

# ENERGY EFFICIENCY, ENVIRONMENTAL PROTECTION AND SUSTAINABLE DEVELOPMENT IN KRAGUJEVAC (SERBIA)

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## Abstract

This paper presents a methodology development and the results achieved in the process of establishing energy management system in the City of Kragujevac (Serbia) and in its public services. The paper is an overview of influential factors in the field of energy management, analyzing their impact on raising the energy efficiency of individual utility service and the city of Kragujevac, as a whole. The paper also presents the most interesting scientific and research projects realized in the cooperation of several actors which were coordinated by Regional Euro Energy Efficiency Center Kragujevac. The municipal companies together with the city administration are the direct beneficiaries of the results realized in the following areas:

- Development of energy management in municipalities and the establishment of energy planning at the local level;
- Improvement of municipal services by applying energy efficiency measures in public enterprises:
  - “Energetika” (heating),
  - “Cistoca” (communal waste management),
  - “Vodovod i kanalizacija” (water and waste water management);

Promotion of ideas and projects realized in the field of energy management, environmental protection and sustainable development at the Festival of energy efficiency (starting from this year) held during the April.

**Keywords:** energy efficiency, sustainable development, public utility municipality

## 1. Introduction

Department of Energy and Process Engineering (DEPE) of Faculty of Mechanical Engineering in Kragujevac have been aware of the development trends and the load to which is exposed modern energy sector in the world and also in Serbia. In accordance with their scientific and technical findings DEPE adopted appropriate strategic plans of its operation and special emphasis was given to:

- Improving the quality of teaching and raising the popularity of studies of energy and process engineering;

- Educational, scientific and professional fostering of energy efficiency, renewable energy sources, environmental protection, modern methods of management of energy and environmental projects, and financial engineering in the field of energy and process technology, as the infrastructure of teaching and research areas in basic courses, master and doctoral studies;
- Inclusion of students in the implementation of local, regional, national and international projects;
- The creation of appropriate internationally applicable forms of organization for the inclusion of productive research potential of DEPE in the strategic development plans at the local, regional, national and international level and
- Taking appropriate recognizable unpretentious marketing-media niche in the territory of the Republic of Serbia and southeastern Europe.

This position and long term action of DEPE, which some authors now call “the new engineering school”, made a number of interesting results to:

- Popularization of studies of energy and process engineering (Figure 1),
- Increasing interest of students for team work and R&D projects and energy and process engineering and
- Inclusion of researchers and students in the implementation of all major projects that are realized on the territory of the City of Kragujevac, Sumadija and Pomoravlje and the Republic of Serbia.

As a special result of DEPE new work methodology and its market-oriented organizational units (REEECKG) we are considering the fact that the administration of the City of Kragujevac and its municipal companies understood the importance and the need to implement in the strategy of development of the city following principles: new policies and principles for improving the energy efficiency of the public and manufacturing sectors, principles wide spread use of renewable energy sources and principles of environmental protection and sustainable development. Signing of the memorandum and agreement/contract on the establishment of permanent/long term business cooperation with the SEEA and REEECKG, City of

Kragujevac has determined the directions of joint activities that will take place through:

- Application to the regional and European projects;
- Exchange of information, organizing seminars, expert meetings and discussions

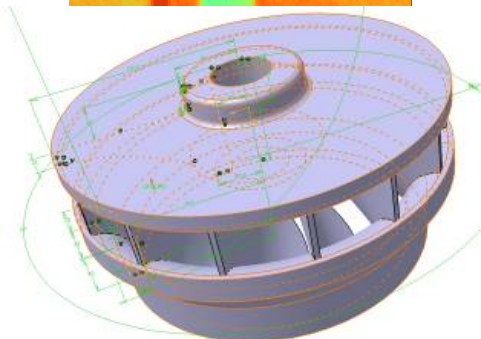
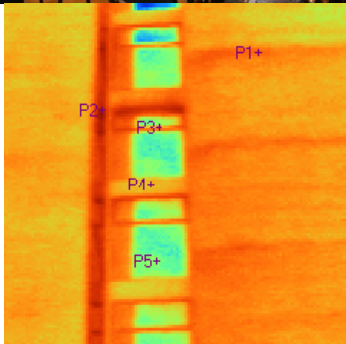


