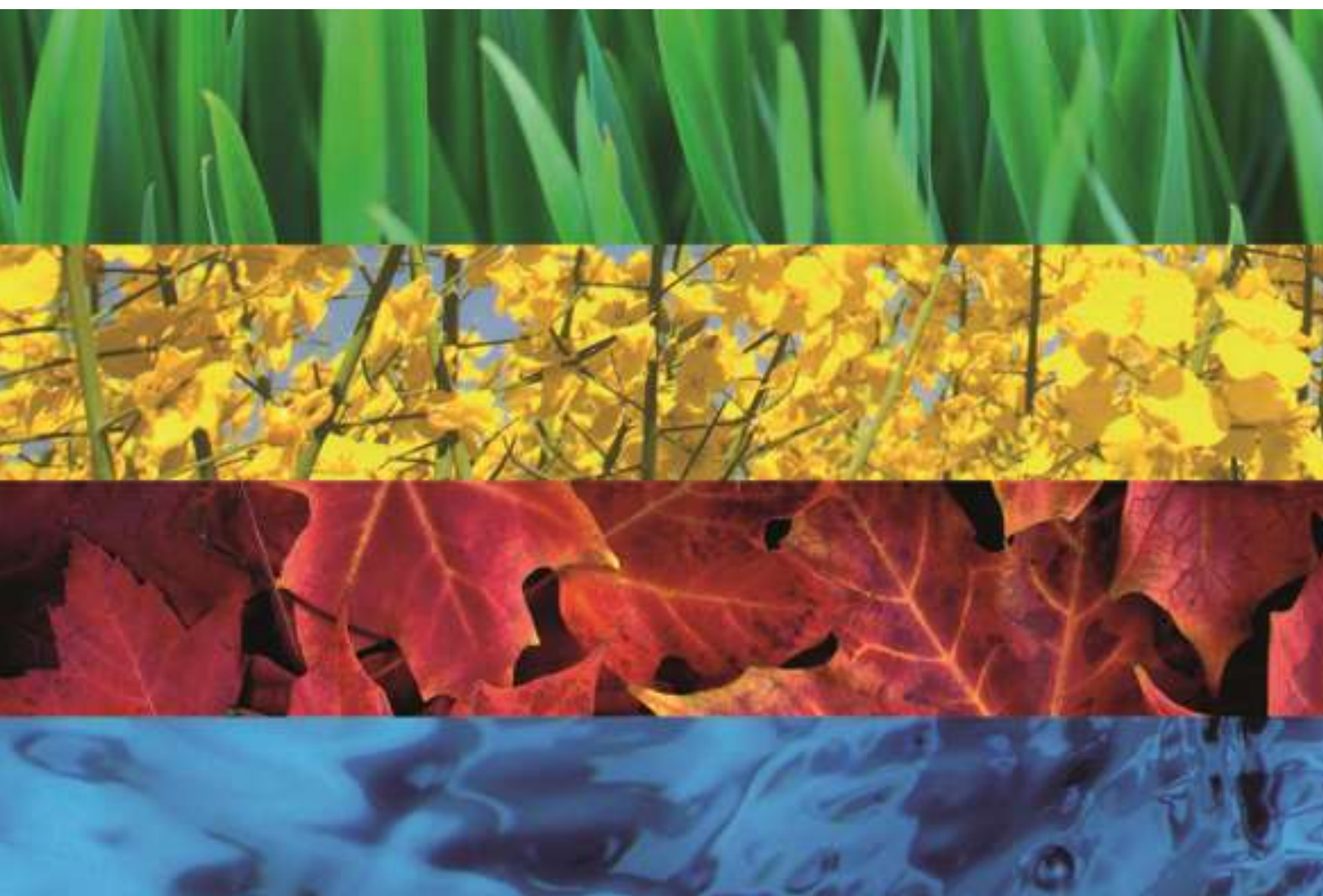


# **City Energy Efficiency Report**

## **City of Ternopil**

Energy Efficiency Transformation in  
Ukrainian Cities

March 2015 - Review after Decision Workshop



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**List of abbreviations**

CHP	Combined heat and power	IBRD	International Bank for Reconstruction and Development, World Bank Group
CA	City Authority	IFI	International Finance Institution
CEETI	City Energy Efficient Cities Initiative	IHS	Individual Heating Stations
CNG	Compressed Natural Gas	KPI	Key Performance Indicator
CoM	Covenant of Mayors, Assist Local Authorities in More Sustainable Local Energies	L, ltr.	Litre
CU	Communal Company	LED	Light Emitting Diode
DH	District heating	LLC	Limited Liability Company
DHW	Domestic Hot Water	LNG	Liquid Natural Gas
EBRD	European Bank for Reconstruction and Development	MHRP	Municipal Heat Reform Program in Ukraine (by USAID)
EE	Energy efficiency	MU	Municipal Company
EIB	European Investment Bank	PE	Public Enterprise
ELENA	European Local Energy Assistance	PEC	Primary Energy Consumption
EnPC	Energy Performance Contracting	RE	Renewable Energy
ESCO	Energy Service Company	REI	Relative Energy Intensity
ESMAP	Energy Sector Management Assistance Program	SCADA	<i>Supervisory Control and Data Acquisition</i>
FEC	Final Energy Consumption	SEAP	Sustainable Energy Action Plan
GDP	Gross Domestic Product	TA	Technical Assistance
GHG	Greenhouse gases	TRACE	Tool for Rapid Assessment of City Energy
GIZ	German International Development Co-operation	UAH	Ukrainian Hrivna (local currency)
GWh	Giga Watt Hours = Million Kilo Watt Hours	VSD	Variable Speed Drive, Frequency Control
HDD	Heating Degree Days	WB	The World Bank
HDI	Human Development Index	WWTP	Waste Water Treatment Plant
HOB	Heat only boiler		

