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TRACE TOOL USABILITY ASSESSMENT OF ENERGY EFFICIENCY MEASURES FOR LOCAL ENERGY AUTONOMY PROMOTION

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Abstract. This paper addresses the local communities' engagement towards the energy autonomy by promoting energy efficiency and massive use of renewable energy sources. Based on software called Tool for Rapid Assessment of City Energy there are presented an objective way of energy consumption sectors prioritisation in order to implement energy efficiency measures. Software usage facilitates the decision-making process at the community level in order to choose the priority sectors to be included in the local energy efficiency action plan. The examined tool covers analysis of four main sectors: buildings, transport, utilities and industry. According to the method presented, energy efficiency level in a particular sector is considered based on the sector specific key performance indicator benchmarking with the same indicator in a peer city. The sectors prioritization is performed based on the total score, calculated as the product of the energy savings potential, annual fuel expenditures and the degree of the city authority control over the sector.

Keywords: *energy efficiency action plan, energy management system, key performance indicators, peer city benchmarking, potential energy savings, relative energy intensity, renewable energy sources.*

Introduction

Climate change fighting and sustainable development is a high priority promoted worldwide by the United Nations (UN) and the European Union (EU). At the UN Summit on September 25, 2015 in New York, the General Assembly adopted the resolution „*Transforming our World: The 2030 Agenda for Sustainable Development*" [1]. At the XXIth Conference of the Parties (CoP) to the United Nations Framework Convention on Climate Change, held on December 12, 2015 in Paris, the world countries agreed to contribute to reducing the greenhouse gas emissions (GHG) to limit the increase of the global average temperature below 2 °C compared to the pre-industrial period; the adopted document is officially known as the *Paris Agreement* [2]. On December 11, 2019, the European Commission presented European Green Deal, which is committing the EU to achieve the climate neutrality (net-zero neutrality) by 2050 [3]. The proposed initiative includes the need for an energy directives amendment, allocation of more investments to combat the climate change, formulation of new strategies to integrate the sustainable development concept into all energy consuming sectors and increasing the capacity of local and regional communities, including energy communities. The local communities play an important role in the global energy transition. In 2008, as a response to the *EU's 2020 Energy and Climate Package* [4], that stands for: (i) 20% reduction in greenhouse gas emissions from 1990 levels; (ii) improving energy efficiency by 20%; (iii) and 20% of energy from renewable sources, the European Commission has launched the *Covenant of Mayors*. In 2013, the Covenant of Mayors was included in the *EU's Climate Change Adaptation Strategy*, by launching a voluntary commitment to adopt local adaptation strategies and awareness-raising activities [5]. In 2016, the EU Covenant of Mayors for Climate and Energy and the Compact of Mayors, a global coalition of mayors and local authorities launched in September 2014 by UN Secretary-General to commit in reducing local GHG emissions, *merged into the most ambitious initiative of local communities* committed to combating climate change - the *Global Covenant of Mayors for Climate and Energy* [6]. In this article, the energy management issue is addressed, in terms of the energy efficiency measures implementation priority in the administrative-territorial units, using practical tools, as a first step in the way towards local energy autonomy.

1. Practical tools for the energy efficiency measure implementation and analysis

1.1. Energy Management Information System

Energy Management Information System - EMIS is a web application to monitor and analyse the energy and water consumption in public sector buildings. Application use consists in the introduction by the operator of static information about buildings (e.g.: surfaces, volume, physical characteristics, etc.) and dynamic information that is present in utility bills (e.g.: energy and water consumption, tariffs, monthly expenditures etc.). Dynamic information can also be introduced for shorter intervals than monthly (weekly, daily, hourly), including remote reading of meter indications. It is possible to calculate different energy performance indicators based on the data introduced in EMIS, what allows a better understanding of how energy is consumed. In addition, EMIS allows the graphical visualization of the energy performance of a selected building and compare the results with similar buildings, in order to identify unwanted, excessive and irrational consumption, to finally develop the most suitable energy efficiency measures, see Figure 1.

Figure 1. Energy Management Information System interface [7].

EMIS is currently officially used to collect data on energy consumption in the public buildings and street lighting sector in Croatia, Serbia, Bosnia and Herzegovina. In the Republic of Moldova there is a pilot project on the use of EMIS in Chisinau.

1.2. Monitoring and Verification Platform

Monitoring and Verification Platform (MVP) is a web tool that allows users to monitor and verify the energy efficiency measures, implemented in accordance with the National Energy Efficiency Action Plan (NEEAP). The MVP also offers the possibility of local energy efficiency action plans integrating.

The tool collects information on energy savings (kWh), GHG reduction (t CO_2) and the cost of each energy efficiency measure (EUR) in four main sectors: residential, industry, commercial and transport.

The final and primary energy savings, as well as the reduction of GHG emissions are calculated based on the engineering formulae integrated in the software, what are displayed to visualise.

The calculation formulae are adjusted depending on the type of energy efficiency measure analysed. MVP includes 46 predefined energy efficiency measures and allows the application of multiple filters and graphical views - Figure 2.

