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TECHNOLOGICAL TRENDS

PART OF WORK PACKAGE 1: MAPPING OF ENERGY EFFICIENCY POLICY INSTRUMENTS AND AVAILABLE TECHNOLOGIES IN BUILDINGS AND TRANSPORT

NATIONAL REPORT FOR SERBIA

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Partner: Centre for Energy, University of Belgrade – Faculty of Mining and Geology

Institution: **University of Belgrade – Faculty of Mining and Geology**

Steering Committee member [(1)]: Prof. Dejan Ivezić

Prepared by: Dr. Marija Živković, Prof. Dejan Ivezić, Dimitrije Manić, Assoc. Professor Miloš Tanasijević, Aleksandar Madžarević

(1) The Steering Committee member has the responsibility for ensuring the quality of the report.

HERON: Forward – looking socio-economic research on Energy Efficiency in EU countries

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ACRONYMS

DHW	Domestic Hot Water
EE	Energy Efficiency
HP	Heat Pump
HVAC	Heating Ventilating Air Conditioning
NEEAP	National Energy Efficiency Action Plan
RES	Renewable Energy Sources
RPM	Revolution per minute
U-value	Heat transfer coefficient
VAV	Variable air volume
VAV	Variable Air Volume
VFD	Variable Frequency Drive

EXECUTIVE SUMMARY

Final energy consumption in households in 2013 was 2.930 Mtoe or 34.85% of total final energy consumption (Statistical Office of the Republic of Serbia, 2014). Tertiary sector (public and commercial sector) is responsible for 0.833 Mtoe or 9.91% of total final energy consumption. In other words, energy consumption in the buildings sector accounts almost 45% and represents the largest share of the country's final energy consumption. According to (Econoler, 2012), possible energy savings in buildings sector are expected to be 1.592 Mtoe or 15.8% of final energy consumption, while the costs for achievement of full savings potential are estimated to €8.8 billion.

According to energy balances of the Republic of Serbia for 2013 (Statistical Office of the Republic of Serbia, 2014), final energy consumption in the transport sector was 1.970 Mtoe, or 23.43% of final energy consumption. The only document that has provided quantitative assessment of energy savings that could be achieved by implementation of energy efficiency measures in the transport sector is the Second National Energy Efficiency Action Plan (Government of the Republic of Serbia, 2013). According to this document, energy savings in the transport sector in period 2010-2018 are expected to be 0.2107 Mtoe. Necessary investments in energy efficiency improvement in the transport sector are projected to €1.05 billion, lowering consumption 17% below BAU by 2030 (UNDP, 2013).

High potential for energy saving is identified in both sectors. Still, the World Bank`s report (World Bank, 2014) has assessed energy efficiency market as undeveloped and proposed financing options for all buildings sub-sectors. Although a number of government and donor funded programs have been initiated over the past decade to demonstrate the viability of EE investments in public and residential buildings, implementation has remained fragmented and piecemeal (World Bank, 2014).

The investments in energy efficiency have the potential to create 5,000 to 8,000 jobs by 2030, depending on the specific policies implemented (UNDP, 2013). Of these, 2,000 to 3,000 would be created in the residential, commercial and industrial sectors and the remainder in the transport sector.

In order to increase efficiency of energy use, Serbia promoted several policy instruments. Existing policy instruments for the buildings sector has not been developed to promote some specific technology for energy efficiency improvement, nether concerning to the type nor concerning to their innovatively. Compared to the buildings sector, policy instruments for increasing energy efficiency in the transport sector are less developed. Except instrument fuel economy/vehicle standards, which supports efficiency of vehicles, other policy instruments are not developed to support some specific technology.

For the buildings sector, technologies for more efficient heating, cooling, ventilating, preparation of domestic hot water, cooking and lighting are presented, including available data of costs, energy consumption, advantages and disadvantages.

Available data about promising measures aimed to improve efficiency in transport: car sharing, eco driving, improved vehicle efficiency, start-stop systems and combined road-rail transport are presented, including available data of costs, advantages and disadvantages.

CHAPTER 1: TECHNOLOGICAL TRENDS IN THE BUILDING AND TRANSPORT SECTOR

1.1 ENERGY EFFICIENCY POTENTIAL

Buildings sector

According to energy balances of the Republic of Serbia for 2013 (Statistical Office of the Republic of Serbia, 2014), final energy consumption in households was 2.930 Mtoe or 34.85% of total final energy consumption. Tertiary sector (public and commercial sector) is named as “other users”, which are responsible for 0.833 Mtoe or 9.91% of total final energy consumption. In other words, energy consumption in the buildings sector accounts almost 45% and represents the largest share of the country’s final energy consumption (Figure 1).