# 1 Summary

## CEETI, ESMAP and TRACE

The City Energy Efficiency Transformation Initiative (CEETI) is a 3-year technical assistance (TA) program led by the World Bank's Energy Sector Management Assistance Program (ESMAP). The initiative helps cities identify, develop and mobilize finance for transformational investment programs in urban energy efficiency across sectors of municipal energy.

This report presents the key findings of the application of the Tool for Rapid Assessment of City Energy (TRACE) and the Energy Efficiency assessment for the city of Ternopil.

## Process of the Energy Efficiency Assessment and Structure of the Report

The purpose of the EE assessment is to analyze the performance of areas of municipal energy, to prioritize areas of intervention and develop a set of energy efficiency measures which will provide the framework for the follow-up Energy Efficiency Program of the city. The process is accompanied by active communication with the city stakeholders to confirm the results of the analysis and generate ownership.

The process of the Energy Efficiency Assessment commenced with the compilation of related data and information from the City Authority of Ternopil as well as utilities of municipal services. Data collection and interviews with stakeholders took place in November – December 2014. The results have been documented in the City Background Report.

Out of that report the Key Performance Indicators for the city of Ternopil have been calculated and aggregated into the TRACE model.

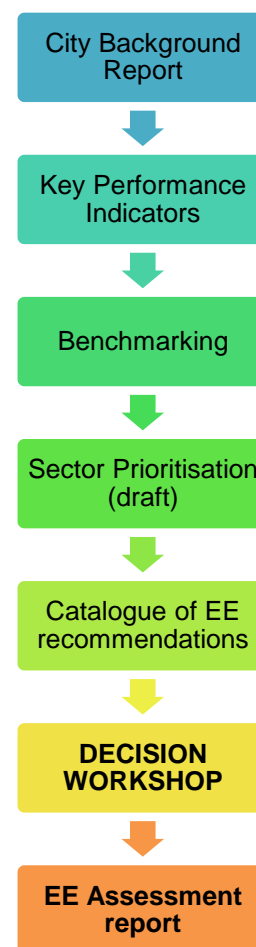
The benchmarking component of the TRACE tool enables the comparison of energy performance with other peer cities of similar characteristic. From this "Relative Energy Intensity" a rough estimate of the theoretical energy efficiency potential in each sector has been derived. → [Chapter 3](#).

