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Cardiff, UK, 11th and 12th February 2016

Edited by Jo Patterson and Fabrizio Varriale

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Introduction

The COST Action TU1104 'Smart Energy Regions' started in March 2012 and ended in March 2016. During its four years of activity, the Action established a network of more than 70 researchers from 27 European countries and Israel, allowing the exchange of experience and engagement with local policy-makers and stakeholders.

The Action organised a Training School on energy retrofit for fifteen early-stage researchers, and enabled twenty-two researchers to conduct Short Term Scientific Missions in partner institutions. The main outputs of the Action are three publications collecting contributions from Action members on the topics of low carbon policy, technology, skills, training, supply chains, and cost and value. These and the other outputs of the Action can be found on the Action website: *www.smart-er.eu*

The international conference 'Smart Energy Regions' took place in Cardiff, UK, on 11th and 12th February 2016. The event gathered Action participants, international keynote speakers and invited delegates. This publication collects the papers and posters presented at the conference. Papers were presented orally according to the following thematic sessions:

1. Energy policy, strategy, cost and value;
2. Urban planning and infrastructure;
3. Energy retrofitting of the built environment;
4. Building energy demand and supply, and low carbon technologies;
5. Energy design tools, modelling and data management for the built environment.

The papers and posters presented at the conference are collected in this publication. The papers were selected and reviewed by the following members of the conference Scientific Committee:

Ingrid Kaltenegger	JOANNEUM Research, Austria
Werner Lang	Technische Universität München, Germany
P. Amparo López-Jiménez	Universitat Politècnica de Valencia, Spain
Jo Patterson	Cardiff University, United Kingdom
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Improving the district heating system in Belgrade - towards smart energy consumption

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Abstract: An efficient system of district heating is the element of a sustainable building that determines a comfortable indoor microclimate. District heating supply exists in 55 towns in Serbia. In Belgrade 50% of apartments and houses are covered with it.

At the moment, the Public Utility Company "Beogradske elektrane" uses lump billing method for collection for heating per square meter of residential space. Such billing method does not reflect the actual consumption of heat energy of each residential building. Furthermore, so far tenants who live in buildings with high consumption had no incentive to improve the energy efficiency of their building. Due to the lump sum principle, no one is stimulated to rationally use expensive energy, neither plants nor consumers.

According to the Law on energy in Serbia, the Law on efficient use of energy and the Decision on the heat supply in the city of Belgrade, PUC "Beogradske elektrane" is obliged to install measuring devices for payment per kWh of energy supplied, regarding fairer distribution of payment costs and rational energy management as well as increase energy efficiency of the buildings. Generation plants are required to switch to reading the central heat meters (located in the substations) and to calculate consumption of heat energy of each building individually.

This paper considers measures to improving the District Heating System (DHS) in Belgrade in order to perceive the reduction of heating energy consumption and environmental pollution. Two case studies are presented as comparative analysis of future costs of central heating for apartments - one in a building from 70-s without insulation and proper windows and another one built recently at the same area in Belgrade.

Introduction

A survey of low-carbon cities worldwide is presented in the new Report from UNEP - United Nations Environmental Program in order to identify the essential factors for their success in increasing energy efficiency and use of renewable energy sources, as well as achieving the goals of zero or low greenhouse gas emissions. District energy systems (DES) emerged as best practice approach for providing a local, affordable and sustainable energy supply, improve energy efficiency and support energy access efforts. The Report represented a significant opportunity for countries and cities around the world to move towards climate-resilient, resource-efficient and low-carbon pathways (UNEP, 2015).

District Heating System (DHS) started in Serbia since 1965, when the Public Utility Company "Beogradske elektrane" was established. This company is the biggest high-quality DHS in Serbia. It provides the regular supply of heat to all consumers of DHS in the city of Belgrade.

District heating supply exists in 55 towns in Serbia (Bozic V. S., et al., 2015). In Belgrade 50% of apartments and houses are covered with it (http://www.energyobserver.com/vesti.php?lang =1&ID=34732). To reduce pollution, in the last 30 years in Belgrade were closed more than 1,035 local

boiler stations running on coal and hard fuel oil, of which 174 were in the competence of the PUC "Beogradske elektrane", according to data from PUC "BE". The same data indicates that today the average annual consumption of natural gas is 85%, while seven local boiler stations are using biomass briquettes and 2 boiler stations are using biomass pellets saving 4,500 t CO_2 per year. It proved the importance of DHS modernization and the transition from consumption of fossil fuels to energy sources that do not pollute the environment, in other words the transition to low CO_2 technologies. Such activities have already been undertaken by PUC "Beogradske elektrane", of which expected positive effects on the regional level. These activities are mentioned in the paper.