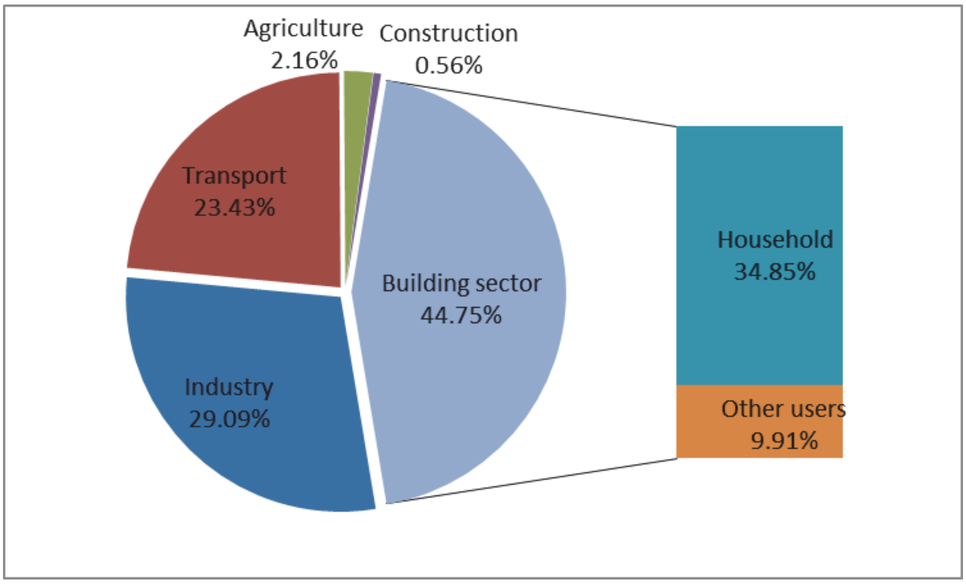

Figure 1: Final energy consumption in the Republic of Serbia in 2013, by sectors (Statistical Office of the Republic of Serbia, 2014)

World Bank has published the National Building Energy Efficiency Study for Serbia (Econoler, 2012). The majority of buildings, about 50%, are single-family houses in both urban and rural environments. Around 90% of building stock is concentrated in cities and towns. The predominant buildings sub sector is residential, followed by the public sub sector, and the commercial sub sector. Estimations of the energy saving potentials in the buildings sector and subsectors are presented in table 1. The biggest potential for savings is found to be in residential sector. The period for achieving proposed savings was not considered in (Econoler, 2012).

Table 1: Average estimated savings per type of building (Econoler, 2012)

Building Sector	**Energy Savings Potential [% Building Consumption]**	**Energy Savings Potential [% Final Energy Consumption]**	**Total Savings Potential [Mtoe]**
I. Residential	39%	10,6%	1.102

Building Sector	Energy Savings Potential [% Building Consumption]	Energy Savings Potential [% Final Energy Consumption]	Total Savings Potential [Mtoe]
II. Public			
Health	47%	0,5%	0.043
Education	44%	0,7%	0.086
Public office buildings	47%	0,8%	0.114
III. Commercial	48%	3,2%	0.247
Total		15,8%	1.592

Estimations about energy consumption by sub sectors (Econoler, 2012), (Statistical Office of the Republic of Serbia, 2014) have shown that residential sector is responsible for 70% to 77% of consumption in the buildings sector, while the rest is for tertiary sector (total consumption of commercial buildings is about 50% bigger than consumption of public buildings). Investments in these sectors have relatively attractive average simple payback period – from 6.4 years for schools and hospitals, to 9.2 years for residential sector (World Bank, 2014).

In (Econoler, 2012) is presented that heating accounts for 61% of energy consumption in buildings. Therefore, most energy saving potential is associated with thermal insulation and heat loss reduction. Current level of averege specific heat consumption in Serbia is estimated to be about 160 kWh/m^2, which is high comparing to Western European countries. (World Bank, 2014) raported different specific heat consumption for subsectors. The highest is in public buildings, folowed by comercial and residential buildings.

If, full energy savings are analized and taken into account, it can be concluded that achieving Serbia's full savings potential would cost a total of €8.8 billion and would result in annual cost savings to investors and end users of about € 1.1 billion. The savings would pay for the measures in about eight years (Econoler, 2012). There are no available, more detailed data about other energy savings (for example, appliences or lighting) in buildings sector.

Transport sector

Transport sector is a significant consumer of energy in the Republic of Serbia. According to energy balances of the Republic of Serbia for 2013 (Statistical Office of the Republic of Serbia, 2014), final energy consumption in the transport sector was 1.970 Mtoe, or 23.43% of final energy consumption (Figure 1).

In terms of oil and oil derivatives consumption, the share of transport is as much as 74%. Approximately, 68% of the final consumption of oil and oil derivatives in the transport sector is related to the consumption in road transport.

The only document that provides quantitative assessment of energy savings that could be achieved by implementation of energy efficiency measures in the transport sector is the Second National Energy Efficiency Action Plan (Government of the Republic of Serbia, 2013). According to this document, energy savings in the transport sector in period 2010-2018 are expected to be 0.2107 Mtoe. The largest number of proposed measures for energy savings in the Second NEEAP, is focused on road transport, due to its dominant share of over 70% in energy consumption of the transport sector, with the expected further increase of consumption.

Necessary investments in energy efficiency improvement in the transport sector are projected to €1.05 billion, lowering consumption 17% below BAU by 2030 (UNDP, 2013). Avoided costs in the transport sector amount to a total of €2.9 billion to a maximum estimated of €5.5 billion, against investments of €1.05 billion. The broad range estimated takes in consideration investments in energy efficiency (low range of avoided costs) and efforts to improve mass transport or non-motor transport (high range of avoided costs). Expected payback of on average, 10 years in the transport sector, is higher compared to investments in building sector (UNDP, 2013). This is due to a variety of factors, including the cost of intervention and energy prices.

1.2 Technologies And Policy Instruments

Existing policy instruments in building sector has not been developed to promote some specific technology for energy efficiency improvement, nether concerning the type nor concerning their innovatively.

Overview of existing policy instruments for the buildings sector

Minimum energy performance requirements for new or reconstructed buildings is the regulatory policy instrument that sets minimal requirements, for newly built buildings to have energy class "C" and for renovated existing buildings to make improvement of at least one energy class. As the energy classes are defined according to annual heat consumption (Ministry of Environment, Mining and Spatial Planning, 2011a-b) it is rationally to assume that technologies for building envelope improvement (walls insulation and low U-value windows) and heating system improvement will have priority. Research into Serbian building stock with respect to its energy performance (Jovanovic Popovic et al. 2012) has shown that the standard measures of improvement (technologies for building envelope) can save from about 25% to as much as almost 90% of the energy currently needed for heating. The advanced level of improvement (technologies for space heating), despite requiring significant investments, often provides savings of about 70%, while in some cases these measures can reduce the annual heat consumption to only 5% of the existing need.