Figure 1 Public presentation of student paper about energy efficiency of wine production line (up) and illustration of student team projects (middle and down)

- Work on fulfilling the obligations of the city administration, which are defined by the applicable Energy Law of the Republic of Serbia (EL RS), which is particularly related to: the creation and implementation of energy policy (Art. 4 EL RS), planning (Art. 7 EL RS), energy auditing and maintaining the database (Art. 9 EL RS), issuing energy permits (Art. 27 and 29 EL RS) and setting the conditions for acquiring the status of privileged manufacturer of thermal energy, fulfillment of the criteria for obtaining these conditions and the process of acquiring the status and maintain the registry of the privileged producers of renewable energy sources (Art. 139, 140 and 141 EL RS).

Following sections will show the most interesting scientific research projects realized in the designed co-operation coordinated by REEECKG, in which participated the MoMe, the Ministry of Science and Technology Development, SEEA,

European Agency for Reconstruction (EAR), the World Bank (WB) and the European Commission, and relevant experts from the government of City of Kragujevac and the municipal companies. Municipal companies, together with the city administration, are the direct beneficiaries of scientific research results realized in the following areas:

- Energy management development in municipalities and the establishment of energy planning at the local level;
- Improvement of municipal companies work by applying energy efficiency measures and
- Promotion of ideas and projects realized in the field of energy management, environmental management and sustainable development at the Festival of energy efficiency (starting from this year) held during the April in the organization of the City of Kragujevac, REEECKG and SEEA.

For illustrations of the methodology and scope of research projects so far implemented, in this paper we will look a little more detailed the project "Improvement of energy efficiency and technical and technological characteristics of the district heating system of the City of Kragujevac".

## 2. A review of the projects implemented in the field of energy efficiency, renewable energy sources and environmental management

In this section, are described some of the projects that were implemented in cooperation of REEECKG, administration of City of Kragujevac, (and competent municipal companies) and SEEA for the period of 2006 until - 2008.

### 2.1 Project 1 "Design and construction of small hydro power (SHP) plant in the water supply system Gruza" (Users: SEEA, "Cistoca" (water and waste water management company) Kragujevac)

The project subject: Building of a SHP plant capacity of 40 kW. Total annual production of SHP plant will be 236,000 kWh, which represents about 3.7% of annual energy consumption in the system for water supply Kragujevac. Majority of electricity produced in the SHP plant will be used for the needs of municipal company for water and waste water management. A smaller portion of electricity produced will be delivered to electricity distribution network.

### 2.2 Project 2 "Improving energy efficiency and technical and technological characteristics of the district heating system of the city of Kragujevac" (Users: "Energetika", Kragujevac, Ministry of Science)

The project subject is:

- Improving energy and economy efficiency of "Energetika", company which supplies the City of Kragujevac with the heating energy. Improving the efficiency of "Energetika" includes a complete analysis of the current situation in the production, distribution and exploitation of heating energy;
- Carrying out appropriate measurements and numerical simulation of behavior of district heating system, in order to detect and eliminate problems in equal distribution of heating energy to the end consumers, because it is observed that some consumers are overheated, and others work in the limits of tolerance and
- Measuring and making analysis of numerical simulation and proposing measures to increase energy and economic efficiency of district heating system, in order to prepare it for market performance that promotes the current Energy Law.

**2.3 Project 3 “Promotion and implementation of recycling technology as a concept of increasing the environmental awareness among the youth” (Users: EAR, the City of Kragujevac, Municipalities of Sumadija and Pomoravlje)**

The project subject is:

- Encouragement of entrepreneurship among youth through promotion of recycling as business,
- Increasing the environmental protection awareness, especially the significance of recyclable materials and sustainable waste management,
- Making conditions for two new production processes in recycling,
- Education and training of 50 high school students in area of recycling technology,
- Establishment of Young Entrepreneurs Support Center within Regional Euro Energy Efficiency Center,
- Designing and producing two machines for secondary raw materials processing,
- Purchasing printing equipment for processing of recycling paper
- Creation of detailed business planes on conducted actions.