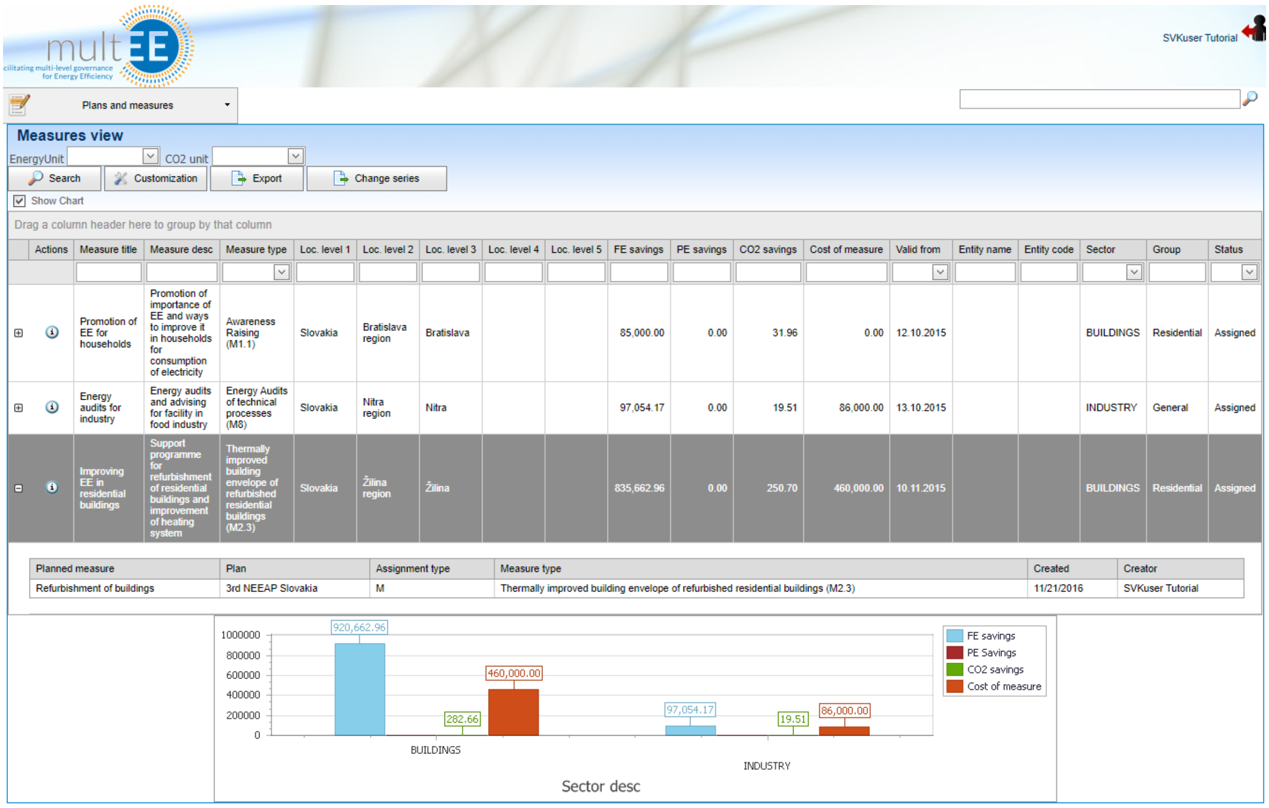


Figure 2. Monitoring and Verification Platform interface [8].

Currently MVP is implemented in the European Union member states and Energy Community contracting parties, being developed within the Horizon 2020 research project - *Facilitating Multi-level Governance for Energy Efficiency*. In the Republic of Moldova, the MVP is piloted by the Agency Efficiency Energy with the support of the Energy Community Secretariat.

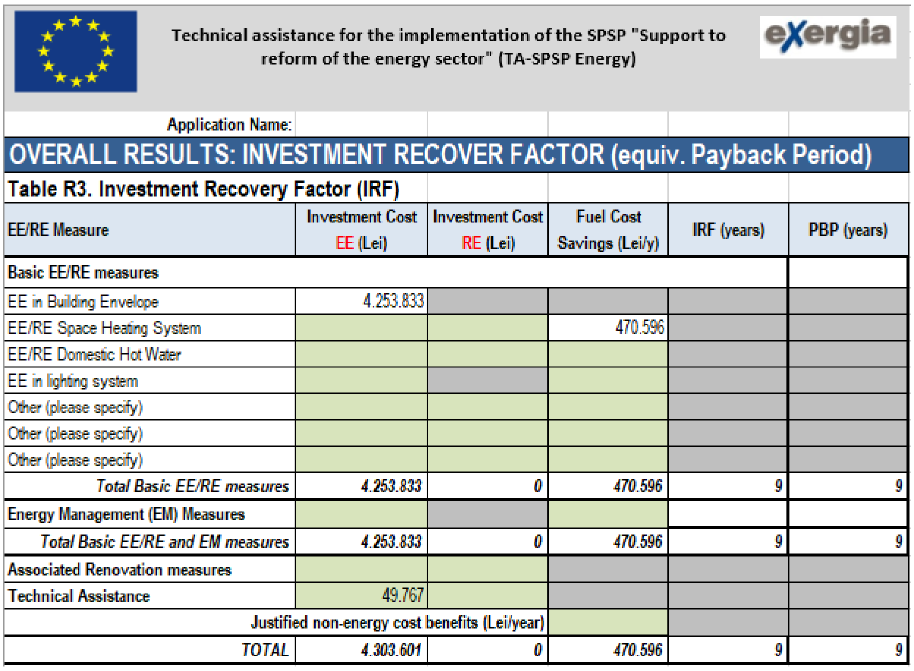
1.3. Energy Efficiency Fund Calculation Software for Buildings

Calculation Software for Buildings is a tool for the energy savings calculation, what had been used by the Energy Efficiency Fund to evaluate the project proposals in the public buildings sector.

The tool is based on the Microsoft Excel use in what the building energy balance calculation formulae are integrated. The calculation methodology is based on standard *SM SR EN ISO 13790:2011 Energy performance of buildings - Calculation of energy use for space heating and cooling*, with some simplifications to facilitate calculations.

The use of the software requires information about the analysed building before energy efficiency measures implementation (e.g.: surfaces, volume, physical characteristics, etc.), information on the cost of energy efficiency measures and heat transfer characteristics before and after energy efficiency measures application.

The software presents the calculated energy savings, the required investments for each measure, the operational costs reduction and the main energy performance indicators. Finally, the simple payback period is calculated, what was one of the eligibility criteria for projects financing by the Fund - Figure 3.