Energy audit (mandatory) is regulatory policy instrument that defines and quantifies possibilities for economy feasible and efficient energy use in buildings. This instrument is used for identification and understanding of energy savings options, and their prioritizing in accordance to conducted economic and financial analysis. Consequently the priority should have technologies that provide maximal energy savings for the same investment. Additional information regarding achieved results and cost efficiency of this instrument are not available yet.

The main objective of **introduction of energy management system** in buildings is the reduction of energy consumption in public and commercial buildings. The designated organizations define targets for energy consumption reduction and prepare the energy efficiency plans and programs for achievement of proposed targets in the most convenient manner - through organizational and investment measures. There is no specific technology promoted by this instrument. This instrument is still not in force, as secondary legislation necessary for its conduction is just partly issued. (Ministry of Mining and Energy, 2015a-b)

The objective of **energy labelling as** policy instrument is to reduce electricity consumption by introducing more energy-efficient household appliances (refrigerators, stoves, washing machines, dishwashers, air conditioners, electrical lamps and luminaries, etc.) (Government of the Republic of Serbia, 2013), (Ministry of Energy, Development and Environment, 2014a-g). Data about cost efficiency and energy savings achieved are not available. Objective is to promote efficient household appliances.

The Law on Efficient Use of Energy (Government of the Republic of Serbia, 2013), provided the framework for establishment of the Budget Fund for energy efficiency, with an aim to provide **subsidies** for financing or co-financing projects, programs and activities directed to increase efficiency of energy use. The Budget Fund was established in 2013 (Government of the Republic of Serbia, 2013c). Financing or co-financing from the Budget Fund is governed in accordance with the annual programs for financing activities and measures for improving energy efficiency. Regulation on establishing the program for financing activities and measures for improving energy efficiency in 2014 (Ministry of Energy, Development and Environment 2014h) was the first Program for financing that was adopted, and in this Program only the public buildings, properties of local self governments were taken into account.

Regulation (Ministry of Energy, Development and Environment 2014h) specifies activities that shall be financially supported: improvement of energy efficiency in buildings (refurbishment, renovation, replacement or installation of new energy efficient equipment in systems for heating and/or cooling, replacement/modernization of interior lighting, introduction of a system for automatic control etc.); connection of new consumers to existing district heating systems; connection of consumers, who use electricity for direct heating or inefficient boilers/stoves for heating to existing gas distribution network; installation of heat pumps with low nominal power and high coefficient of performance; installation of biomass boilers; installation of solar collectors for heating domestic hot water; promotion of energy efficient appliances in households; raising awareness of the importance of energy efficiency.

Rulebook on the conditions for allocation and use of the Budget Fund, defines as the first criteria for ranking the expected energy savings in kWh/RSD. Although, for the first open call, projects that shall be financed are selected (Ministry of Energy, Development and Environment, 2014i), (Ministry of Energy, Development, 2014j), expected energy savings are still not presented.

It should be noted that within the first call for financing there were no funds allocated for funding energy efficiency improvement in the transport sector (Ministry of Energy, Development and Environment 2014h).

Instruments related to **capacity building**, are new, adopted in 2015, and can be classified in two sections: education and training for energy managers (under jurisdiction of the Ministry in charge for energy) and education and training for engineers to be specialized in area of energy efficiency of buildings (under jurisdiction of the Ministry in charge for construction). There is no relevant data about cost efficiency. Within trainings all measures aimed to energy efficiency improvement should be analyzed. This policy instrument is not targeting some specific technology.

Model of **Energy Service Agreement for Public Buildings** is defined by Rulebook on Model Energy Service Contracts for the Implementation of Energy Efficiency when Users are from Public Sector (Ministry of Energy, Development and Environment, 2015c). This document was created to help public entities, as well ESCOs in preparation of the Energy Service Agreement. Two models for contracts are provided, one for the public buildings and another for the public lighting. Since necessary back up legislation is adopted this year, first agreements are expected to be signed. Regarding the buildings sector, this policy instrument is supporting energy efficiency improvement in the public sector.

Strategy of science and technological development of the Republic of Serbia for the period 2010-2015 (Government of the Republic of Serbia, 2010a) identified **Energy and Energy Efficiency** as one of the top priorities in the domain of science and technology in Serbia. This priority is supported partly through the co-funding of integral and interdisciplinary research in “energy efficiency of production, distribution and use of energy, with a special attention to improvement of energy efficiency in buildings” and partly through the funding of projects in Program of technological development (The Ministry of Education, Science and Technological Development, 2010). Data about the outcomes of ongoing and realized projects, and their effects to energy efficiency in buildings are not available. No specific technology is supported.

Overview of policy instruments in the Transport sector

Compared to the buildings sector, policy instruments for increasing energy efficiency in the transport sector are less developed. It should be noticed that in the Program for financing measures for energy efficiency improvement from the Budget fund measures related to the transport sector have not been included (Ministry of Energy, Development and Environment 2014h).

Improvement of bicycle and pedestrian infrastructure is aimed to reduce transport by private own cars in cities. There are no officially available documents about energy savings achieved by this policy instrument or about cost efficiency.

Traffic calming as policy instrument was developed with an aim to reduce and slow intensity of road traffic. Objective of this policy instrument is to ensure an increase of quality of transport intensity and safety, by changes in road geometry and placement of proper traffic equipment, pavement markings and traffic signs. Traffic calming measures are developed to ensure reduction of vehicle speed. Data about cost efficiency and energy savings are not available.