**2.4 Project 4 “Initiating Small and Organized Business in Area of Fruit and Vegetable Processing Through Capacity Building and Networking of Small-Scale Farmers Groups” (Users: EAR, the City of Kragujevac, Municipalities of Sumadija and Pomoravlje)**

The project subject is:

- Designing, production, promotion and implementation of new dryers for farming;
- Creating conditions for new production processes and production of fruit dryers, which use the new technology of drying;
- The organization and training of 5 teams in the area of agribusiness in the Sumadija;
- 4 courses for farmers on new technologies of fruit drying;
- 10 new dryers for farming

**2.5 Project 5 “Calculation and design of SHP plant Bosnia 1” (User: “Kragujelektrane”, Kragujevac)**

The project subject is design, construction and commissioning of two SHP plants power of 2 x 100 kW (Figure 2).

**2.6 Project 6 “Improving energy efficiency of the car paint shop” (User: “Zastava automobile” company, Ministry of Science)**

The project subject is creating the detailed energy audit and defining organizational, technical and technological measures to improve the energy efficiency of plant for painting car shells by 15%.

**2.7 Project 7 “Development of energy and environmental information system of City Kragujevac” (Users: Assembly of the City of Kragujevac, Ministry of Science of the Republic of Serbia)**

The project subject is to improve the energy efficiency of municipal energy system of City of Kragujevac through exploitation of energy resources from waste through:

- Development and implementation of energy and environmental information system (launching internet site),
- Designing pilot project for adequate energy exploitation of waste,

- Preparation of feasibility study about economical justification for realization of plant for waste exploitation for energy production,
- Promotional activities.

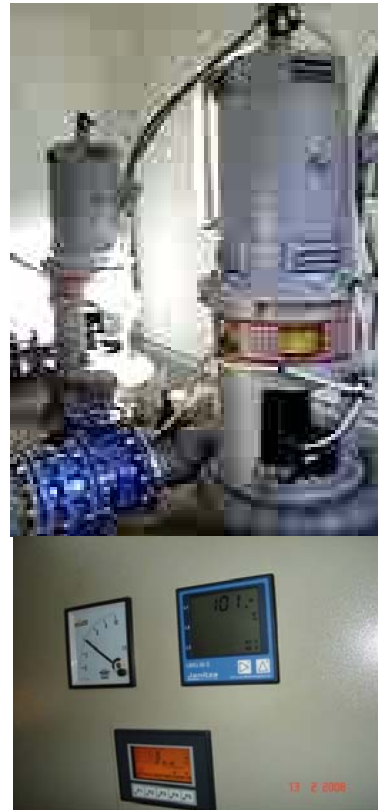


Figure 2 SHP plant “Bosnia 1”

**2.8 Project 8 “The program of implementation of Energy Sector Development Strategy for the area of new and renewable energy sources” (Users: Ministry of Energy and Mining of the Republic of Serbia, City of Kragujevac and municipalities in Serbia)**

The project subject is realization of the program of implementation of Energy Sector Development Strategy for the area of new and renewable energy sources, preparing the Government Regulation of the Republic of Serbia, and five scientific monographs on the application of renewable energy sources.

**2.9 Project 9 “The research of thermal conductivity of public buildings envelope in the Republic of Serbia” (Users: SEEA, Ministry of Energy and Mining, WB, City of Kragujevac)**

The project subject is to determine the amount of heat losses using the IR camera, in order to increase energy efficiency.

**2.10 Project 10 “Energy Auditors for Serbia Energy Efficiency” (Users: SEEA, Ministry of Energy and Mining, WB, City of Kragujevac)**

The project subject is the improvement of energy efficiency of buildings in order to increase the heat comfort. An important goal of this project is the reduction of local environmental pollution. The aim was to encourage the replacement of the old and inadequately designed boilers with modern and energy and environmentally efficient boilers and raise energy efficiency of selected public buildings (schools, hospitals, etc.). Conducted activities in this project included the replacement of doors and



windows, thermal insulation of external walls and roofs, installation of thermo regulated valves on radiators, pump installation, replacement of boilers and/or burners, insulation of pipes for heating and replacement incandescent bulbs with fluorescent and fluorescent compact lamps. World Bank provided credit for implementation of these measures. For selected building were carried out preliminary energy audits and made the rank list for crediting by the World Bank.