Technical assistance for the implementation of the SPSP "Support to reform of the energy sector" (TA-SPSP Energy)

exergia

Application Name:

OVERALL RESULTS: INVESTMENT RECOVER FACTOR (equiv. Payback Period)

Table R3. Investment Recovery Factor (IRF)

EE/RE Measure	Investment Cost EE (Lei)	Investment Cost RE (Lei)	Fuel Cost Savings (Lei/y)	IRF (years)	PBP (years)
Basic EE/RE measures					
EE in Building Envelope	4.253.833				
EE/RE Space Heating System			470.596		
EE/RE Domestic Hot Water					
EE in lighting system					
Other (please specify)					
Other (please specify)					
Other (please specify)					
Total Basic EE/RE measures	*4.253.833*	*0*	*470.596*	*9*	*9*
Energy Management (EM) Measures					
Total Basic EE/RE and EM measures	*4.253.833*	*0*	*470.596*	*9*	*9*
Associated Renovation measures					
Technical Assistance	49.767				
Justified non-energy cost benefits (Lei/year)					
TOTAL	*4.303.601*	*0*	*470.596*	*9*	*9*

Figure 3. Energy Efficiency Fund Calculation Software for Buildings interface [9].

Calculation Software for Buildings was developed within *The Technical Assistance Project for the Implementation of the Sector Policy Support Program: „Energy Sector Reform Assistance” (AT-PSPS Energy Project).*

1.4. Buildings Energy Performance Calculation Tool

Buildings Energy Performance Calculation Tool is used to calculate the energy performance of buildings in accordance with the *Law no. 128/2014 on the energy performance of buildings*, in order to issue the building energy performance certificate. The software is based on Microsoft Excel, being similar to Calculation Software for Buildings - Figure 4.

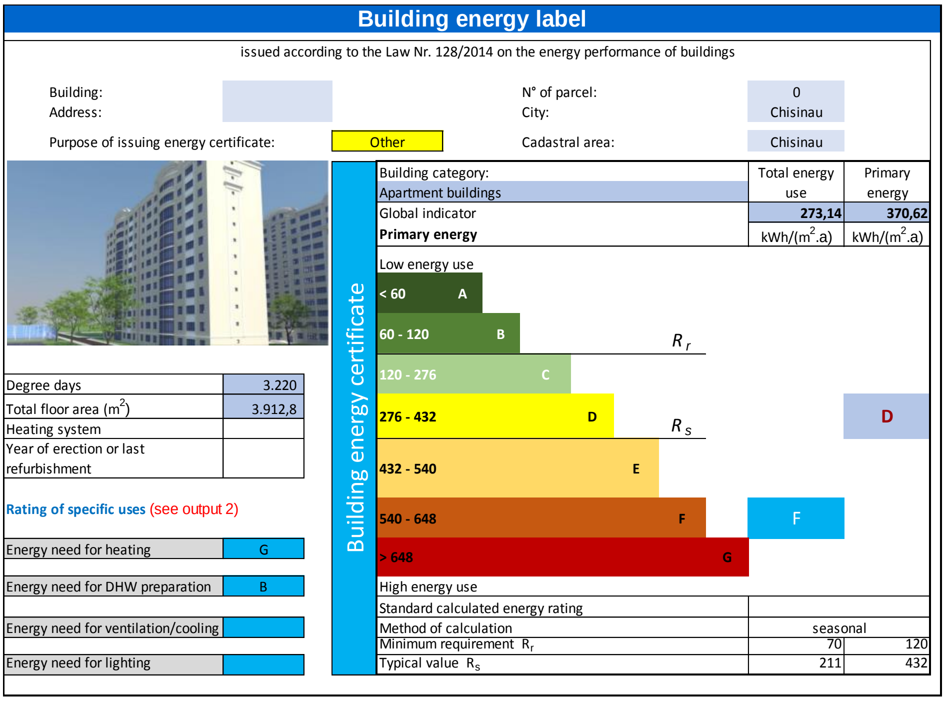


Figure 4. Buildings Energy Performance Calculation Tool interface [10].

The software integrates the building energy balance calculation formulae, what is largely based on the standard *SM SR EN ISO 13790: 2011 Building energy performance. Calculation of energy consumption for heating and cooling*.

Tool use involves entering the information about the building (e.g.: surfaces, volume, physical characteristics, etc.), separately for each heat transfer element of the envelope, including thermal bridges.

Also are required the technical characteristics of the building's engineering systems: heating and domestic hot water system, ventilation, lighting and cooling.

1.5. Sustainable Energy and Climate Action Plan Tool

Sustainable Energy and Climate Action Plan Tool is a software used by local communities, signatories to the Covenant of Mayors, designed to develop Sustainable Energy and Climate Action Plan, what aims at the voluntary commitment to reduce GHG emissions by 2030 and the implementation of adaptation to climate change.

The tool covers most of the sectors in what energy is consumed: buildings; transport; industry; agriculture; waste, which are further divided into other subcategories.

The tool is based on the Microsoft Excel use, being similar to others Microsoft Office programming environment and is uploaded on an online platform.

The tool allows graphic visualisations and export of data to other applications - Figure 5. Tool use involves drawing up the carbon dioxide baseline emission inventory, by entering information on the final energy consumption by type in each sector and assuming specific emission factors. The user assesses the risks associated with climate change, adaptability and the impact on vulnerable groups of the population. The climate change mitigation and adaptation measures choice take place through the tool.

Sustainable Energy and Climate Action Plan Tool instructions and the GHG emissions reduction calculation methodology are given in the *Guidebook 'How to develop a Sustainable Energy and Climate Action Plan'* [12].