Traffic management system is targeting problem of traffic organization and transport infrastructures in all transport modes. Regarding results related to traffic management system implementation on road transport, it shown that, after implementation of different measures the increase of traffic flow was up to 25% and the travel time reduction was up to 25%. Reduction of energy consumption was almost 30% (Public Enterprise "Roads of Serbia, 2009).

Fuel Quality Standards prescribe technical and other requirements to be met by petroleum based liquid fuels which are used in internal combustion engines, which are as fuels placed on the market of the Republic of Serbia. It also defines method for assessment of compliance (of selected fuel) with standards (Ministry of Energy, Development and Environment, 2013a). There are no official data on increasing energy efficiency related to increased quality of fuels used in the transport sector.

Fuel economy standards/vehicle CO_2 - emission standards is regulatory and mandatory policy instrument. All new imported vehicles need to be equipped with engines that meet at least Euro 5 standard (Government of the Republic of Serbia, 2013b), while for the import of used vehicles minimum Euro 3 standard is required (Government of the Republic of Serbia, 2010b). Official data about energy savings are not available. This policy instrument supports efficiency of vehicles.

1.3 Market Perspectives due to Technological Trends

According to the World Bank, investments into energy efficiency improvement in essentially social public buildings in Serbia had a catalytic effect on local markets by demonstrating the exemplary role of the Government to the private sector and general public, while at the same time stimulating nascent markets for energy efficiency goods and services.[1] A number of government and donor-funded programs have been initiated over the past decade to demonstrate the viability of EE investments in public and residential buildings. However, implementation has remained fragmented and piecemeal (World Bank, 2014).

Some data about cost-effectiveness for retrofitting public buildings were reported in (Kogalniceanu, 2011). Serbia has introduced a very comprehensive set of measures for schools, hospitals and public welfare buildings. In 27 bildings was invested aprox €40.9 milion. Annual energy consumption was

[1] World Bank http://documents.worldbank.org/curated/en/2013/10/18477181/serbia-energy-efficiency-ee-project

reduced by more than 39 % at investment costs of around 35 €/m^2. In hospitals, the annual energy demand for space heating was reduced by 43.8 % through investments with costs ranging from 21.1 to 58.8 €/ m^2 (Kogalniceanu, 2011).

Analysing effects of investments in energy efficiency (Eric and Babin, 2013) concluded that energy efficiency improvement financed by the public debt increase, would not have positive effects only on trade balance, i.e. decrease of energy imports. Local companies and labour force would increase economic growth and improve budgetary stance by revenue increase. Such investments would especially stimulate the demand for the construction material, which is mostly made locally. Therefore, it can be expected not only energy efficiency improvement, but also increase in GDP and decrease in unemployment.

The investments in energy efficiency has the potential to create 5,000 to 8,000 jobs by 2030, depending on the specific policies implemented (UNDP, 2013). Of these, 2,000 to 3,000 would be created in the residential, commercial and industrial sectors and the remainder in the transport sector. According to the International Trade Union Confederation (ITUC, 2012), more conventional investments could create up to 80 jobs per €1 million invested, leading to the potential creation of 6,000 jobs during the initial years of investment. On the other hand, job creation would be limited if transport energy efficiency improvements would be achieved only through the impor of new passenger vehicles. (UNDP, 2013).

Overwiev of invesments in energy efficiency conducted for 2013 has shown that sorces of financing were as follows: regional loan funds, country loan funds with technical assistants grants, country mixed EE loan, country grant funds (Western Balkan Investing Framework, 2013).

The World Bank`s report Western Balkans: Scaling Up Energy Efficiency in Buildings (World Bank, 2014) has assessed energy efficiency market as undeveloped and proposed financing options for all sub sectors. For the residential sector the four major financing options are as follows: EE funds, commercial bank financing (credit lines), partial credit guarantees for commercial financing, utility EE credit programs (on-bill financing). For the public buildings proposed financial options are: Ministry of Finance financing with budget capture, EE revolving funds or public ESCOs. Generally speaking, it can be concluded that the market perspective for energy efficiency technologies is likely to become more positive, as soon as the Government installs or gives clear support to viable financing options.

By establishing legal framework for operation of ESCO (Government of the Republic of Serbia, 2013a), (Ministry of Mining and Energy, 2015c) additional investments in in energy efficiency improvement are expected. Still, there are no active ESCO projects in Serbia.

Data for the Buildings Sector

Reliable official data about energy consumption are provided by Statistical Office of the Republic of Serbia, which is in charge for the country`s energy statistics. Data about final energy consumption are reported for overall sectors, while additional information regarding consumption in subsectors or more detailed structure are not available. (World Bank, 2014) has reported as one of the key obstacles poor data on baseline energy use.

Available data regarding technologies for energy efficiency improvement in buildings are presented in tables 3-23. Some data about cost effectiveness of proposed technologies are available for building envelope improvements only.

Table 2: Existing building stock by subsector and structure of final energy consumption

<table>
<tr><td>Technology</td><td></td></tr>
<tr><td></td><td>
Residential sector:

Space heating types (Lilić, 2007)

District heating 14%
Local boilers 12%
Electrical resistance heaters 14%
Natural gas 10%
Solid fuels in stoves and furnaces 50%

Air conditioning (how many households use air conditioning?)
Data not available
Water heating (how many households use which water heating systems?)
Data not available

Single family houses (Jovanović Popović M. et al., 2012)
<table>
<tr><td>Total m²</td><td>Stock</td><td>New buildings</td></tr>
<tr><td>176,048,838</td><td></td><td></td></tr>
</table>
Multi-family[2] houses (Jovanović Popović M. et al., 2012)
<table>
<tr><td>Total m²</td><td>Stock</td><td>New building</td></tr>
<tr><td>113,638,882</td><td></td><td></td></tr>
</table>
Commercial/services sector:

Space heating
Data about stucure of the heating sources used for heating in comercial/services sector are not available
Air conditioning
Data about percentage of biuldings that have air conditioning systems are not availabe
Water heating
No available data about water heating systems structure

</td></tr>
</table>

[2] Multi-family houses is a classification of housing where multiple separate housing units for residential inhabitants are contained within one building or several buildings within one complex. A common form is an apartment building. Sometimes units in a multifamily residential building are condominiums, where typically the units are owned individually rather than leased from a single apartment building owner. Source: en.wikipedia.org

<table>
<tr>
<td></td>
<td>
Public sector buildings (Encoler, 2012)
<table>
<tr><td>Total [million m^2]</td><td>Stock</td><td>New buildings</td></tr>
<tr><td>41</td><td></td><td></td></tr>
</table>
Commercial sector buildings (Encoler, 2012)
<table>
<tr><td>Total [million m^2]</td><td>Stock</td><td>New buildings</td></tr>
<tr><td>18</td><td></td><td></td></tr>
</table>
Additional data regarding energy consumption in public and commercial sectors are not available.
</td>
</tr>
</table>

1.3.1 Building envelope

Available data regarding isolation of building envelope and implementation of low U windows, including anticipated advantages and disadvantages are presented in tables 3 and 4. Aim of proposed measures is decrease of annual energy needed for heating and cooling. Proposed measures are influencing energy performance of building by lowering heat transfer coefficients.

Cost effectiveness of building`s envelope improvement for some types of houses in existing building stock in the residential sector is analysed in (Jovanovic et al. 2013). It was shown that for different retrofit scenarios (depending of quality of walls insulation and/or low U-value windows), and depending of fuel used for heating, payback period is in interval from 6 to over 30 years.

Table 2: Building exterior wall insulation

Sector	Buildings
Sub-Sector	Residential sector, commercial sector, public sector
Category	Space heating / air conditioning
Technology	Walls insulation
Origin of technology	National product (% of imports?) N/A
Cost of purchase	13 €/m^2 (depends on type of isolation)[3]
Cost per kWh	-
Average energy consumption (kWh/a)	-
Advantages / disadvantages of use	Advantages are reduced energy consumption for heating and cooling, prevention of condensation in the walls and on interior surface of walls and improved comfort. Potential problems with specific façade types e.g. the buildings with façade brick cladding,

[3] www.fasade.co.rs (30.07.2015)

	which is technically difficult to re-apply; in this case it is possible to use special market ready systems in which ceramic cladding as the final façade layer has integrated thermal insulation (Popovic, Ignjatovic et al. 2012).
Easiness to use	Generally easy to apply (Popovic, Ignjatovic et al. 2012).

Table 3: Low U-value windows

Sector	Buildings
Sub-Sector	Residential sector, public sector, commercial sector
Category	Space heating/air conditioning
Technology	Low U-value windows
Origin of technology	National product. Percentage of imported materials and prefabricates is unknown.
Cost of purchase	From [4] 95 €/m^2
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Advantages are reduced energy consumption for heating and cooling and improved comfort since temperatures of radiating surfaces e.i. windows have values closer to optimal. Disadvantages may include condensation on new windows (Carmody, 2000).
Easiness to use	Generally easy to apply.

1.3.2 Heating systems

Available data regarding technologies for heating systems with enhanced efficiencies, including anticipated advantages and disadvantages are presented in tables 5 to 10. Aim of proposed measures is decrease of annual energy needed for heating by increasing efficiency of the heating system.

Table 4: Gasification wood boilers

Sector	Buildings
Sub-Sector	Residential sector
Category	Space heating

[4] www.ibcapital.rs (30.07.2015.)

Technology	Gasification wood boilers
Origin of technology	Imported
Cost of purchase	25 kw ~ 1600 €; 45kw ~ 2000 €[5]
Cost per kWh	Depends on price and quality of firewood
Average energy consumption (kWh/a)	Average energy consumption for heating in households in Serbia is around 160 kWh/m^2a (Econoler, 2012)
Advantages / disadvantages of use	The wood log gasification boiler is the most efficient type of wood log boiler available on the market (SEAI, 2015) Purchase price is more than two times higher comparing to conventional solutions[6].
Easiness to use	Easy to use and maintain.

Table 5: Condensing boilers

Sector	Buildings
Sub-Sector	Residential sector
Category	Space heating
Technology	Condensing boilers (gas fuel)
Origin of technology	Imported
Cost of purchase	22 kw ~ 900 €[7];
Cost per kWh	0,036 € (Depends on the cost of natural gas[8]).
Average energy consumption (kWh/a)	Average energy consumption for heating in households in Serbia is around 160 kWh/m^2a (Econoler, 2012)
Advantages / disadvantages of use	Maximal possible efficiency for gas heating. At the moment, purchase price is almost equal to conventional – non condensing gas boilers[9].
Easiness to use	Easy to use and maintain.