Additional factors for the prioritization of the target sectors are the spending for energy and the City authority level of control in terms of budget control, regulatory and enforcement power. → [Chapter 4](#).

A long list of possible energy efficiency recommendations have been collected from various sources and interviews. The preliminary evaluation leads to a set of Energy Efficiency recommendations by sector. → [Chapter 6, 7 and 8](#).

Key sector features and challenges together ([Chapter 5](#)) with the EE potential analysis have been presented and discussed at the DECISION WORKSHOP in February 2015. Decision makers of the city and utilities agreed on the conceptual and integrated approach and confirmed the intervention areas for the EE program.

The present energy efficiency assessment report reflects the decisions of the workshop with key energy stakeholders of the city with confirmation of the sector priorities and a refined list of EE measures.



## Energy efficiency targets

The city joined the European initiative "Covenant of Mayors" in 2012 and has prepared a Sustainable Energy Action Plan (SEAP), which targets the lowering CO<sub>2</sub> emissions by 20% by 2020, gas consumption by 24%, heat (13%) and electricity consumption (30%).

## City background – energy consumption

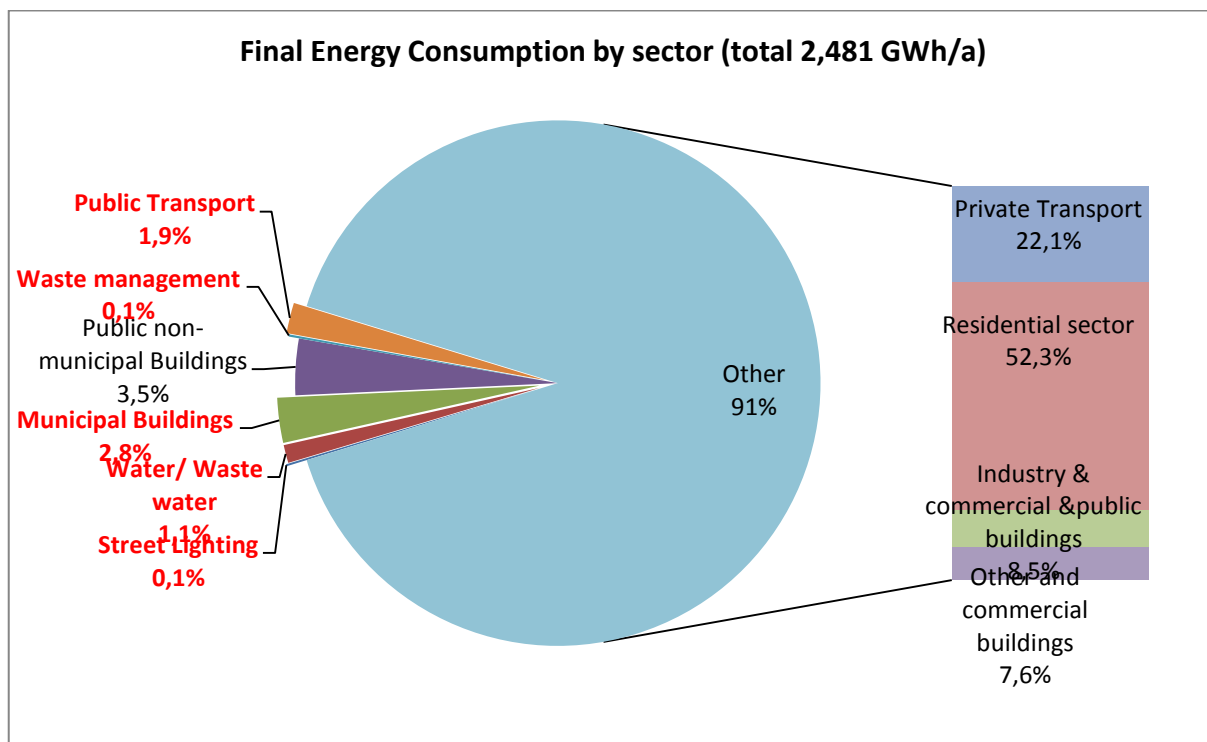
Ternopil's primary energy consumption amounts to 48,190.7 GWh in 2013 with the highest share with natural gas of almost two thirds. The majority of gas is utilized for the generation of power and district heat for the distribution to various end consumers.