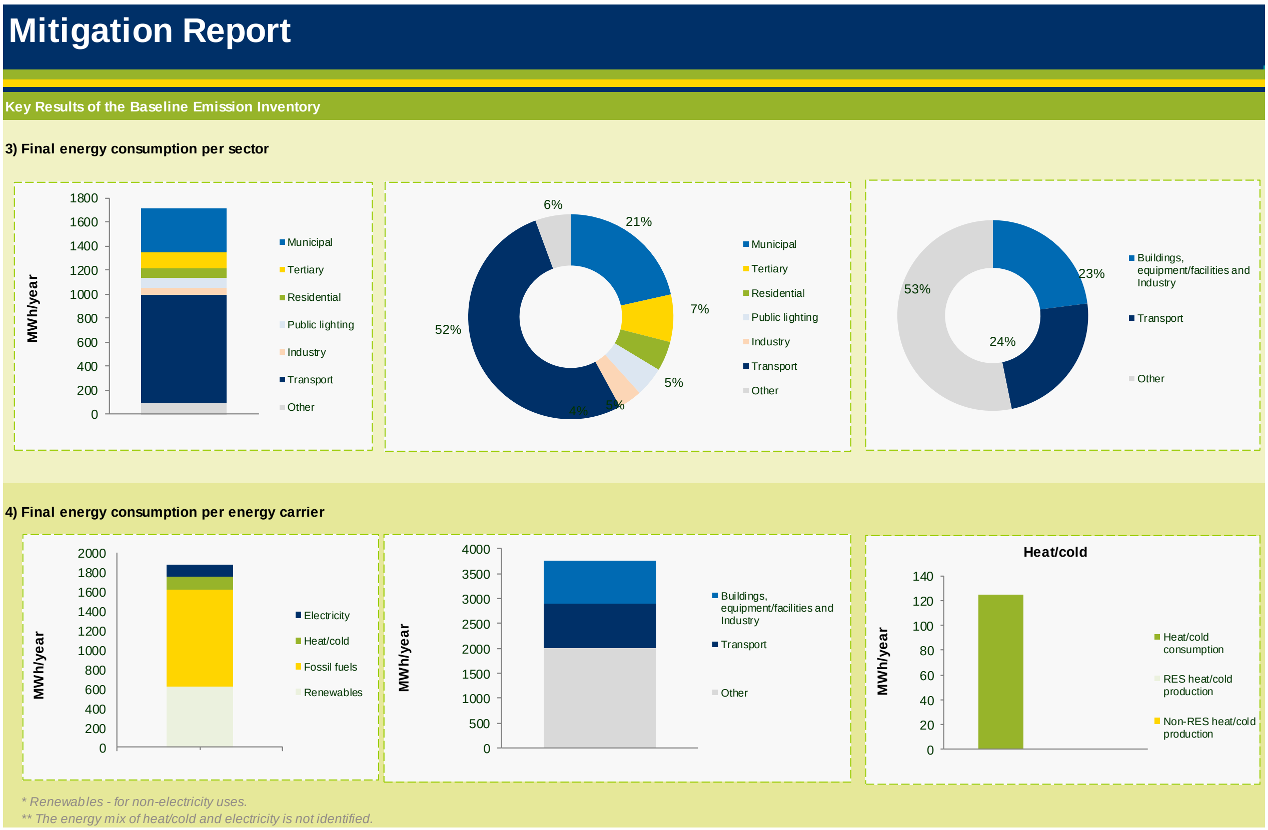


Figure 5. Sustainable Energy and Climate Action Plan Tool interface [11].

1.6. Tool for Rapid Assessment of City Energy

Tool for Rapid Assessment of City Energy (TRACE) is a tool provided by the World Bank, through the Energy Sector Management Assistance Program, to support cities in its efforts to improve energy efficiency. The tool is based on the use of Microsoft Excel integrated with macros and VBA (Visual Basic for Applications). TRACE interface allows easy navigation through the 12 tool's sections, modifying the data entered in the previous steps, working with external files and saving the accumulated progress - Figure 6.

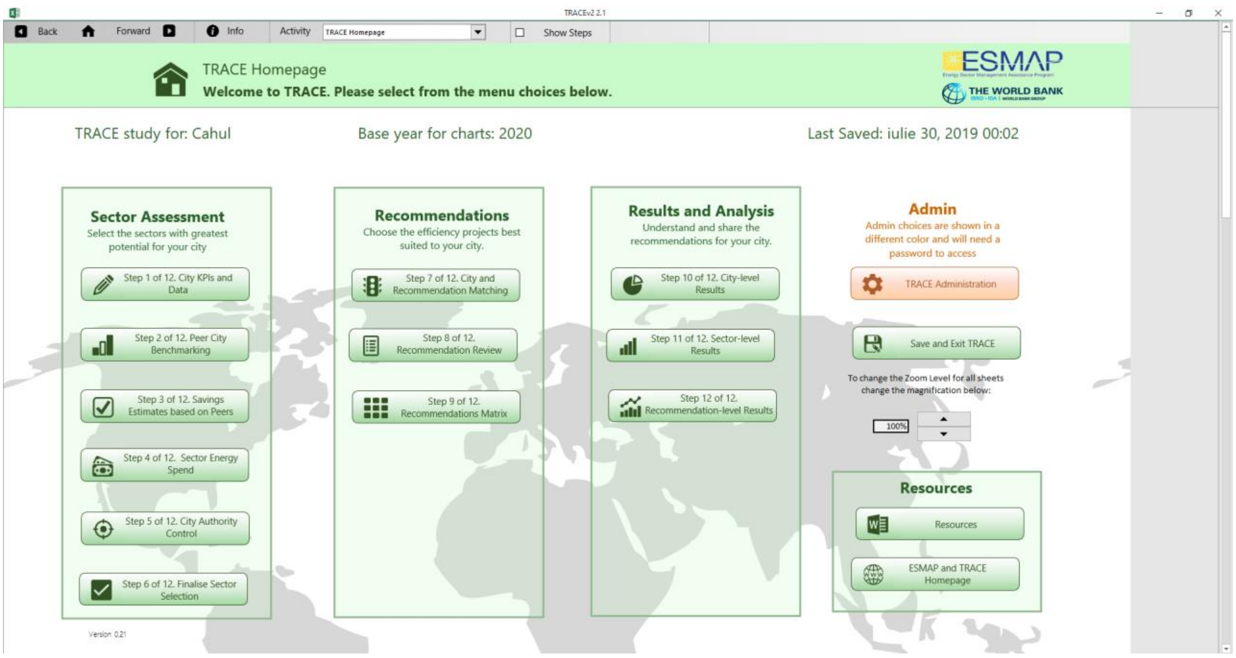


Figure 6. Tool for Rapid Assessment of City Energy interface [13].

The energy performance indicators calculation formulae for each sector are developed in the TRACE user manual for experts and city officials [14].

TRACE covers all possible sectors in which energy is consumed in a city, such as: transport; buildings; utilities; and industry. TRACE can be used for the Local Energy Efficiency Action Plan (LEEAP) development in accordance with the *Template / Form for LEEAP, with filling instructions*, approved by the Energy Efficiency Agency [15].

