new policy regulations, creating new markets, meeting the energy demand efficiently, developing strategies to improve customer engagement and participation, etc. At a broader level, successful integration of ICT in the energy sector will help protect the environment, save money and stimulate economic development [1,2].

The new focus is on direct engagement with communities, or on so-called social capital that could promote spreading these innovations in the energy sector. Nowadays social networks are recognized as one of the best options for receiving real and valid information/feedback from citizens [3,4].

The paper is structured as follows: the next section defines social capital and its importance; section three describes models of user motivation with regard to energy consumption; section four offers tools available to energy utilities and customers, whereas section five deals with current issues and challenges of using social networks in this respect.

II. SOCIAL CAPITAL

So far energy has been mostly studied through technological and economic disciplines, whereas nowadays social sciences are considered to bring a fresh point of view in this field. Their contribution is seen in the promotion of energy efficiency, and it mostly deals with the role of social capital on the household level [5].

There is no set or officially adopted definition of what the social capital is, but it is agreed that it focuses on social relations, shared norms, and values of individuals and groups in one society. Numerous definitions of social capital can be found in literature depending on its relation to the particular discipline, context, focus or effects [6,7].

The strength of social capital lies in its social ties and links. We greatly rely on our family and friends, on our colleagues, and in a way we form family networks, networks of friends or colleagues and others. These networks do not exist only in the real world, but in the virtual one, too. Various groups of people who may never have met physically share same interests online. These online communities influence the way their members think and act. They also present various sources of information, moreover, they facilitate access and diffusion of knowledge [8,9].

From the above-said it can be concluded that these networks and communities can be, among others, very useful for spreading the information on energy efficiency and consumption, and may result in adopting some energy efficient measures, too; particularly if they come from the source that we trust.

III. MODELS OF USER MOTIVATION

Social networks, although primarily oriented towards creating and sharing content between users, are increasingly becoming a platform for the realization of different applications that are based on mutual interaction and collaboration. In recent years, this idea has served as a basis for developing a special category of social networks called Collective Awareness Platforms (CAPS) with the aim to motivate users in the realization of collective actions, particularly in the area of improving energy efficiency. IT professionals and the scientific community are constantly searching for new ways of improving social inclusion on the basis of these platforms in order to deal with the problems of energy consumption.

These efforts are also supported by the increasing use of social networks, whose average share of total mobile data traffic is around 15% (second largest share). In the period from 2011 to 2014, total sales of 5 billion units of mobile devices have been recorded, through which users are accessing social networks [1]. Besides, the development of technology allows an increasing number of devices in the household to be connected to users' mobile devices and thus enable control and monitoring of their exploitation.

Research in the field of energy indicates that social norms influence the behavior and habits of individuals with regard to energy consumption [10,11]. An increasing number of applications is based on the principles of social networks in household energy management, this way introducing social media into the so-called Smart grid – fully automated system of energy control and optimization of all connected elements [12]. The changes in the way individuals consume energy as a result of the social influence is a significant step in the fight against climate change.

For the effective implementation of online social networks in the domain of energy efficiency it is essential to understand techniques of motivating individuals to so-called pro-environmental behavior. Petkov et al. [13] have dealt with the problem of motivation, which is the basis for the development of the CAP applications. Their research highlights two basic motivational techniques taken from psychology: feedback and comparison.

A. Feedback as motivation

Feedback represents a mechanism for constant collection of data relating to the level of resource consumption. This model of user motivation proved to be very effective since it can reduce power consumption in households up to 15% [14]. Monitoring of consumption in recent years has been facilitated by the implementation of advanced metering infrastructure (AMI) where consumers are connected to the network so it is possible to achieve automated readings of the consumption in real-time.

B. Comparison as motivation

On the other side, comparison technique, which is often referred to as comparative feedback, motivates users to change their behavior based on the comparison to previous measurements or with results of other users. For this reason, comparison techniques can be divided into two groups.

Temporal comparison represents a motivational technique which compares the levels of individual consumption at different points in time. In the literature, it is also referred to as self-comparison [15] and produces significant effects on the motivation of individuals, especially if the measurements show that there is progress.

Social comparison also represents a technique of comparisons but with other individuals or comparison targets. User motivation by this technique is achieved through social sharing and social validation which represents individuals' need to behave in accordance with the opinions and attitudes of relevant individuals.

There are three subgroups of social comparison, depending on the cardinality and anonymity of comparison: normative comparison, one-to-one comparison and comparison by ranking.

Normative comparison is a comparison of an individual or a group with the average performance of similar entities. The results of previous studies imply that this comparison technique shows significant results in reduction of energy consumption [16].

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One-to-one comparison is the comparison between two individuals. This motivation technique shows positive results if the compared entities are closely related, such as close friends, colleagues and the like. Otherwise, when comparing unknown persons, energy savings have not been recorded.

Comparison by ranking feedback is the comparison of the performance of individuals or groups in the long run. Unlike previous techniques, this comparison can be made among the participants who do not have to be closely related. Although this is an often applied methodology, there is no significant research on the effects on the reduction of energy consumption.

The analysis of behavior in social networks specialized in energy conservation imply that two categories of users can be distinguished. The first category has a primary interest in the preservation of energy for financial reasons, while the other is showing interest in protection of the environment (pro-environmental motivation).

