UNITED NATIONS
Economic Commission for Europe

Energy Efficiency Investments and Introduction of Consumption Based Billing in District Heating

Prof. Dr Dragoslava Stojiljković

Prof. Dr Aleksandar Jovović

University of Belgrade
Faculty of Mechanical Engineering

dstojiljkovic@mas.bg.ac.rs

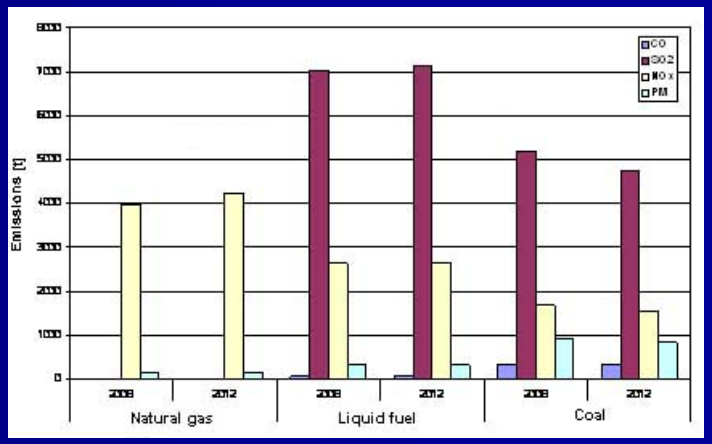
ajovovic@mas.bg.ac.rs

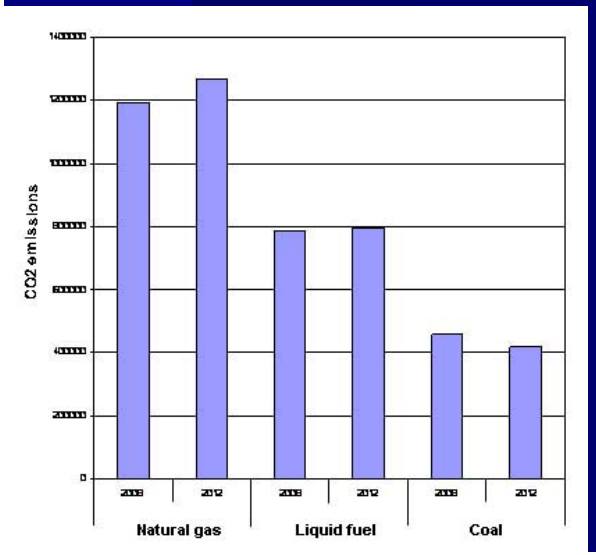
District heating system in Serbia

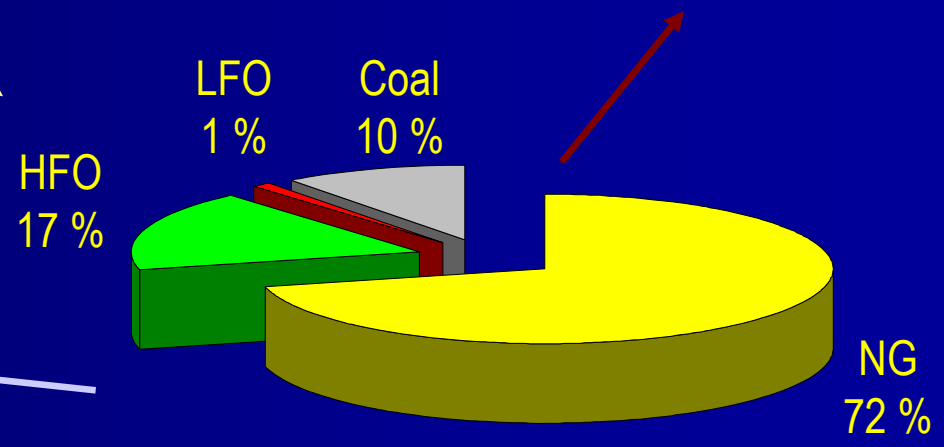
- District heating systems are present in 55 towns
- Overall capacity of heat generating boilers - 6,587 MW_{th}
- overall heat demand of the consumers connected to the district heating systems - 5,799 MW_{th} (82% residential and 18% office space heat consumers)