2. Methodological aspects regarding the TRACE use

Tool use requires many initial data, such as energy consumption by sectors and by type (e.g.: fuels, electricity and heat, etc.), but also the main services provided expressed in natural units (e.g.: used surface of buildings - m^2, length of the illuminated streets - km, volume of delivered potable water - m^3, volume of municipal solid waste - m^3, length of the public transport routes - km and number of passengers etc.). Information introduction into the tool is preceded by data collection in the field and on-site measurements.

The instrument is divided into 12 distinct sections (Excel spreadsheets), which represent the stages of the energy consumption sectors prioritization and the choice of the most suitable energy efficiency measures in the specific situation of the city analysed.

Cells filling is assisted with instructions and comments in which the operations algorithm is explained by steps.

As a result of data entering on consumption and services in the tool, *Key Performance Indicators - KPIs* are calculated, what are specific to each sector (e.g.: specific heat consumption for heating buildings - kWh/m^2, specific electricity consumption for lighting streets - kWh/km, specific electricity consumption for potable water supply - kWh/m^3, specific energy consummation for waste transportation – MJ/m^3, specific energy consumption for passenger transportation - MJ/passenger/km etc.).

The calculated key performance indicators are compared with similar indicators in other *peer cities* in the TRACE database, based on benchmarking. TRACE contains a database of 28 key performance indicators collected from over 100 cities around the world.

Potential energy savings, following the energy efficiency measures implementation, are estimated based on the performance indicators benchmarking of the analysed city compared to peer cities with better performance indicators - Figure 7.

Tool allows filtering the cities with which the analysed city is to be compared, and this is extremely relevant in the case of key performance indicators that depend on climate (e.g. climate region, number of heating degrees days etc.).

Next step, after energy savings estimation in all consumption sectors (benchmarking), is to enter the annual energy expenditures in each sector and indicate the budget from which payments are made (city authority or city wide).

Third step consists in city authority control degree calibration over each sector analysed, assigned depending on the decision-making power of the authority (financial, regulatory, policy-making, corporate etc.) - Figure 8.

Finally, sector prioritization for the energy efficiency measures implementation is based on the total score ($S_{tot,i}$), calculated as the product of the energy saving potential ($\Delta E_{save,i}$), annual expenditures for fuel or energy within the sector ($Ex_{t,i}$) and the degree of the city authority control over the sector ($P_{LPA,i}$) - Ec. (1).

$$S_{tot,i} = \Delta E_{save,i} \cdot Ex_t \cdot P_{LPA,i}. \tag{1}$$

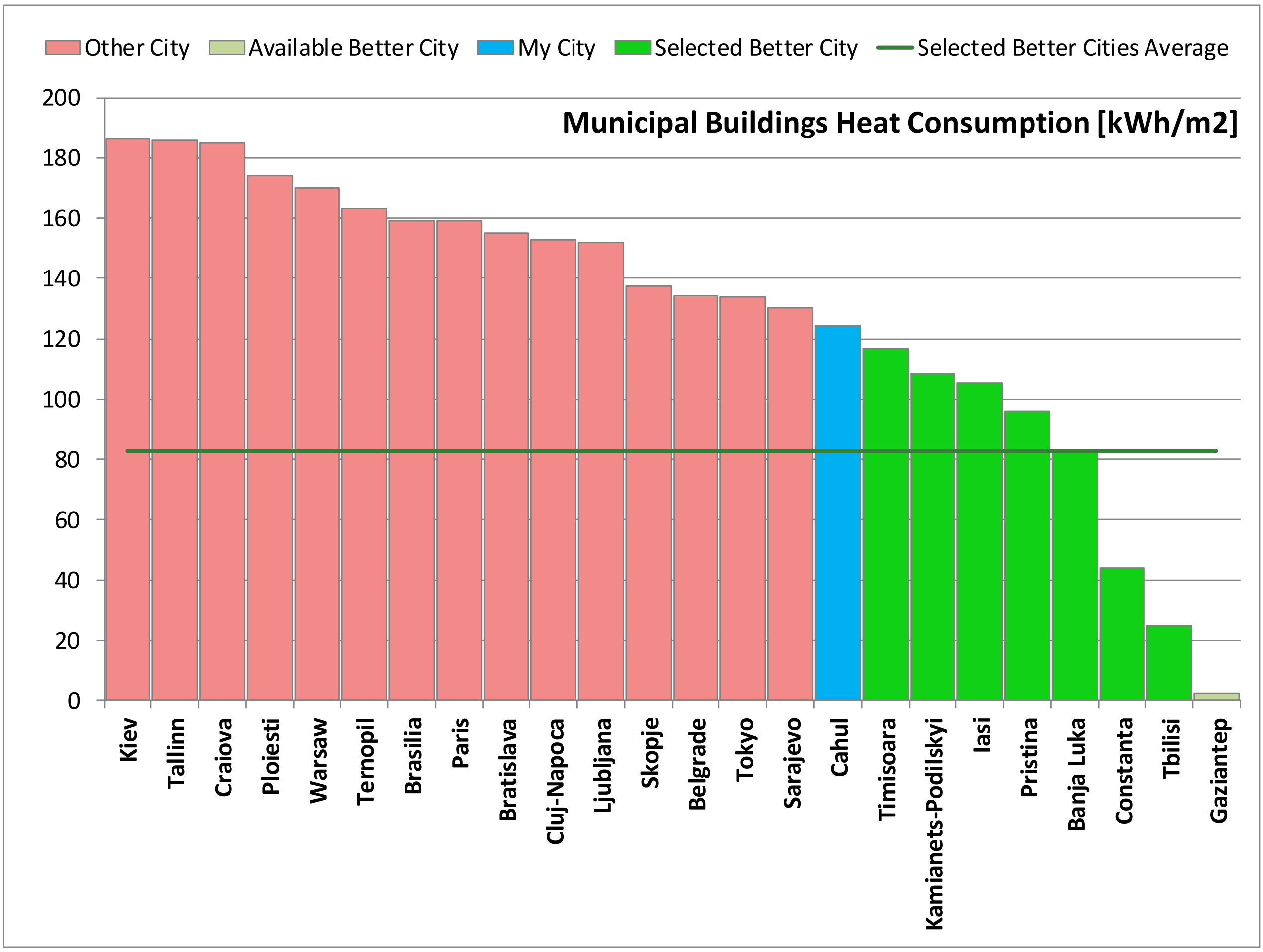


Figure 7. Benchmarking of the specific heat consumption in municipal buildings.