Currently, in Serbia the heating rate is not calculated according the actual consumption of heating energy, but according to specific consumption of Qh = 140 kW/h per square meter per year, although the average specific consumption of buildings primarily depends on the insulation and exterior joinery, i.e. heat losses. According to the Law on energy in Serbia, the Law on efficient use of energy and the Decision on the heat supply in the city of Belgrade, PUC "Beogradske elektrane" is obliged to install measuring device for payment per kWh of heat energy supplied, regarding fairer distribution of payment costs and rational energy management as well as increase energy efficiency of the buildings. This is necessary to achieve the trends of developed countries in terms of calculation of energy consumption for heating and to generate a responsible attitude of the society towards energy consumption. In this sense, the paper presents a comparative analysis of two examples of residential buildings in Belgrade, with different facade thermal performance, systems of calculation and billing of energy consumption.

The biggest challenge for Balcanic countries regarding district heating policy, is the fact that the tariff revenue does not cover the full costs of district heating. This is the main factor for poor maintainance of the heating system, big losses, inefficiency and slow process of modernization. On the other hand, both low tariffs and non-payments also reduce incentives for consumers to save (Roshchanka, Evans, 2012).

In this paper the methodological approach includes the following steps:

- Review of procedures and measures for improvement of DHS in Serbia and city of Belgrade.
- Consideration of methods for measurement of supplied heat energy to the buildings and collection; Analysis and discussion of case studies.
- Comparative analysis of case studies.

The aim of the paper is to show the activities performed by DHS in Serbia and Belgrade due to reduce the consumption of fossil fuels for heating and thus environmental pollution at the regional level.

The existing infrastructure of district heating in Serbia and Belgrade, and measures of improvement

The DHS in Serbia has not been modernised. Waste heat is not utilized in DHS nor is renewable energy. Heat production in DHS in Serbia is solely based on fossil fuels, mostly high quality imported fuel such as natural gas. Heat is produced in large scale boilers designed to deliver optimal heat to most distant consumers in the coldest days (http://serbia-energy.eu).

The total number of dwellings in Serbia is 2,423,208, of which 2,380,810 with private ownership and 41,068 with other types of ownership, according the Census from 2011 (Book 25, 2013). The number of apartments with district heating installation is 535,456, which represents 22.1% of the total, while the number of apartments without district heating installation is 77.8% of which is 20.6% with central heating and 57.2% without district and central heating, as shown in Chart 1 (Book 30, 2013; http://www.vibilia.rs/srpski/izvestaj/0508/Popis%20stanovnistva%202011%20stanovi%20prema%20vrsti%20grejanja.pdf). According to the data received from PUC "Beogradske elektrane" at the end of

2015, all the heating plants in Serbia are supplying around 700.000 apartments (25% of all apartments in Serbia).

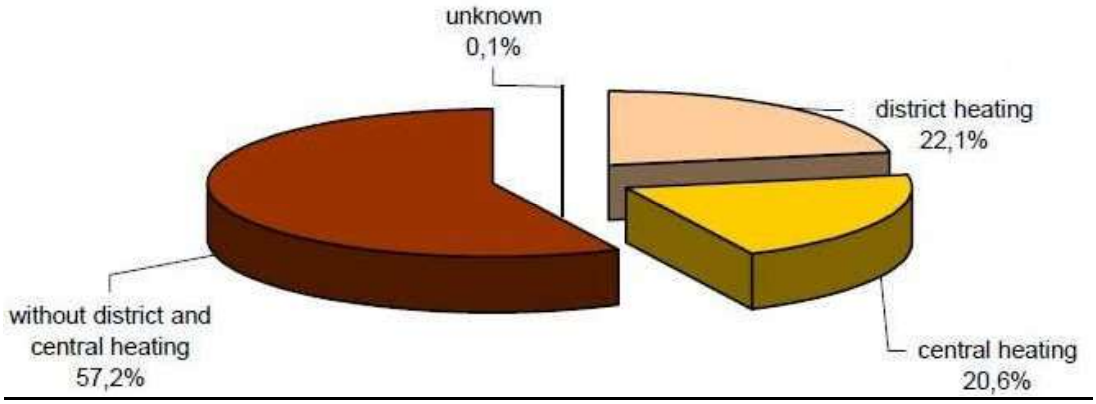

Figure 1 - Occupied dwellings according to the type of heating in the Republic of Serbia, (Book 30, 2013).