District heating system
- fuel consumption and emissions -

Fuel		Consumption
Natural gas	Mm^3	523
Fuel Oil (heavy)	t	128,000
Fuel Oil (extra light, light)	t	793
Coal	t	233,000

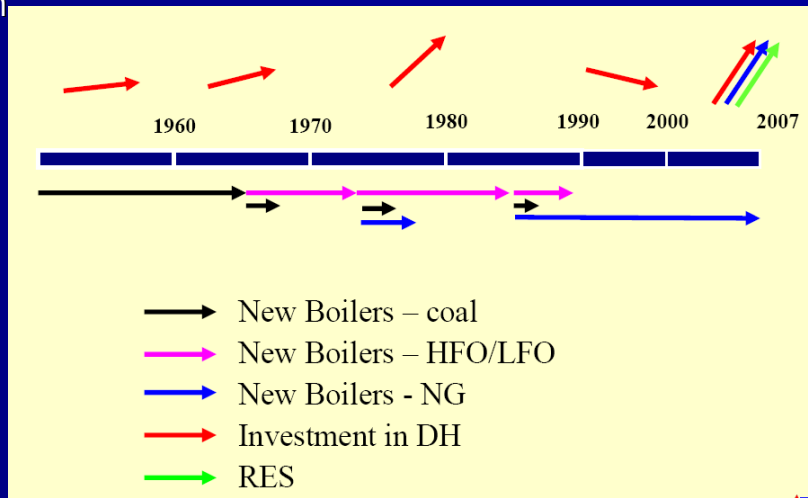






District heating system
- problems -

- Problems occurring in the boiler house
  - insufficient number of boiler units
  - old dated boilers, equipment and devices (boilers up to 30 years old)
  - low level of operation automation
  - low efficiency boilers and boiler facilities
  - frequent malfunctions and failures during heating season
- Problems occurring in heat distribution network
  - old dated and deteriorated distribution network
  - large water and heat losses
  - poor quality and damaged thermal insulation
  - hydraulically unbalanced network
  - frequent malfunctions and failures during heating season
  - lack of capacities
- Problems occurring in heat substations
  - old dated equipment in poor condition
  - absence of heat meters and flow regulators
  - low level of operation automation
  - low efficiency and considerable heat losses



Case study
- Subotica DH System -

- Municipality – 1,008 km^2
- Population – 148,000
- Production capacity – 141 MW
- Fuel – NG/HFO
- Total number of heat connections – 1140
- Annual heat production – 110,965 MWh

  - Boilers: 2 hot water + 3 steam
  - Hot water distribution network – 30 km
  - Hot water distribution line – 5 km
  - Total number of heat substations – 300 (direct and indirect type)
  - Nominal water temperature mode is 130/70°C for direct and 130/75°C for indirect type heat substations
  - Consumer heating systems are based on radiator heating: two-pipe (80%) and one-pipe (20%) distribution systems

Case study
- Subotica DH System -

- 9500 (25% of all city households) housing units are connected to the district heating system
- 500 family houses and 400 public and office buildings are connected to the district heating system
- 500,000 m^2 is overall household heated area
- 300,000 m^2 is heated public and office space area

Project objectives

- Problems were indicated through the analysis conducted over several heating seasons
  - some of the consumers were being supplied with significantly larger amount of heat than needed
  - some consumers were being supplied with insufficient amount of heat, causing them to use additional energy sources for space heating, mainly electricity
- Activities identified as a solution to the problems
  - reconstruction of heat substations through introduction of ambient temperature-based regulation and frequency control mode of pump regulation
  - installation of heat meters in heat substations
  - installation of thermostatic valves and heat allocators on all radiators
- Two projects have been carried out in Subotica DH system, both aimed at determining energy efficiency increase and CO_2 emission reduction
  - PROJECT 1: heat substation reconstruction and installation of I&C equipment
  - PROJECT 2: heat substation reconstruction, installation of I&C equipment and a shift to the consumption-based billing in the residential sector