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[5] www.etazgrejanje.com (30.07.2015)

[6] www.etazgrejanje.com (30.07.2015)

[7] www.vailant.rs, (30.07.2015)

[8] www.srbijagas.co.rs, www.novisadgas.rs (30.07.2015)

[9] www.eponuda.com; www.etazgrejanje.com (30.07.2015)

Table 6: Heat pumps

Sector	Buildings
Sub-Sector	Residential sector
Category	Space heating
Technology	Heat pump
Origin of technology	Imported
Cost of purchase	Source and site dependant. For geothermal heat pumps, price of drilling varies from 15 €/m to more than 100 €/m, depending on the type of soil and total drilling depth.[10] Heat pump prices ranges from 10 €/m^2 of heated space[11].
Cost per kWh	Price of electricity is around 0,08 €/kWh [12]. Heat pump COP depends on type and boundary conditions. Price of kWh of heat from HP = (price of electrical energy)/(heat pump COP)
Average energy consumption (kWh/a)	Average energy consumption for heating in households in Serbia is around 160 kWh/m^2a (Econoler, 2012)
Advantages / disadvantages of use	Renewable energy based system. Geothermal heat pumps require additional investment costs for drilling. Air to water heat pumps have lower COP in wintertime (Sauer and Howell, 1983), (Cengel, Boles et al. 2002). Requires expertize for planning and optimization of heating system in order to operate properly over the span of time. Current prices of electricity and heat pumps make heat pump costs recovery period too long comparing with electrical heating.
Easiness to use	Requires low temperature heating system (e.g. floor heating) for optimized performance

[10] www.srbijabunar.com, www.busenje-bunara.com, geosonda-fundiranje.rs (30.07.2015)

[11] www.etazgrejanje.com; www.vailant.rs; www.artel.rs, (30.07.2015)

[12] www.servisinfo.com/cena-struje (30.07.2015)

	(Hepbasli and Kalinci, 2009).

Table 7: VFD for circulating pumps

Sector	Buildings
Sub-Sector	Residential sector, public and commercial sector
Category	Space heating
Technology	VFD for circulating pumps
Origin of technology	Imported
Cost of purchase	From around 600 € for 5 kW VFD to 7000 € for 130 kW VFD [13].
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Electricity savings for pumping are around 70% to 90%[14]. Electricity prices in Serbia make payback period too long[15].
Easiness to use	Needs engineering expertise in design phase.

Table 8: Thermostatic valves

Sector	Buildings
Sub-Sector	Residential sector, public and commercial sector
Category	Space heating
Technology	Thermostatic valve
Origin of technology	Imported
Cost of purchase	Around 15 €[16]
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Can save up to 20% of heating energy (Ristanovic, M., 2015). Very robust appearance comparing to simple

[13] www.indas.rs, (30.07.2015)

[14] www.buildinggreen.com, (30.07.2015)

[15] www.servisinfo.com/cena-struje, (30.07.2015)

[16] www.etazgrejanje.com (30.07.2015)

	valves.
Easiness to use	Easy to use.

Table 9: Room controllers for central heating system

Sector	Buildings
Sub-Sector	Residential sector, public and commercial sector
Category	Space heating
Technology	Room controllers for central heating system
Origin of technology	Imported
Cost of purchase	From 80 to 200 €[17].
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Can achieve high energy savings, but requires knowledge for proper device selection (if it has or does not have weather compensating control). (Ristanovic, M., 2015).
Easiness to use	Moderate ease of use.

1.3.3 Cooling

Available data regarding technologies for cooling systems with enhanced efficiencies, including anticipated advantages and disadvantages are presented in table 11. Aim of a proposed measure is decrease of annual energy needed for cooling by increasing efficiency of the applied system.

Table 10: Split systems with inverter technology

Sector	Buildings
Sub-Sector	Residential sector, public and commercial sector
Category	Cooling
Technology	Split systems with inverter technology
Origin of technology	Imported
Cost of purchase	From 400 €[18].
Cost per kWh	Depends on price of electricity and device COP
Average energy consumption (kWh/a)	No data on average energy consumption for

[17] www.grejanje.com, (30.07.2015)

[18] www.eponuda.com, (30.07.2015)

	cooling in residential or tertiary sector in Serbia
Advantages / disadvantages of use	At least 30% to 50% cheaper run, as it consumes less power[19]. It is several times more expensive than split system without inverter. Therefore payback period is reasonable only for excessive use and not for very small units[20].
Easiness to use	Easy to use.

1.3.4 Mechanical Ventilation Systems

Available data regarding technologies for ventilating systems with enhanced efficiencies, including anticipated advantages and disadvantages are presented in tables 12 to 14. Aim of proposed measures is decrease of annual energy needed for ventilating by increasing efficiency of the applied system.

Table 11: VAV systems

Sector	Buildings
Sub-Sector	Public and commercial sector
Category	Mechanical Ventilation Systems
Technology	VAV systems
Origin of technology	Imported (% of national production of system devices is unknown)
Cost of purchase	Depends on the system (includes devices like VFD, bypass boxes, VAV boxes etc.)
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Can achieve high energy savings (Sekhar, 1997).
Easiness to use	Demands expertise un HVAC and control systems design.

Table 12: Economizer systems

Sector	Buildings
Sub-Sector	Public and commercial sector
Category	Mechanical Ventilation Systems

[19] www.airconditioner.me.uk, (30.07.2015)

[20] www.eponuda.com, (30.07.2015)

Technology	Economizer systems
Origin of technology	
Cost of purchase	Depends on the system
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Using outside air for free cooling when conditions are favourable (Brandemuehl and Braun, 1999). Increased investment costs for ventilation systems.
Easiness to use	Demands expertise un HVAC and control design.

Table 13: Heat recovery from exhaust air (heat exchanger)

Sector	Buildings
Sub-Sector	Public and commercial sector
Category	Ventilation
Technology	Heat recovery from exhaust air (heat exchanger)
Origin of technology	National
Cost of purchase	Recuperator price depends on the size and efficiency[21].
Cost per kWh	0 €
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Reduces energy consumption for heating and cooling.
Easiness to use	Easy to use.

1.3.5 DHW preparation

Available data regarding technologies for domestic hot water preparation with enhanced efficiencies, including anticipated advantages and disadvantages are presented in tables 15 to 19. Aim is decrease of annual energy needed for domestic hot water preparation.