According to the data measured in substations and received from PUC "Beogradske elektrane", the surface of apartments with district heating installation is around 45,000,000 m^2. Measurements in the substations throughout Serbia show that the annual energy consumption for heating is in the range of 130-200 kWh/ m^2.

It is obvious that a large number of apartments are individually heated using coal, wood and electricity as energy sources, which points to significant carbon emissions. The number of dwellings for which heating is used another type of energy, for example solar, geothermal energy, wind energy, etc., in the Republic of Serbia is very small. To Census data, this kind of energy for heating is used in only 16,706 flats. Most of these apartments are in the region of Vojvodina (http://www.vibilia.rs/srpski/izvestaj/0508/Popis%20stanovnistva%202011%20stanovi%20prema%20vrsti%20grejanja.pdf).

Municipal DHS in Serbia operate in 55 cities and towns with the installed capacity of around 6,800 MJ/s (thereof 3,000 MJ/s in Belgrade, which is about 44%), and total heat production of 7,000 GWh (Indicators of District Heating in Heating Plants which are Members of Business Association "Heating Plants of Serbia" (in Serbian), Association of Serbian Heating Plants, Belgrade, 2010). Approximately 22.1-25% of Serbian households are connected to the district heating system. The district heating systems are fueled by natural gas (65%), heavy and light fuel oil (18%), electricity (2%), and coal (15%). (Bozic V. S., et al., 2015). Structure of fuel consumption per generation plants in Serbia is presented in Table 1. Liquid fuel and natural gas make up about 80% of total consumption in generation plants in Serbia.

Table 1 - Structure of fuel consumption per generation plants in Serbia.

Natural gas	65%
Heavy and light fuel oil	18%
Electricity	2%
Coal	15%

When it comes to the implementation of organized and efficient measures to reduce energy consumption and environmental pollution, then the improvement of infrastructure of district heating is the procedure that is government supported and in a short time can make improvements at the regional level.

In Belgrade power plants average annual consumption and percentage of certain fuels in PUC "Beogradske elektrane" is as follows:

- app. 350 million cubic meters of natural gas (85%),
- app. 46,000 tons of heavy fuel oil (13.5%),
- app. 3,200 tons of coal (0.4%),
- app. 2,000 tons of pellets (biomass – 0.25%),
- app. 1,500 tons of briquettes (biomass – 0.2%),
- app. 500,000 liters of heating oil (0.1%).

Share of gas and heavy fuel oil in total planned fuel consumption changes depending on the price of these fuels. Fuel consumption is planned on the basis of average energy consumption of 140kWh/ m^2 per year (http://serbia-energy.eu/belgrade-district-heating-development-a-modernization-strategy-overview/).

The PUC "Beogradske elektrane" has conducted the following measures in order to reduce environmental pollution and start the transition to renewable energy sources:

- In the last 30 years this company closed more than 1,035 local boiler stations (on coal and hard fuel oil). Existing customers are connected to the large heat sources.
- During heating season 2007/2008, "Beogradske elektrane" run big plants on pellets and briquettes.

The company's commitment towards the introduction of renewable energy sources can be identified through running big plants on pellets and briquettes: 7 local boiler stations are using biomass briquettes; 2 boiler stations are using biomass pellets (Fig. 2); total installed capacity is 24 MW (using biomass). Average consumption per heating seasons is 2,000 tons of pellets and 2,000 tons of briquettes. Thus reduction of CO_2 emissions in the amount of 4,500 tons per year is achieved.

Figure 2 - Pellets (biomass) as a fuel in a local boiler station "Simiceva" of PUC " Beogradske elektrane" in Belgrade.

Savings are achieved by increasing in operation efficiency of the PUC "Beogradske elektrane", which is shown in Table 2.

Table 2 - Increase in operation efficiency of PUC "Beogradske elektrane".