**2.11 Project 11 “Development and implementation of educational courses for the management of energy and eco-projects at the Department for Energy and Process Engineering at Faculty of Mechanical Engineering in Kragujevac” (Users: Ministry of Science, Faculty of Mechanical Engineering in Kragujevac, the City of Kragujevac)**

The project subject is the implementation of six educational courses for energy and ecological management at the Department for Energy and Process Engineering at the Faculty of Mechanical Engineering in Kragujevac, with the intention to create conditions for the complete training of students and other interested parties in the field of energy efficiency.

Among the limitations of this project was a lack of appropriate literature so several monographs were prepared and published.

**2.12 Project 12 “Tempus IB JEP 41092 project Ecological Training Courses for Capacity Building of Local Communities in Serbia” (Users: EUK, City of Kragujevac, Municipalities of Sumadija and Pomoravlje)**

The project subject is environmental training courses in the field of solid waste management and energy efficiency in the municipalities of central Serbia.

**3. Results of the project “Improving energy efficiency and technical and technological characteristics of the district heating system of the city of Kragujevac”**

In this section project “Improving energy efficiency and technical and technological characteristics of the district heating system of the city of Kragujevac” will be a little more explained for the purpose of illustrating of the extent and quality of creation and the achievements of the development policy of the City of Kragujevac realized so far in the area of improving energy efficiency, environmental protection and sustainable development, which is implemented in cooperation with the REECKG.

**3.1 General characteristics of thermal-distribution system of the City of Kragujevac**

Development of thermal-distribution system of the City of Kragujevac (TDS-K) followed the urban, population and economic progress of the city, and today represents, together with its thermal sources, one of the most valuable municipal infrastructure systems in Serbia.

Since the dynamics of development of the City, historically speaking, was uneven, in the present structure of the TDS-K are noticeable technical and technological disproportions that limits further development, and not rarely, are the obstacles to high quality supply of all consumers. Therefore, the Board and management of “Energetika” (company responsible for the development and maintenance of TDS-K) relying on the strong support of the administration of the City of Kragujevac, along with REECKG and enterprise "Geopremer" from Kragujevac, started two years ago a comprehensive project aimed to provide:

- Precise electronic GIS maps of the entire TDS-K;
- Electronic database of all operating substructure, pipelines, valves and district heating (DS) substation;
- A reliable software for simulation of behavior of TDS-K in different regimes of exploitation and which could be used for the introduction of proactive current and investment maintenance, as well as for the creation of high-quality basis for further expansion and increase in the number of service customers of “Energetika”;
- Creation of internet portal for rapid internal and external communication with the dispatching center of the TDS-K;
- Definition of organizational, technical and technological measures to increase energy efficiency of TDS-K and reducing costs in the heating energy production and distribution.

Within the TDS-K (managed by company “Energetika”) all forms of energy (except electricity) for the needs of industrial plants of former company “Zastava” and for the supply of households and public institutions in Kragujevac have been produced. The company is a limited liability company but plans are to be transformed in the public service company which will be primarily responsible for the supply of the City with heating energy and also to work as CHP plant.

Currently, the TDS-K plants produce no electricity, but provide necessary steam and hot water for factories and for the most of the needs of the city district heating. It should be mentioned that “Energetika” have two steam-turbine units that are out of work for more than 10 years, mainly due to insufficient maintenance and low cost of electricity. TDS-K plants are used to distribute 1/3 of the produced heating energy to district heating system, and 2/3 industry. Now, when the “Zastava” is working with reduced capacity, 2/3 of heating energy produced is supplied to district heating system, and 1/3 to industrial customers.

TDS-K has 14,500 customers and delivered heating energy to residential customers is charge by volume of the heating space. There are 2,000 DH substations from which 1,000 DH substations are located in large buildings, hospitals and schools and the others are in private homes or small residential buildings. Average designed power of DH substations in private houses is 23.35 kW. Maximum designed power of DH substations in this category is 45 kW, while the minimum is 10.1 kW. Average power of installed heat exchanger is 35.62 kW (in the range from 15 kW to 250 kW).