Table 14: DHW preparation with district heating (Centralized supply)

Sector	Buildings
Sub-Sector	Residential & tertiary sector
Category	domestic hot water preparation

[21] www.jakkagroup.com, (30.07.2015)

Technology	DHW preparation with district heating
Origin of technology	
Cost of purchase	
Cost per kWh	About 0,06 €/kWh[22]
Average energy consumption (kWh/a)	For DHW preparation in households - 966 kWh/a (Stojiljkovic and Todorovic, 2015)
Advantages / disadvantages of use	Using lower grade energy (than electricity) for DHW heating leads to reduced conversion losses in the energy system. Unreliable operation of DH companies. Higher possibility of contamination of water in storage tanks (Engineers, 2015) ,(CeSID 2011).
Easiness to use	Easy to use.

Table 15: Gas water heaters with storage tank

Sector	Buildings
Sub-Sector	Residential, public and commercial sector
Category	domestic hot water preparation
Technology	Gas water heaters with storage tank
Origin of technology	
Cost of purchase	From 300 € (www.etazgrejanje.com)
Cost per kWh	0,036 € (Depends on the cost of natural gas[23])
Average energy consumption (kWh/a)	For DHW preparation in households - 966 kWh/a (Stojiljkovic and Todorovic 2015)
Advantages / disadvantages of use	Lower conversion losses in the energy system (compared to electrical water heaters). Requires connection to gas network or gas storage tank.
Easiness to use	Easy to use.

Table 16: Combined water heaters (kombi boilers)

Sector	Buildings
Sub-Sector	Residential, public and commercial sector

[22] www.beoelektrane.rs, (30.07.2015)

[23] www.srbijagas.co.rs, www.novisadgas.rs (30.07.2015)

Category	domestic hot water preparation
Technology	Combined water heaters (or kombi boilers)
Origin of technology	
Cost of purchase	From 400 €[24]
Cost per kWh	
Average energy consumption (kWh/a)	For DHW preparation in households - 966 kWh/a (Stojiljkovic and Todorovic 2015)
Advantages / disadvantages of use	Using hot water from central heating network for domestic hot water preparation during heating season. Needs additional plumbing.
Easiness to use	Easy to use.

Table 17: Solar DHW preparation system

Sector	Buildings
Sub-Sector	Residential & tertiary sector
Category	DHW preparation
Technology	Solar DHW preparation system
Origin of technology	
Cost of purchase	1300 € for 200 l system; 2020 € for 300 l system etc.[25]
Cost per kWh	0 €
Average energy consumption (kWh/a)	For DHW preparation in households - 966 kWh/a (Stojiljkovic and Todorovic 2015)
Advantages / disadvantages of use	Enables using of solar energy source for DHW preparation. Solar energy is intermittent heat source, hence system needs backup energy source (e.g. gas or electricity). With current electricity prices, for average household, payback period is not reasonable.
Easiness to use	Moderate – can cause lack of hot water in the morning hours if not properly backed up with gas or electrical water heating.

[24] www.itim.rs, www.eponuda.rs, (30.07.2015)

[25] www.solarni-kolektori.net, www.solarnisistemi.rs, (30.07.2015)

Table 18: Air to water heat pump

Sector	Buildings
Sub-Sector	Residential, public and commercial sector
Category	domestic hot water preparation
Technology	Air to water heat pump
Origin of technology	
Cost of purchase	400 € for 200 l system; 2020 € for 300 l system etc.[26]
Cost per kWh	Depends on COP (which depends on device and operating conditions)
Average energy consumption (kWh/a)	For DHW preparation in households - 966 kWh/a (Stojiljkovic and Todorovic 2015)
Advantages / disadvantages of use	Enables usage of non-intermittent RES for DHW preparation. Electricity prices in Serbia cause too long payback period.
Easiness to use	Easy to use.

1.3.5.1 Lightning

Available data regarding technologies for efficient lighting with anticipated advantages and disadvantages are presented in tables 20 and 21. Aim of proposed measures is decrease of annual energy needed by applying efficient light bulbs and introduction of occupancy sensors.

Table 19: Energy efficient light bulbs

Sector	Buildings
Sub-Sector	Residential, public and commercial sector
Category	Lightning
Technology	Energy efficient light bulbs
Origin of technology	Imported
Cost of purchase	2 to 10 €[27]
Cost per kWh	
Average energy consumption (kWh/a)	Residential average: 294 kWh/a
Advantages / disadvantages of use	Produces 60 lm/W or more, compared to 16 lm/W from incandescent bulbs[28].

[26] www.protem.co.rs, (30.07.2015)

[27] www.winwin.rs, (30.07.2015)

	Several times more expensive than incandescent bulbs.
Easiness to use	Easy to use.

Table 20: Occupancy sensors

Sector	Buildings
Sub-Sector	Public and commercial sector
Category	Lightning
Technology	Occupancy sensors
Origin of technology	Imported
Cost of purchase	7 €[29].
Cost per kWh	
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Enables lightning control based on occupancy (lights are off if space is vacant).
Easiness to use	Easy to use.

1.3.6 Cooking

Available data regarding technologies for cooking with enhanced efficiencies, including anticipated advantages and disadvantages are presented in tables 22 to 23. Aim of proposed measures is decrease of annual energy needed for cooking by introducing efficient appliances and avoiding conversion losses.

Table 21: Microwave oven

Sector	Buildings
Sub-Sector	Residential and public and commercial sector
Category	Cooking
Technology	Microwave oven
Origin of technology	Imported
Cost of purchase	From 50 € [30]
Cost per kWh	

[28] eartheasy.com, (30.07.2015)

[29] www.eponuda.com, (30.07.2015)

[30] www.tehnomanija.com (30.07.2015)

Average energy consumption (kWh/a)	Residential average: 1260 kWh/a (Stojiljkovic and Todorovic 2015)
Advantages / disadvantages of use	Uses less electricity for cooking than any other electrical cooking device[31]. Suitable only for specific purposes[32].
Easiness to use	Moderate ease of use.