Year	2001	2014
Installed power	2.700MW	3.000MW
Generation plant efficiency	0.78	0.88-0.96 (new boiler)
End user specific energy consumption	150KWh/m^2	109KWh/m^2

Measures to improve the district heating in Belgrade are planned through the high level of the plant automation as the basic objective and through the high level of substations automation as additional objective, taking into account lower operation and investment costs as final objective (Fig. 3). Also, SCADA and TERMIS modules are implemented in order to create connections for further DHS in Belgrade and optimize the system.

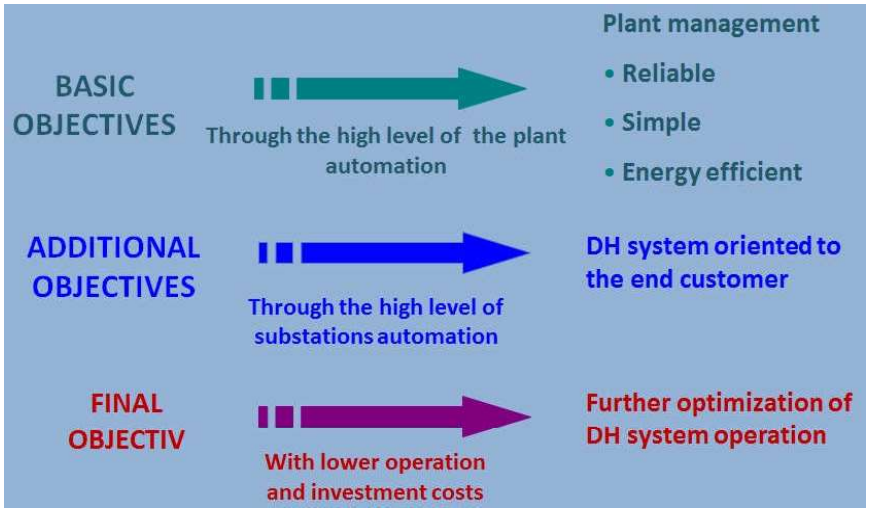

Figure 3 - District heating system improvement in Belgrade.

Serbia ranks among the 20 most energy intensive and among the 10 most carbon intensive countries in the world in terms of GDP (Climate Change Aspects of Energy Sector Development in Serbia, 2012). GHG emissions of Serbian energy sector are estimated at 31 million t CO_2 eq. (year 2010, without Kosovo), which is about 45% of Serbia's total CO_2 emissions and it is expected that the emissions of greenhouse gases will increase by about 10-13% by the year 2020 comparing to 2010, as a result of increased demand for electricity (Bozic et al., 2015). In Serbia, due to outdated energy production and distribution facilities, there is a great potential for energy efficiency and reduction of operational losses and emissions of greenhouse gases. Through improvement using new technologies and increase of existing Thermal Power Plants (TPP) capacity, as well as closing some old TPP which operate with low efficiency, significant reduction of CO_2 emissions could be achieved. Additional decrease of CO_2 emissions could be achieved by retrofitting of existing buildings by putting thermal insulation, replacement of windows, replacement of existing lighting systems with more efficient ones, as well as by glazing the balconies and loggias. Total mitigation potential in energy and building sector is estimated at 12.5 Mt CO_2 eq./year (Assessment of the Projects' Potential in the Field of Renewable Energy Sources, Energy Efficiency and Framework of Clean Development Mechanism Foreseen by the Kyoto Protocol in the Republic of Serbia, 2007).

Measurement of supplied heat energy to the buildings and collection/billing

The current method of payment for heating of residential space in Belgrade is lump billing method. Lump billing method is a collection for heating per square meter of residential space. Such billing method does not reflect the actual consumption of heat energy of each residential building. The heating rate is calculated according to specific consumption of Qh = 140 kW/h per square meter per year.

The zones of Belgrade covered with district heating system PUC "Beogradske elektrane" are presented in Figure 4.

Figure 4 - Zones of Belgrade covered with district heating system PUC "Beogradske elektrane".

The average specific consumption of buildings primarily depends on the insulation and exterior joinery, i.e. heat losses. Depending on the thermal performance of building envelope, buildings have different energy consumption for heating, but that the current method of payment does not take into account. It has the following negative effects:

- Customers who live in buildings that consume less energy than the average (Qh = 140 kW/h per square meter per year), now pay more for heating annually.
- Customers who live in buildings with high consumption until now had no incentive to improve the energy efficiency of their building.
- Because of the payment according to the lump sum, no one is stimulated to rationally use expensive energy, neither plants nor consumers.