PROJECT 1
heat substation reconstruction and installation of I&C equipment

- Description
  - Prior, system regulation was performed manually, with measurements carried out in larger time intervals
  - Within the PROJECT 1, heat substations were equipped with modern I&C equipment, enabling continuous measurement of ambient conditions and parameters of heat supply.
  - Flow regulators regulate the flow of hot water to the consumers via control valves installed in the primary water return line.
  - Regulation of hot water temperature is carried out in boiler houses, as a function of the ambient air temperature.

PROJECT 1
heat substation reconstruction and installation of I&C equipment

- Description
  - During the investigation period following parameters were measured:
    - supply water temperature
    - return water temperature
    - ambient air temperature
    - average monthly water flow
    - monthly heat quantity delivered to heat substation
  - Energy related effects have been determined based on the quantity of heat delivered to the heat substation during the heating season 2007/08 (after the reconstruction), assuming the same weather conditions as those during the heating seasons 2005/06 (prior to reconstruction).

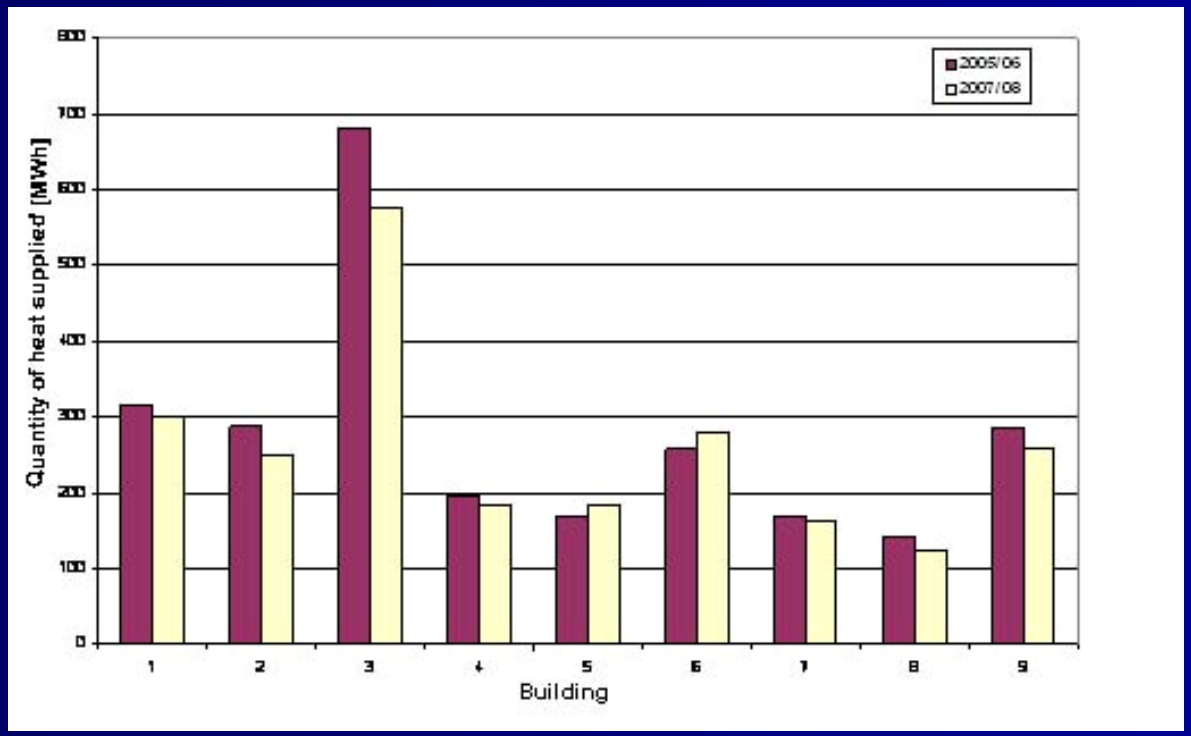
PROJECT 1
heat substation reconstruction and installation of I&C equipment