The energy saving potential ($\Delta E_{save,i}$) in each sector is calculated by the expression:

$$\Delta E_{save,i} = E_{city,i} - \bar{E}_{better,i}, \tag{2}$$

where $E_{city,i}$ is the value of the key performance indicator of the city analysed in the sector i;
$\bar{E}_{better,i}$ - the average value of the KPI in cities with better energy performance.

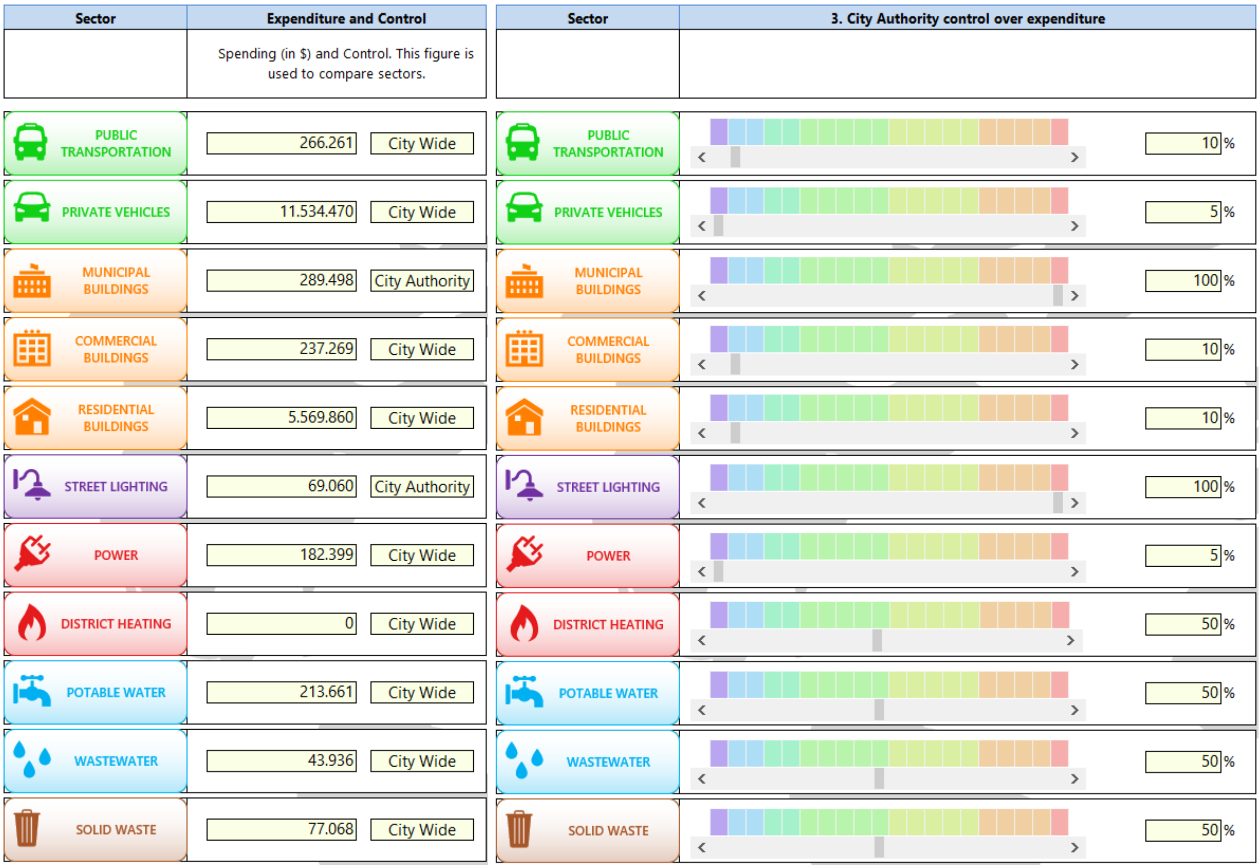
The annual expenditures on energy or fuel in each sector ($Ex_{t,i}$) is determined by the expression:

$$Ex_{t,i} = E_t \cdot T_t, \tag{3}$$

where E_t represents the annual energy or fuel consumption in the year t;
T_t - the value of the energy / fuel tariff or price in the year t.

The degree of the city authority control $P_{LPA,i}$ is assigned depending on the competence of the municipality in regulating the sector i analysed. In the last stage of prioritization, the tool user has the possibility to decide whether to keep the sector for the energy efficiency measures formulation or not.

The TRACE concept consists in selecting only those sectors in which the municipal authorities has decision-making power.



Sector	Expenditure and Control		Sector	3. City Authority control over expenditure
	Spending (in $) and Control. This figure is used to compare sectors.			
PUBLIC TRANSPORTATION	266.261	City Wide	PUBLIC TRANSPORTATION	10 %
PRIVATE VEHICLES	11.534.470	City Wide	PRIVATE VEHICLES	5 %
MUNICIPAL BUILDINGS	289.498	City Authority	MUNICIPAL BUILDINGS	100 %
COMMERCIAL BUILDINGS	237.269	City Wide	COMMERCIAL BUILDINGS	10 %
RESIDENTIAL BUILDINGS	5.569.860	City Wide	RESIDENTIAL BUILDINGS	10 %
STREET LIGHTING	69.060	City Authority	STREET LIGHTING	100 %
POWER	182.399	City Wide	POWER	5 %
DISTRICT HEATING	0	City Wide	DISTRICT HEATING	50 %
POTABLE WATER	213.661	City Wide	POTABLE WATER	50 %
WASTEWATER	43.936	City Wide	WASTEWATER	50 %
SOLID WASTE	77.068	City Wide	SOLID WASTE	50 %

Figure 8. Sector energy expenditures and city authority control.