In buildings with multiple apartments (buildings, public buildings) the average designed power of DH substations is 612.1 kW. Maximum designed power of DH substations in these facilities is 915 kW and minimum is 254.2 kW, while the average heat exchanger power is about 809 kW (heat exchanger power is in the range from 300 to 1300 kW).

Total installed power of all 19 existing boiler units is 356.9 MW, while the total installed power of consumers is 456.8 MW. The maximum recorded production of heating energy was 116 MW at -18°C outdoor temperatures. Total length of pipes that make distribution network of TDS-K is 126 km (including pipes of steam network). The losses of heating energy are estimated at 12% and losses of water are about 144,000 m<sup>3</sup>/year. The DH substations are mainly composed of heat exchanger and valves. Installed heat exchangers are mainly countreflow tube heat exchangers (61%) and 39% are plate heat exchangers. It should be noted that in all the new DH substation are installed plate exchanger and ratio mentioned above is constantly changing in their favor.

TDS-K is, on average, over 20 years old. Annually in the TDS-K averagely occur about 500 unplanned interventions because of

leakage. From that number, 19 interventions are damages that cause termination of energy supply to a significant number of users. The rate of breakdowns per kilometer of the distribution network is 8.4, which is a high frequency if it is a known fact that this percentage in the Eastern Europe is between 1 and 2 and in the modern district heating systems it is only 0.1.

Generally TDS-K is not very well balanced, so the users who are located near the boiler house and main pipelines are overheated, while users on the periphery of the system do not receive adequate amount of heating energy.

Problems with circulation to the periphery of the TDS-K are presently solved in various ways. Balancing of the distribution network is usually done closing valves, installing blends or in some cases, placing additional pumps in the supply distribution network. These problem solutions are mainly solving problems for one or group of customers but they often caused problems with other customers.

In the following text are described the research efforts of “Energetika” and REEECKG experts to determine:

- Accurate electronic maps of TDS-K, precise dimensions of pipelines;
- The actual thermal power of the facilities that are located in the TDS-K;
- Structure of heat production plant no. 2 (TC-2),
- The actual capacity of the existing pumps and belonging equipment;
- The actual heat capacity of the DH substation located with the final consumer of heating energy;
- Hydraulic and temperature regimes and diagrams;
- Whether the existing district heating network have the capacity to meet DH substation needs and temperature demand of the end users;
- Critical places in TDS-K (the places which don't not have quality heating) and
- Proposal of solutions for the problems.

### 3.2 Determination of TDS-K geometry

Work of recording of distribution network was entrusted to the company “Geopremier” from Kragujevac. The complete network recording was done using a GPS (Global Positioning System), with the precision of  $\pm 20$  mm in the horizontal plane and  $\pm 50$  mm in the vertical plane. Underground pipelines are located using the underground pipe detector.

In this way geometry of distribution network was recorded completely. Each line of TDS-K is determined by the nodes at which pipes are divided, or points in which pipeline change its direction. These nodes are defined by three coordinates and the objects (cesspit) are additionally defined with the symbol and other relevant information. The final result obtained from the recording is AutoCAD document with precisely defined pipelines of distribution network (Figure 3).

### 3.3 Development of TDS-K database

When recording was finished, the collection of additional field data started. Collection of data was related to: length and diameter of pipelines, the state of pipe insulation, valves, and other elements that are important for the hydraulic and thermodynamic simulation of the TDS-K. After collecting this additional data database was. Diameters of pipelines were in the cesspit, because that is the only place where the pipeline diameter can be measured without high costs.