- Description
  - The effects were monitored based on data recorded in 9 heat substations:
    - 5 substations TYPE 1 - heat substation with one heat exchanger (one measurement in the primary water flow) and one circulation pump installed in the secondary water flow circuit
    - 4 substations TYPE 2 - heat substation with one heat exchanger (one measurement in the primary water flow) and two circulation pumps installed in the secondary water flow circuit

PROJECT 1

heat substation reconstruction and installation of I&C equipment

- Energy efficiency aspects



Energy difference – total → 185.47 MWh/a → 7.40 %

PROJECT 1
heat substation reconstruction and installation of I&C equipment

- Financial aspects
  - Project was realized with financial support of European Agency for Reconstruction
  - Total investment for 72 substations: 700,000 €
  - For calculation of the payback period, the unit price of the heat supplied was taken to be the price charged to the residential consumers i.e. 0.0525 €/KWh (including VAT)
  - Payback period: 6 years

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Description
  - The following energy efficiency measures were implemented:
    - reconstruction of heat substations through introduction of ambient temperature-based regulation and frequency control mode of pump regulation
    - installation of heat meters in heat substations
    - installation of thermostatic valves and heat allocators on all radiators

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Description
  - The project was carried out in three apartment buildings having the following similarities:
    - same size and quality of construction - each building had 12 floors, 76 apartments, 4500 m^2 of total heating area
    - same age - all building were built in the mid ’70s
    - same location
    - similar behavior of the tenants

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Description
  - Measures implemented in each of the project buildings were defined
    - Building A – heat substation reconstruction, including heat meter installation, but keeping the existing central regulation of the amount of heat delivered to the primary distribution network, carried out in the heating plant via boiler load regulation as a function of ambient conditions
    - Building B – installation of completely new heat substation with ambient temperature based regulation
    - Building C – installation of completely new heat substation with frequency control mode of pump regulation and installation of thermostatic valves and heat allocators on all radiators. Apart from central regulation of the amount of heat delivered to the primary distribution network, carried out in the heating plant, as well as regulation carried out in the heat substation, another regulation level was introduced i.e. end-consumer regulation (consumption-based billing). In addition, circulation pump with variable speed was installed.