L2 CALCULATION: Streelighting Retrofit Calculator

Background Information

Current no. street lights	1.206	
Post-retrofit no. street lights	1.493	
Cost of electricity for street lighting for CA ($/kWh)	0,14	
CO2 Conversion Factor	0,00043	tCO2 per kWh
LED Replacement Fixture Costs (CAPEX)	$ 250	per fixture
Annual project budget available (CAPEX)	$ 500.000	per annum

Attribute | **Current Street Lighting**

Average run-hours for street lighting (hr/yr) pre-retrofit 3.877

Attribute	% Breakdown	Wattage	No. Street Lights	Total kW	Total kWh	Annual Replacement Budget ($)
LED	15%	25	181	5	17.534	2.338
HPS	52%	75	627	47	182.351	24.313
Metal Halide	17%	100	205	21	79.486	8.832
Mercury Vapor	16%	250	193	48	187.026	6.234
Other 1			0	0	0	
Other 2			0	0	0	
Other 3			0	0	0	
Other 4			0	0	0	
Total	100%		1.206	120	466.397	41.717

Figure 9. TRACE street lighting retrofit calculator.

TRACE includes a database of 95 predefined energy efficiency measures. Energy efficiency measures are recommended depending on the institutional capacity of the municipality - financial; human resources; information availability and quality; regulatory power; and infrastructure management. Each energy efficiency measure has an integrated calculator for the energy savings calculation, as well as investments needed and operational costs reduction - Figure 9.

The work with TRACE is completed with the report drafting that includes the energy efficiency measures in the sectors selected by the user.

3. Case studies: Improving energy efficiency in Cahul and Ungheni

Cahul and Ungheni municipalities are very similar in terms of energy demand drivers (e.g.: population number, number and surface of buildings, number of transport units, streets length, volume of potable water delivered etc.).

Table 1

Key city statistics and key performance indicators

Key performance indicators	Cahul	Ungheni
Population Within Municipal Boundary	37 021	36 100
Gross Domestic Product, USD	43 480 230	42 038 158
City Annual Heating Degree Days, HDD	2 850	3 600
City Annual Cooling Degree Days, CDD	125	80
Primary Electricity Consumption, kWh	28 483 916	42 036 158
Primary Energy Consumption, GJ	1 178 615	1 118 074
Primary Energy Consumption per GDP	27,11	26,60

In Cahul and Ungheni, the highest energy consumption is attested in the residential buildings and private transport sectors. Fuel consumption in the sectors under the municipality control is below 5%. In both cities, the sector with the highest energy consumption that is under the municipality control are the municipal public buildings - Figure 10.

Following the data introduction in TRACE and the application of prioritization filters, for both cities - Cahul and Ungheni, the same order of sectors for the implementation of energy efficiency measures resulted, namely:

1) Municipal public buildings;
2) Water supply and sewerage;
3) Public street lighting.

Despite the perception that the public street lighting is a major energy consumer in the country, in this respect call for project proposals had lately been launched by the Energy Efficiency Fund and Agency, the water supply and sewerage sector is ranked higher in terms of energy saving potential.

High electricity consumption in this sector is because of outdated infrastructure both physically and morally: electric drives corresponds to IE1 energy efficiency class according to the standard *SM EN 60034-30-1:2014 Rotating electrical machines. Part 30-1. Efficiency classes of line operated AC motors (IE code)* and large water losses in networks.