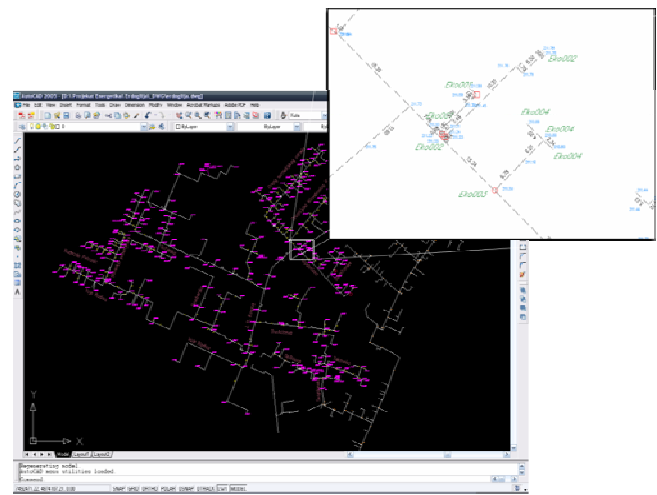


Figure 3 AutoCAD map of TDS-K

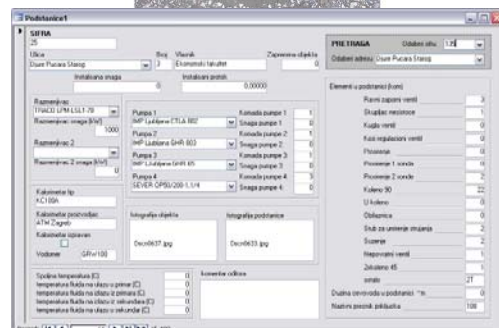
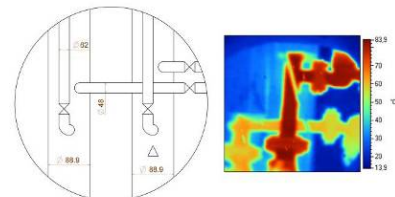
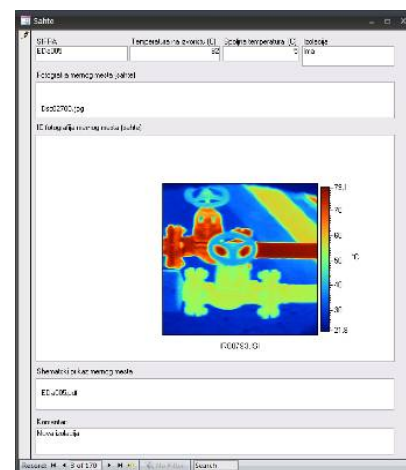


Figure 4 Cesspit and DH substation database card

The database is formed in the MS Access application and is divided into two parts. One part of the database contains information about distribution network and according to the measuring site is called “cesspit card” (figure 4). The second part of database is related to consumer and has the name “DH substations card” (figure 4). Each cesspit card has a cesspit code which is linked to the location on recorded map. The following fields in the card are reserved for the incoming fluid temperature, outgoing fluid temperature, a description of insulation and comment.

Together with the distribution network data collection was done the DH substation data collecting. The most important goal of this part of the project is to determine the actual capacity of DH substation.

Similarly as for cesspit card the collected data was recorded in the DH substations card. The DH substations card, also has a unique code that specifies the location of DH substations on the map.

In addition to addresses, object volume, owner’s name, this record contains all data relevant to the hydraulic and thermodynamic calculation and data that considered that would be used in future analysis. As in cesspit card this record contains photographs of objects where DH substations are located.

Data recorded includes: the type of heat exchanger, its capacity, type of water meter, the type of pumps, etc. Also listed are all components that affect the pressure drop in the DH substations (valves, elbow, extensions, etc).

### 3.4 Software for simulation of TDS-K behavior in various regimes

After the collection and systematization of collected data project turned to:

- Hydraulic calculations of TDS-K, defining the hydraulic regimes and creating a working diagrams for a complete distribution network;
- Analysis of existing situation and defining the critical places (places which don’t have required heating quality) and
- Defining a proposal for distribution network balancing.

Formed database updated with pressure drop data in the number of typical DH substation, represent input data for developed simulation software for the prediction, and/or tracking of behavior of TDS-K in possible regimes of work. Developed software gives us graphics and numerous, fast and reliable answers about impact of changes in the TDS-K, and can be used as a tool for planning optimal reconstruction and/or scenarios for development of the system. Databases data provide us other opportunities of which we point out possibilities for proactive maintenance of the TDS-K and various other tasks such as possibilities for faster preparation of tender documentation etc.