In order to ensure proper accounting of consumed thermal energy, the following legal obligations of generation plants in Serbia are introduced:

- According to the Law on energy in Serbia, the Law on efficient use of energy and the Decision on the heat supply in the city of Belgrade, PUC "Beogradske elektrane" is obliged to "install measuring device for supplied heat energy which provide accurate information on the actually supplied amount of heat, as well as the exact time of supply of heat energy to the building".
- Generation plants are required to switch to reading of the central heat meters (located in the substation) and to calculate consumption of heat energy of each building individually.
- Consumption of heat energy of the building is distributed per apartments according to their heating surface (m^2 of apartment).

In order to meet legal obligations in 2004 the PUC "Beogradske elektrane" has started modernization of district heating in Belgrade (more than 8.500 substations - located in residential buildings). Modern measuring and control equipment are installed in a few substations that enable rational heat supply and measurement of building heat energy consumption.

According to the "Law on the efficient use of energy", customers in Serbia shall hire companies that are on the market, at their own expense, in order to:

- Install thermo-regulatory valves on each radiator (for consumption management);
- Install heat cost allocators or heat meters (depending on the internal installation) - for the allocation of consumption of each flat.

Companies that are on the market can install equipment and carry out the allocation of heat energy that is delivered to the building. By installing this equipment, consumption can be managed by each user in order to economize and reduce the cost.

Transition to collection according to consumption of building and/or apartment does not necessarily mean that heating bills will be lower. It depends on the consumption of heat energy of building / apartment (insulation, windows, as well as customer's needs for heat energy).

Analyses and discussion of case studies

Two case studies will be presented in terms of calculating the costs of central heating for apartments - one in a building from the '70s without insulation and proper windows and another one built recently at the same area in Belgrade.

The first example refers to the building in the Block 45 in New Belgrade. The building was built in 1972 (Fig. 5). Facade of the building has no thermal insulation. The measured specific energy consumption is Qh=184 kWh/m^2 per year.

Figure 5 - The building in the street Nehruova 178, Block 45 in New Belgrade.

The residents currently pay (e.g. apartment of 50 m²) 114 RSD/ m² (current price) x 50 (floor area) x 12 (months) = 68,400 RSD per year.

When customers pay according to measured consumption, the following items are taken into account:

- The fixed part-input power – 24,522.5 RSD per year/12 months = 2,043.5 RSD per month.
- Consumed energy (kWh) – 62,744 RSD per year.
- The total amount – 87,266.5 RSD per year.

The second example relates to the building in the Block 70 in New Belgrade. The building was built in 1994 (Fig. 6). Facade thermal insulation has a thickness of 5 cm of mineral wool. The measured specific energy consumption of the building is Qh=122 KWh/m² per year.

Figure 6 - The building in the street Jurija Gagarina 31v, Block 70 in New Belgrade.

The residents currenty pay (e.g. apartment of 50 m²) 114 RSD/ m² (current price) x 50 (floor area) x 12 (months) = 68,400 RSD per year.

When customers pay according to measured consumption, the following items are taken into account:

- The fixed part-input power – 24,522.5 RSD per year/12 months = 2.043,5 RSD per month.
- Consumed energy (kWh) – 41,602 RSD per year.
- The total amount – 66,124.5 RSD per year.

Payment based on the measured consumption means that each customer will receive an invoice for part of the consumed heat of the concrete building, according to the heating surface of his apartment. Invoice will include fixed and variable costs. Like invoice for the electricity, the invoice will include: engaged power and consumed kWh.

The engaged power represents a fixed cost of the energy company that is paid as lump sum, but in the current invoice it is not separately shown, so the customer can not notice it. Fixed costs are very severely restricted by legislation. These are justified costs approved by regulations.

Consumed kilowatt hours (kWh) of heat energy are variable costs, costs relating to energy costs (gas, fuel oil, coal, biomass, fuel oils). City of Belgrade, by the "Decision on the heat supply in the city of Belgrade", respecting international standards (derived from the German standard DIN) in the field of technical conditions for designing residential buildings, in Article 45 of the Decision, has prescribed achieving and maintaining an internal temperature in the room of tariff customers of 20 (+/- 1) ° C, in order to achieve the required conditions of comfort. In this way, it is possible to ensure rational use of primary energy. Procedure of calculation includes the following:

- Consumed kWh are recorded by central heat meter located in the substation of the building.
- Total consumption of the building is distributed on the heated area of the apartments.
- The current price of kWh of heat energy with VAT is 8.39 RSD since 30.09.2015.