PROJECT 2

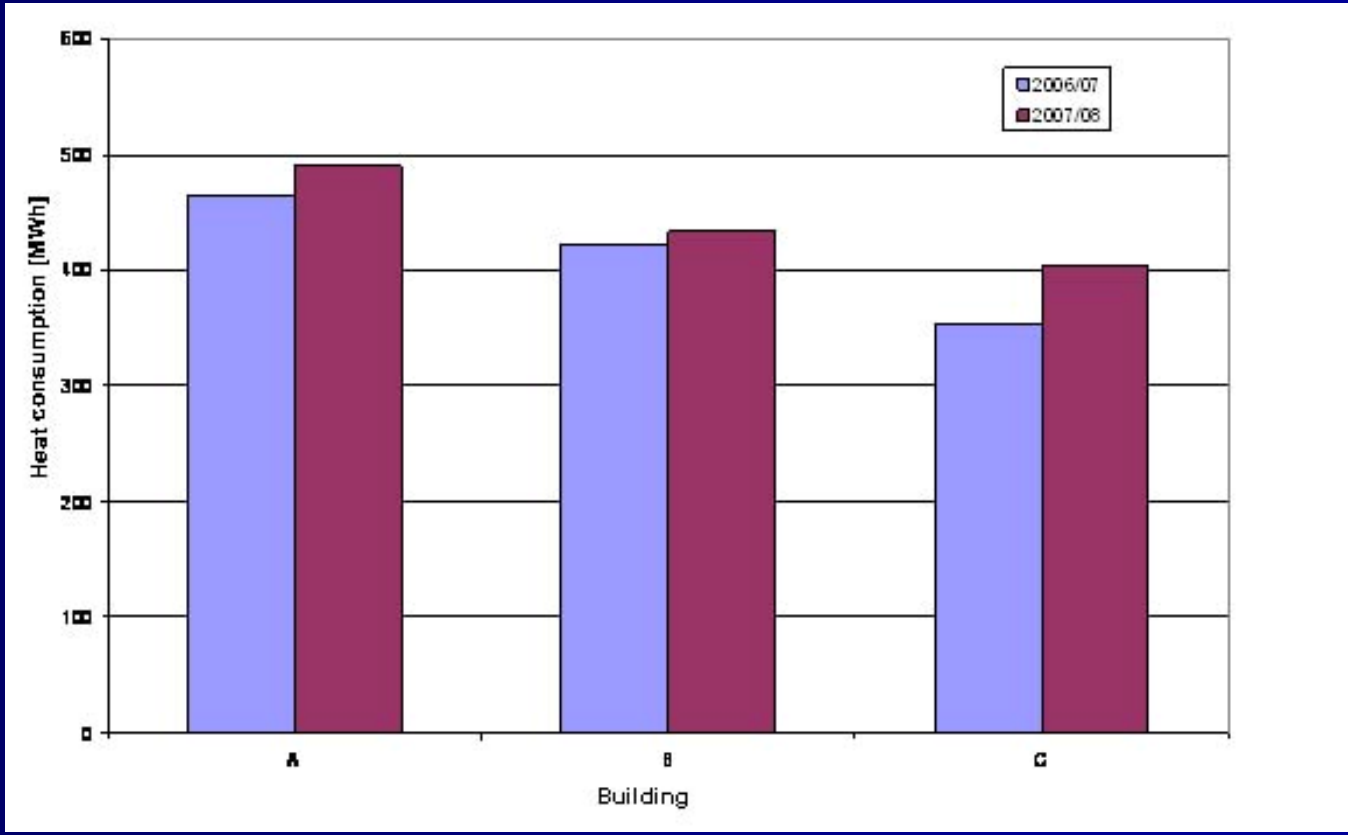
heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Description
  - Consumption of heat and electricity was monitored and recorded during two heating seasons (2006/07 and 2007/08).
  - Analysis and evaluation of the effects of specified energy efficiency measures were carried out in such a manner that the first building (building A), with the smallest scope of energy efficiency measures implemented, was adopted as a reference building.