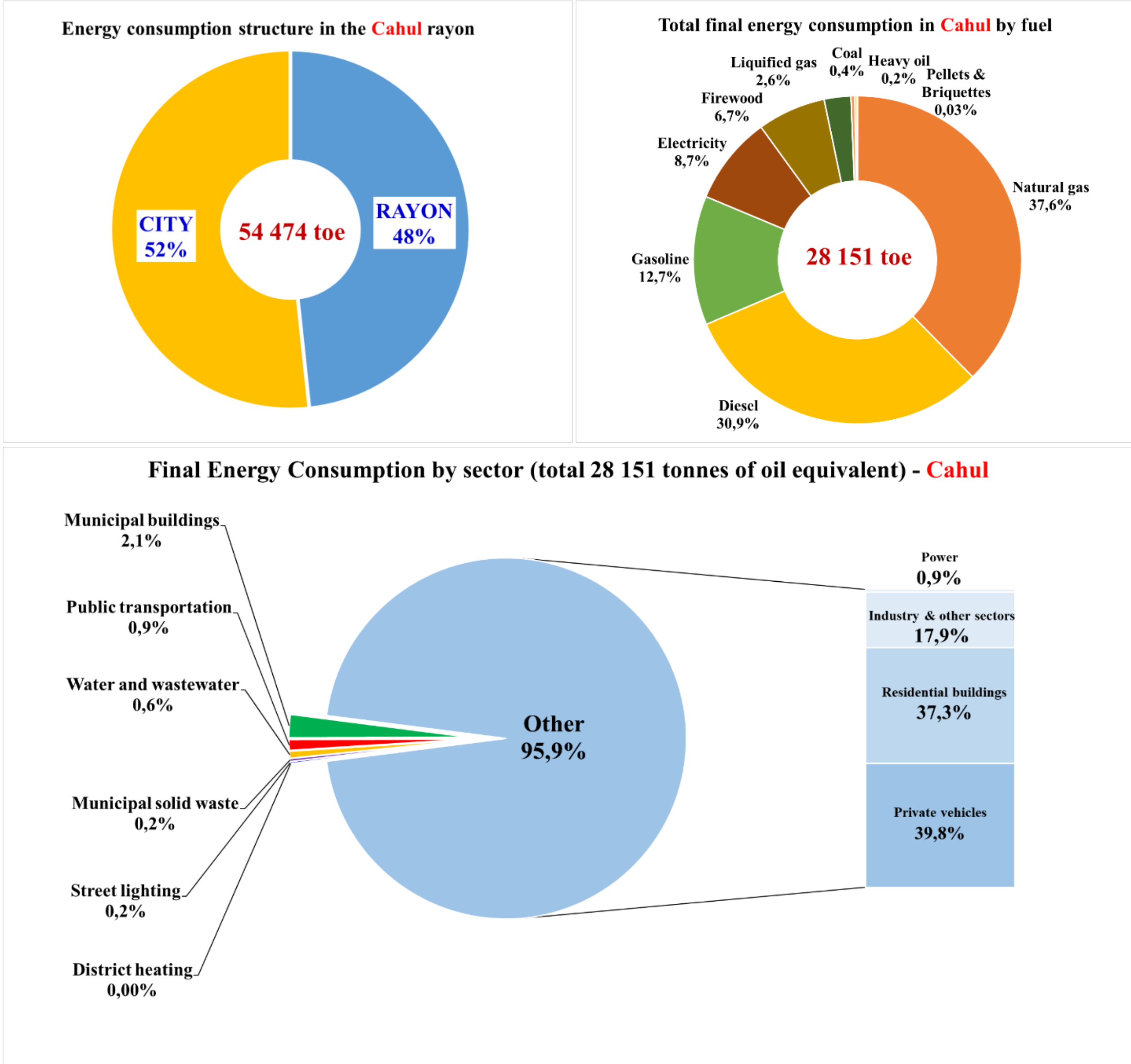


Figure 10. Final energy consumption by sector and by fuel in Cahul.

Finally, the following energy efficiency measures were selected for both cities:

- Municipal Schools Audit & Retrofit Program;
- Municipal Offices Audit & Retrofit Program;
- Street Lights Audit and Updating Program;
- Improve Efficiency of Pumps and Motors.

TRACE contains a special module dedicated to the technical-economic analysis of the selected energy efficiency measures and allows to visualise graphically the benefits generated separately for each measure or sector - Figure 11.

TRACE is based on linear programming and allows the dynamics associated with annual price growth rates to be introduced into the calculation model, what finally leads to an increase in the energy savings revenues.

In the case of the two cities analysed, the cumulative energy savings over 10 years period become equal to the investment expenditures, provided that the annual growth rate of prices for energy is 10%.

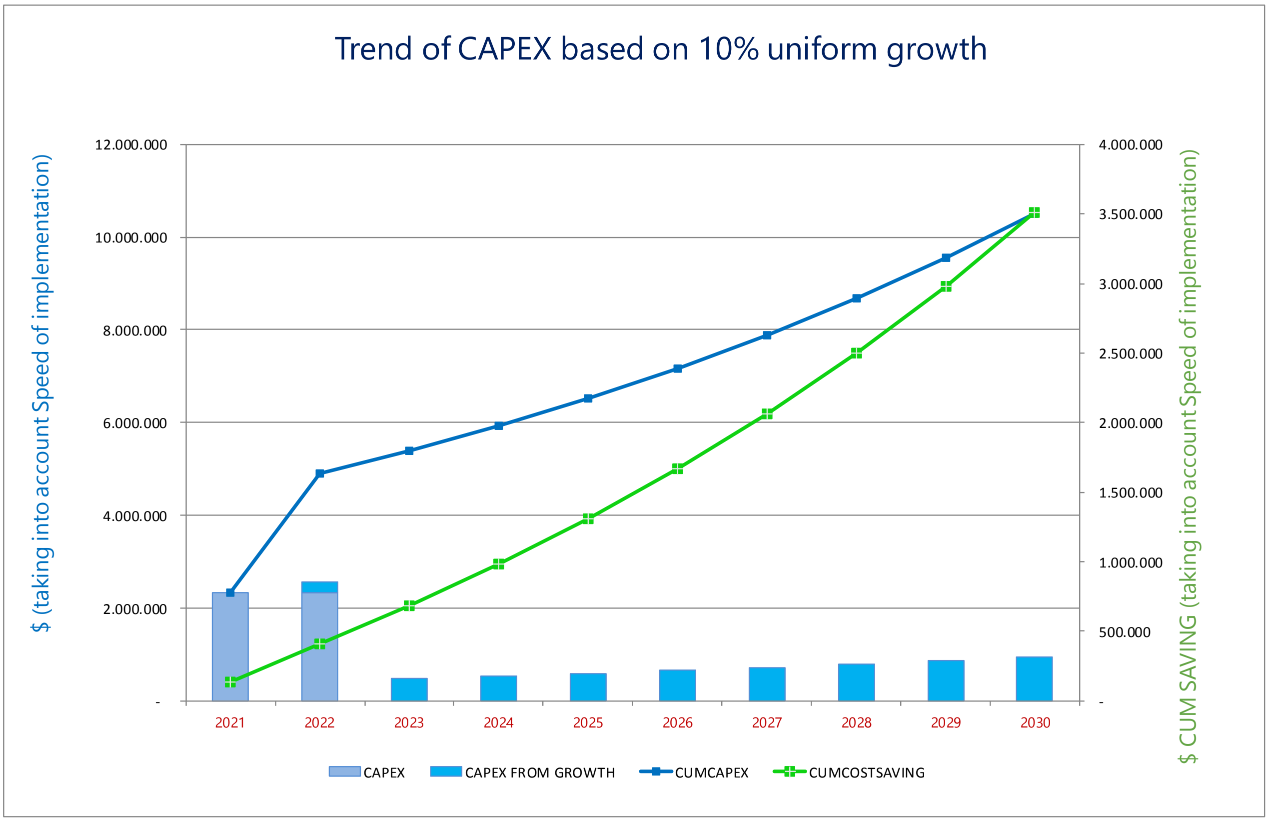


Figure 11. Investment costs compared to cumulative energy savings.

Conclusions

Local communities play an important role in the transition towards 100% renewable energy. Small and compact administrative-territorial units can reach the energy autonomy level in a relatively short period of time - up to 15 years.

Energy consumption in the sectors under municipality control constitutes less than 5% of the total consumption of the community. Municipal public buildings are the largest energy consumers in a city.

To promote energy efficiency at the local level, as presented here, there are multiple practical tools for planning and analysis of the energy efficiency measures.

TRACE allows to objectively prioritize sectors and choose the most suitable energy efficiency measures.

The water supply and sewerage sector has a major energy efficiency potential and should be included in the list of priority areas for funding in the event of calls for project proposals, launched by dedicated funds.

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