Here are a few more data about developed software:

- Developed in Fortran-EPANET,
- Requires a minimum number of input data,
- Simulate the flow and pressure changes in TDS-K in conjunction with one or more pumps, whose performances are given as input data,
- Provides the ability to simulate entering of additional pumps throughout the distribution network (which is quite common practice in a variety of balancing the system),
- Provides an opportunity to determine how new customers and reconstruction of the network affect the distribution of heating fluid in the TDS-K,
- Provides the opportunity to provide necessary distribution of heating fluid to individual consumers estimating the locations

at which should throttle the valves with the least hydraulic losses etc.

Software passed test period and compared with other software that can found on the market and is more advanced than those for which we know. Software allows us the simulation of the additional pumps on the network. To this problem and its improvement we paid special attention.

At the time of writing this paper, we conducted hydraulic and thermodynamic calculation of an independent part of TDS-K, called “Erdogljija“. Therefore, we present one of the results of the simulation (Figure 5).

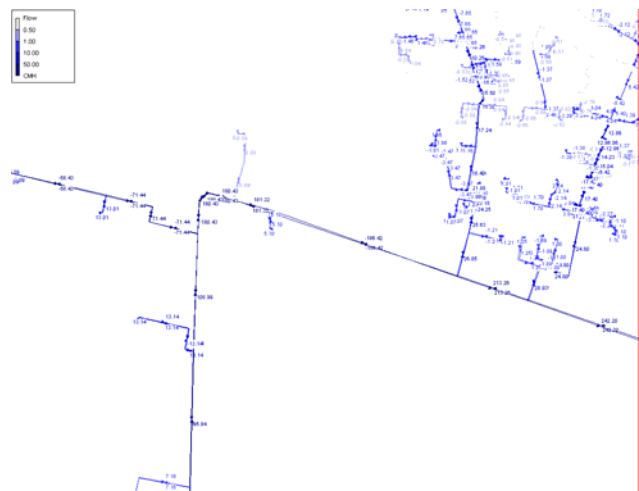


Figure 5 Results of hydraulic simulation on one part of TDS-K

It is planned to launch the web portal with results, for internal and external use.

### 4. Financial analysis of the project

In Table 1 is given proposal of investments for the implementation of expected measures. All proposed measures have a rate of return (IRR) over 20%, which means that they are highly cost-effective.

### 5. Conclusion

Together with our students we constantly change concept of studding. At this point we consider it as a time of intensive professional maturing in which students with our help try themselves as researchers, designers, PR and marketing experts, but the most valuable lesson is to practice working as a part of a team. As we include them in all our projects they have opportunity to learn and participate in real-life projects and that makes them more responsible to work and self assure.

### References

- [1] Babić M., Milovanović D., Jovičić N., et al.: New concepts and experience in education of engineers (Novi koncepti i iskustva u školovanju inženjera energetičara), Energija, 2009, No 1, Beograd
- [2] Babić M., Končalović D., Jelić D., et al.: Research of status and possibilities for improvement district heating system of the city of Kragujevac (Istraživanje stanja i mogućnosti za unapređenje toplotno-distributivnog sistema grada Kragujevca); KGH, 2008., Beograd

Table 1 Proposal of investments for expected measures

INVESTMENT TYPE	TOTAL INVESTMENT [€]	EQUIPMENT COST [€]	RAW MATERIAL AND LABOR COST [€]	IRR [%]
PIPELINE REPLACEMENT	1920000	900000	1020000	22%
RECONSTRUCTION OF „ZVEZDA“ DH SUBSTATION AND INSTALLATION OF NEW BOILER	1449000	1086750	362250	29%
BOILER CONTROL AND MEASURE EQUIPMENT	600000	160000	440000	36%
INSTALLATION OF VFD PUMPS	350000	262500	87500	83%
MONITORING OF DH NETWORK	320000	320000	-	-
CHP PLANT RECONSTRUCTION	3545000	2375150	1169000	30%
BURNERS REPLACEMENT IN „KBC“ BOILER ROOM	147541	98361	49180	37%
TOTAL	8331541	5202761	1218180	