Table 3 - A comparison of case studies.

Year of construction			1972	1994
Case studies in New Belgrade			Nehruova 178, Block 45	Jurija Gagarina 31v, Block 70
			Floor area 50m^2	
The principle of payment	Current	Energy consumption	184 kWh/m^{2}year	122 kWh/m^{2}year
		Billing	114RSDx50m^{2}x12months	
		Total amount	**68,400RSD per year**	
	Consumption-based billings	Fixed part	24,522.5RSD per year	24,522.5RSD per year
		Consumed energy	62,744.0RSD per year	41,602.0RSD per year
		Total amount	**87,266.5RSD per year**	**66,124.5RSD per year**

A comparative analysis of two case studies shows that a significant increase in the amount to be paid can be noticed in the case of building without thermal insulation, while a small reduction in the amount to be paid is present in the case of buildings with poor thermal insulation thickness (in this case 5 cm).

Generally, it can be concluded that excessive consumption of energy is present in households, mostly as a result of the construction of energy irrational buildings. Removing these irrationalities, may represent the largest energy resource in Serbia in the next 5 - 10 years. In this sense, it is necessary to recover the building stock in terms of improving energy performance. Incentive for the building reconstruction could be caused by the implementation of payment based on the measured consumption, payment per kWh of heat energy supplied, and a short payback period of investment.

According to the data received from PUC "Beogradske elektrane", in terms of measures taken to reduce energy consumption for heating should be noted that it is fully completed pilot project of installation of thermostatic radiator valves and heat cost allocators to 135 apartments in New Belgrade's Block 34. For consumers that are covered by this pilot project the consumption of thermal energy is reduced by 15 %. This means that consumers, in accordance with their needs, regulate the temperature in their own apartments and thus rationalize consumption. In addition, electricity consumption in modernized substations is lower by as much as 40 %. Also, training on software for the calculation and payment according to the consumption of thermal energy is carried out.

Conclusion

DHS in Serbia plays an important role in meeting basic heating needs and faces serious challenges that must be resolved regarding economical sustainability. Building level heat metering, coupled with technical solutions to improve efficiency of heat delivery to households, would provide mutual benefits for customers, district heating companies, and the Government. Heat metering and consumption-based billings are important steps towards improving the financial sustainability of the District Heating sector.

The measures for improving of District Heating System in Belgrade are presented in the paper. The proposed changes towards consumption based billing for heating should have the effect of increasing citizens' awareness regarding saving the energy and providing more sustainable buildings (according the energy consumption). District heating system in Serbia plays an important role in meeting basic heating needs and faces serious challenges that must be resolved regarding economical sustainability. Heat metering and consumption-based billings are critical steps on the path to sector reform. Building level heat metering, followed with technical solutions to improve efficiency of heat delivery to households, would provide mutual benefits for customers, District Heating companies, and the Government. The Government can play an important role by promotion of heat metering and consumption-based billing as well as by improving the financial sustainability and affordability of DH services and financing energy efficiency improvements. Furthermore, retrofitting of existing buildings (by adding the insulation, changing the windows, glazing balconies) would decrease CO_2 emission.

District heating policy should be examined in the broader context. Based on the experience in Eastern Europe, the success of district heating reforms relies largely on coordination and sequencing with other policies and sectors, such as energy, economic performance, and social policy (Roshchanka, Evans, 2012; Lampietti, J. A., Meyer, 2002).

In order to meet EU legislatives it is necessary to apply metering in district heating system (Semikolenova, Pierce, Hankinson, 2012). District heating system in Serbia, like in other Eastern European countries, was a social welfare for final consumers rather than a commercial activity. During the transition period the politicians have been afraid about increasing heating bills. Many consumers still believe that district heating is a social welfare and that it should still be provided with a lower price for everyone. Political support is necessary for applying metering in Serbia.

Prioritising the technological modernisation of energy facilities and installations to reduce emissions from generation plants aims not only to a significant increase in the heating production capacity of a large part of existing plants, but also to a reduced threat to the environment. Increasing energy efficiency and the use of renewable energy resources by 2020 that directly contribute to greenhouse gasses emissions reduction are main priorities for DHS in Serbia.

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