Depending on the above mentioned groups, the obtained results can be visualized in different ways. In addition to the classic visualization of savings in finance, corresponding to the first category of users, second user group supports the so-called eco visualization which is reflected in savings in, for example, numbers of trees or other units of energy consumption [17].

IV. TOOLS

In this part, contemporary social networks that apply the CAP model for preserving energy will be presented. In addition to a brief overview of their features, differences and peculiarities of each of these networks will be particularly highlighted.

A special category of applications in the field of application of social networks in achieving energy efficiency are the platforms that rely on smart grid. These include:

Opower [18] represents an industry leader in connecting online social networks with smart grid concept. The application has a desktop and mobile version and helps customers to save energy through collaboration. User motivation is achieved through comparative feedback between groups of households that have similar consumption but also by comparing individual consumption. Results of the application of social networks show an increase in energy efficiency by 12-18% per year.

In addition to OPOWER in this segment other applications can be singled out, such as Silverspring Network [19], Tendril [20] eMeter. This is a rapidly growing business so the development of such platforms increasingly includes global companies such as Siemens, Oracle and others.

On the other hand, there are applications that are more oriented to stimulating normative social influence and comparative feedback to influence the consciousness of citizens. These include the following social networks:

Citegreen [21] is a web application that inspires people to carry out activities to protect the environment by giving them the right incentives for each viable activity they carry out. Different actions are supported such as recycling, transport and energy saving.

StepGreen [22] is a similar application, developed with the aim to motivate people to reduce energy consumption. Actions of users can be shared via an applet on private profiles of popular online social networks such as MySpace and Facebook. This way, their friends on social networks can monitor their behavior and propose actions in the aim of energy conservation.

EnergyWiz [23] is a mobile application that allows users to compare their consumption with their neighbors, contacts from other SM sites but also other users of this application.

Wattsup [24] is an innovative online application that displays data gathered from Watson energy monitor in real time and allows users to compare their consumption with Facebook friends.

Welectricity [25] is another in a series of simple social applications that helps users track but also reduce energy consumption. Comparison feedback is implemented through comparison with households of similar characteristics. Consumption data of the users are not collected in real time through reading by smart meter or other devices but by simply entering the amounts of electricity bills.

Social electricity [26] Social is a large scale ICT application that targets energy awareness of citizens on the basis of social and local comparison of electricity consumption. In order to protect the privacy of the users, the application collects information from municipal and national institutions. Thus, reliable and detailed statistics on consumption in the country are provided, respecting user privacy. The application provides additional functionalities, such as learning material about green practices, online social educational games relating to energy and others.

Smergy [27] is the European campaign for energy saving, which is focused on young people aged 18 to 29. The aim of the application is to exchange ideas on potential energy efficiency and to encourage young people to engage in such activities. Young people represent the early adopters in the acceptance of new technologies and are part of the population that is most represented in the use of smartphones, so it is clear why SMERGy was created specifically for this target group.

There is a special category of social networks that is aimed at promoting events regarding energy saving. These include CarbonRally.com [28] and Race.com Energy [29] which invite users of social networks to accept various kinds of challenges in order to promote energy conservation in the world.

It is interesting that global IT leaders such as Microsoft, Google and Apple are interested in energy efficiency and start many initiatives in this field. In 2009, Microsoft has launched Hohm initiative [30] to enable users to analyze energy consumption and to share recommendations on the subject of energy. Google has developed a special device to monitor energy in households called TED5000 [31]. Apple has entered the game with two patents: Intelligent power monitoring [32] and Intelligent Power enabled Communication [33].

Regardless of their specificities, it can be expected that these platforms and applications will further include social activities in order to achieve better effects in energy efficiency.

V. CONCLUSIONS AND FURTHER REMARKS

Comprehensive studies that would indicate which of these approaches in the implementation of social networks in the energy conservation process has the best performance have not been yet conducted. Research regarding specific tools indicates positive effects. In addition, it is necessary to study the usefulness, effectiveness, acceptance, privacy, and potential of this approach in order to shed light on the incentives and social dimension, which motivates people to engage in green social ICT application.

The positive aspects determined so far are reflected through the education of users in energy efficiency, stimulating the engagement in actions of energy conservation and reducing consumption of energy through positive competition.

The negative effects that diminish the effectiveness of the above mentioned actions are mainly related to the violation of user privacy since the actions and consumption profiles in the community are visible to other users. Therefore, many are reluctant to use social platforms of this type. Taking into account that this is an early stage of implementation of social networks in the control of energy consumption, analyzed data relate to a short period of time so the results cannot be considered reliable. Many users do not provide credible information on the platforms (Stepgreen) which reduces the reliability of comparisons. Besides, comparison feedback in many cases can be treated as ineffective because it is very difficult to find adequate samples for comparison.

In the future, expansion of such platforms is to be expected, which are supposed to be even more 'social' but also connected to popular social networks, such as Twitter and Facebook. Improving the mechanisms of privacy policy would greatly contribute to the success of these platforms, so that improvements in this part should be expected. Finally, smart grid, IoT and other devices that can monitor the energy consumption of individual devices and forward information through networks are expanding, so this would be another incentive for the development of the concept of social networks in the energy efficiency.

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