Table 22: Gas cookers

Sector	Buildings
Sub-Sector	Residential and tertiary sector
Category	Cooking
Technology	Gas cookers
Origin of technology	Imported
Cost of purchase	Similar to electric cookers
Cost per kWh	0,04 to 0,05 €/kWh[33]
Average energy consumption (kWh/a)	
Advantages / disadvantages of use	Decreased conversion losses compared to electrical cookers. Requires gas storage or connection to gas network.
Easiness to use	Easy to use.

[31] www.uswitch.com, (30.07.2015)

[32] World Health Organization (www.who.it), (30.07.2015)

[33] www.srbijagas.co.rs, (30.07.2015)

1.4 DATA FOR THE TRANSPORT SECTOR

Available data about measures aimed to improve efficiency in transport sector are presented in tables 24-28 and include: car sharing, eco driving, improved vehicle efficiency, start-stop systems and combined road-rail transport. There are no available data about cost effectiveness of proposed technologies.

Table 23: Car sharing

Sector	Transport
Sub-Sector	Passenger transport - System efficiency
Category	Road transport: • passenger transport: ○ short distance,
Technology	Car sharing is a model of car rental where persons rent cars for short periods of time, often by the hour. It is acceptable to customers who only occasionally use a vehicle, as well as others who need different type of vehicle compared to their own. Car sharing systems may be organized at the level of a company, community, or by commercial rentiers.
Origin of technology	It is based at experience from EU countries with some adaptation to local conditions[34]. Car sharing systems in Serbia[35] don't have significant place yet.
Cost of purchase	n/a
Cost per kWh	n/a
Average energy consumption (kWh/a)	n/a
Advantages / disadvantages of use	Advantages are: no vehicle maintenance, no registration or insurance costs, road assistance, a wide selection of vehicles depending on the needs, initial costs are lower. Disadvantages are: responsibility, consequences of potential damage, needs for reservations, long-term profitability[36].

[34] www.invers.com/en-eu/carsharing (30.07.2015)

[35] www.car4use.com (30.07.2015)

[36] www.spendingprofile.com/blog/2011/08/car-sharing-is-this-worth-it (30.07.2015)

Easiness to use	It is needed to make reservation before usage.

Table 24: Eco driving

Sector	Transport
Sub-Sector	Passenger transport - Travel efficiency
Category	Road transport: • passenger transport: ○ short distance,
Technology	**Eco driving**, driving techniques which can provide significant fuel savings. There are five basic rules to follow: Anticipate traffic flow, Maintain a steady speed at low RPM, Shift up early, Check tire, and Consider any extra energy consumer (air conditioner). Eco driving is similar with self-control fuel consumption.
Origin of technology	Experience from EU countries is applied with little adaptation to local conditions[37].
Cost of purchase	n/a
Cost per kWh	n/a
Average energy consumption (kWh/a)	n/a
Advantages / disadvantages of use	Advantages are related to decrease of fuel cost, reductions of GHG emissions, increased safety and comfort. Disadvantages of driving with low RPM causes possibility of engine failure.
Easiness to use	Eco driving represents a driving culture, not technical solution and is connected to the motivation and patience of drivers.

Table 25: New generation engines with increased efficiency

Sector	Transport
Sub-Sector	Passenger transport - Vehicle efficiency
Category	Road transport: • passenger transport: ○ car short distance, ○ car long distance, ○ bus,

[37] www.ecodrive.org (30.07.2015)

	○ coach,
Technology	Usage of vehicles with new generation engines.
Origin of technology	Limited imports of vehicles in accordance with the EU standards[38].
Cost of purchase	n/a
Cost per kWh	n/a
Average energy consumption (kWh/a)	n/a
Advantages / disadvantages of use	Imports of euro 6 for new and euro 4 for old vehicles, would have a positive impact on increasing the number of energy-efficient vehicles. Expected costs of purchase will increase. Renewing of vehicles require large initial investments. Long payback period.
Easiness to use	New vehicles provide higher level of comfort

Table 26: Start stop systems

Sector	Transport
Sub-Sector	Passenger transport - Vehicle efficiency
Category	Road transport: • passenger transport: ○ car short distance, ○ bus, ○ coach,
Technology	Usage of vehicles with start-stop system.
Origin of technology	Experience from EU is applied.
Cost of purchase	n/a
Cost per kWh	n/a
Average energy consumption (kWh/a)	n/a
Advantages / disadvantages of use	Benefit is the reduction of fuel consumption up to 10% in urban areas. The adverse impact on engine[39].
Easiness to use	Does not affect the reduction in driving comfort. Potentially increases maintenance costs.

[38] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:l28186 (30.07.2015)

[39] www.autocar.co.uk/car-news/new-cars/stop-start-long-term-impact-your-car-s-engine (30.07.2015)

Table 27: Combined road-railway freight transport

Sector	Transport
Sub-Sector	Freight transport - System efficiency

Category	Road transport:
	• freight service:
	  ○ truck
	Rail transport
	• freight service:
	  ○ short distance,
	  ○ long distance,

Technology	Combined road-railway freight transport
Origin of technology	Both transport systems are developed and optimized based on past experience[40].
Cost of purchase	n/a
Cost per kWh	n/a
Average energy consumption (kWh/a)	n/a
Advantages / disadvantages of use	Advantages are related to achieving advantages of rail and road transport simultaneously. Disadvantages are related to potential problems with waiting time and breakdowns and the necessity of container packing.
Easiness to use	Good organization is needed

40 http://www.zeleznicesrbije.com/system/en/home/newsplus/viewsingle/_params/newsplus_news_id/26178.html (30.07.2015)

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