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

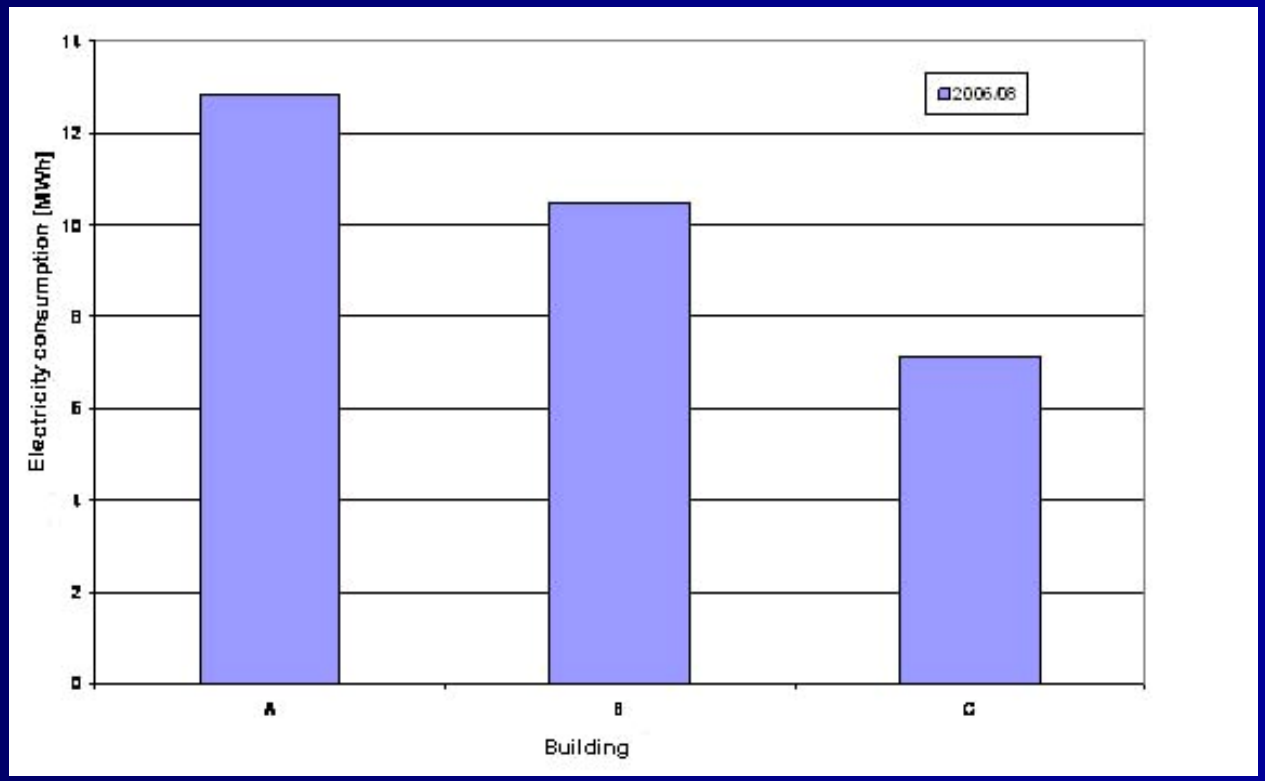
- Energy efficiency aspects – Heat consumption



PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

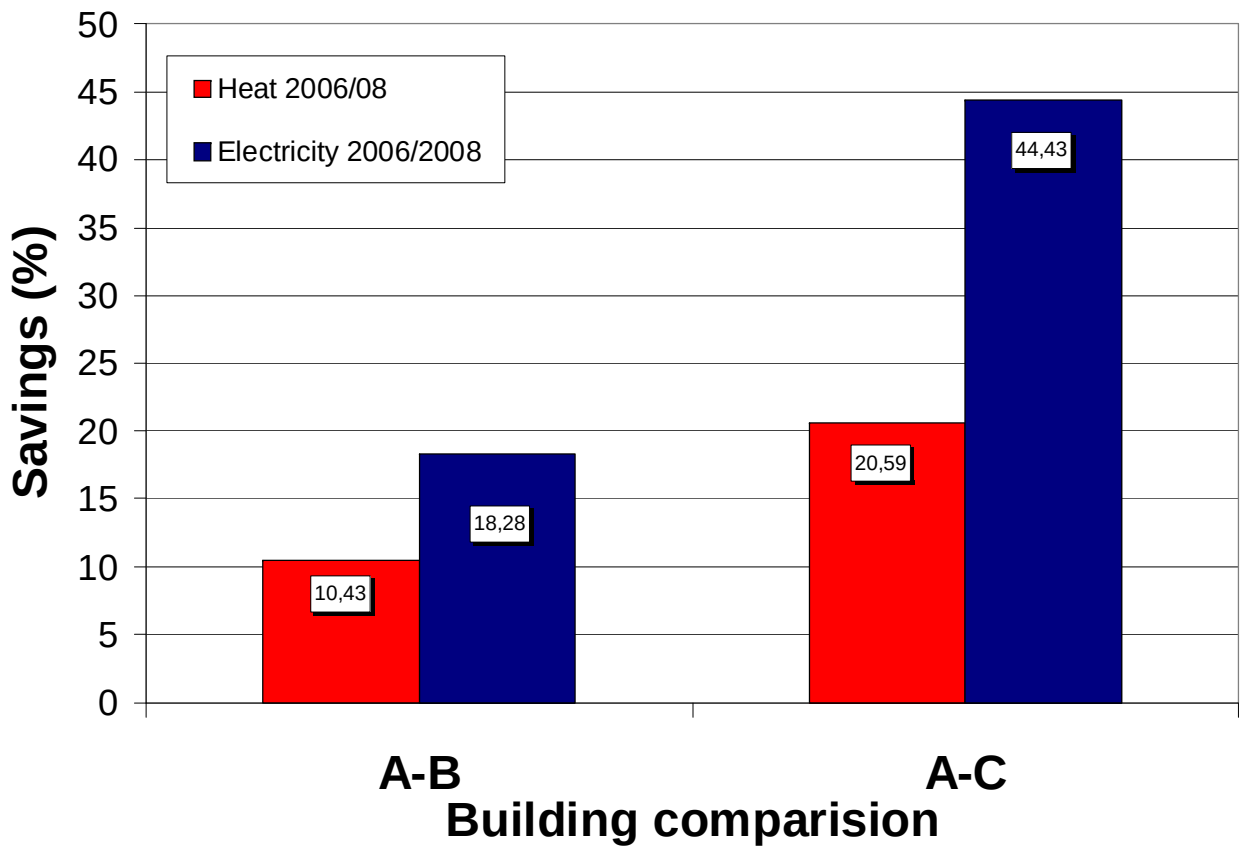
- Energy efficiency aspects – Electricity consumption



PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Energy efficiency aspects



PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Energy efficiency aspects

building C - significant savings in energy consumption were achieved only after the old radiator valves had been replaced with thermostatic valves and consumption-based billing system, based on the readings of the heat allocators installed, had been introduced

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Environmental aspects – reduction of total CO_2 emissions

Building –comparison		2006/2008 (cumulative)
A-B	t	22.61
A-C	t	45.62
A-B	%	11.01
A-C	%	22.13

2,000 t CO_2 per heating season

↓

2.5 kg CO_2 per m^2 of heating area per heating season

reduction of 4,000 t CO_2 per heating season

↓

5.1 kg CO_2 per m^2 of heating area per heating season

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Financial aspects
  - Three different methods for billing the apartment residents for the heat delivered is used in Subotica DH System, depending on the level of heat metering and regulation, but based on uniform unit price for the heat consumed:
    - billing based on the overall quantity of heat supplied to the building, as recorded by a central heat meter, whereby allocation of heating costs to individual apartments is carried out based on the apartment surface area – 85% of consumers
    - billing based on the readings of electronic heat allocators installed – 12% of consumers are billed based on this principle
    - billing based on the readings of individual heat meters installed – 3% of consumers
  - Having in mind different heat billing methods and reductions in heat consumption achieved, tenants of the building C had received a 20.59% lower heating bill compared to the bill received by the tenants of the building A i.e. 11.34% lower compared to the bill received by the tenants of the building B.

PROJECT 2

heat substation reconstruction, installation of I&C equipment, consumption-based billing in the residential sector

- Financial aspects
  - Investment
    - Building A – 3,226.72 €
    - Building B – 19,693.96 €
    - Building C – 52,901.82 €
  - Payback period (calculated for the total savings achieved)
    - Building B: 5.06 years
    - Building C: 9.81 years

Conclusions

- Energy efficiency measures carried out in Subotica DH System, are important for several reasons:
  - indicate how the applicability of certain energy efficiency measure can be evaluated – energy efficiency, environmental and financial effects,
  - indicate potentially significant reduction in the greenhouse gas emissions,
  - indicate possible fund allocation and direction of financial effects achieved,
  - increase the interest of local public and municipal utility companies in achieving energy savings and rational use of energy,
  - illustrate the importance of the energy and energy efficiency related reforms implemented up to date, as well as, those planned to be carried out in the future,
  - indicate a requirement for energy managers to be more involved in the activities carried out in the construction sector, contributing to the construction quality improvements and monitoring the effects of similar projects.

Conclusions

- Municipality of Subotica has consumption-based billing system (one of the few municipalities)
- Consumption-based billing system is implemented based on experiences from the presented projects