The residential sector is the largest energy consumer with more than 50 % of the city's final energy consumption as it is typical for all Ukrainian cities. This is followed by the private transport sector at 22% and the industry and commercial sector (including other buildings) at 16%.



Final energy consumption under direct control by the city is 149.2 GWh (6%) out of 2,481 GWh.

**Figure 1: Share of Final Energy Consumption by sector in %**



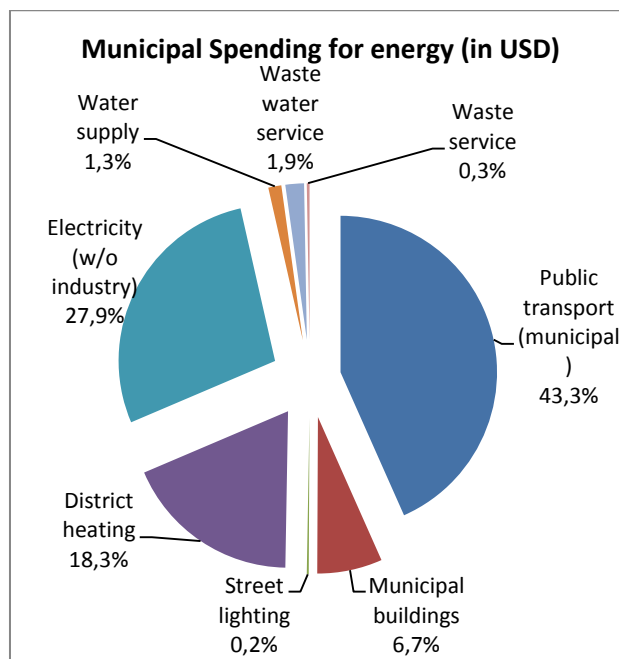
### City background – budget and energy spending

Ternopil had a population in 2013 of 218,000 inhabitants and is economically based on the sectors manufacturing industry, trade and services.

The overall GDP<sup>1</sup> of Ternopil amounted in 2013 to 708 million USD of which 140 million USD (20%) have been spent on energy.

The municipal budget amounted to 99 million USD in 2013 with approximately 17.8 million USD spent on energy municipal services for public transport, public buildings, street lighting, waste, water supply and waste water disposal.

Major segments of energy spending like power (30%) and private vehicles (44%) are not under the control of the City Administration.



**Figure 2: Share of spending for energy, 2013**

Energy Spending for Municipal sector facilities (municipal public transport, municipal buildings, street lighting, waste, water and waste water services) amount to 17.7 million USD in 2013, out of which more

<sup>1</sup> Estimated on respective share of regional GDP, 2013

than 45% are spent for the energy supply of municipal buildings. Those 17,7 million USD make a share of 8.1 % of the annual municipal budget.

Even if the energy consumption in the sectors under direct control by the city administration is only 6% of the total city wide energy consumption the intervention in EE measures in those sectors is important for the city and for the city government.

First, because saving energy in those sectors will directly lead to the reductions of energy costs and reduce municipal budget spending or governmental subsidies. This is in particular true for the expected perspective of drastic increase of energy cost, where investments in energy saving will counteract against consequent raise of end user tariffs and the risk of non-affordability of energy or services.

Second, EE investments in those sectors will have long-term and sustainable influence on some citywide sectors, such as (i) reduction of fuel consumption in private transport, due to the modal shift of transport towards lower specific energy consuming public transport, and (ii) reduction of energy consumption in the residential sector due to improved heat supply and consumption based billing at cost covering tariffs.

Third, investments in energy saving in urban infrastructure and facilities are well visible for the population and thus contributing to the public awareness on (i) resource saving, (ii) improvement of public services for the population, and finally (iii) on Ukraine's return to a sustainable growth path by right decisions for investments.

### **Benchmarking of Energy Performance of Ternopil**

The benchmarking component of the TRACE tool is intended to assess the energy performance of the city compared to other peer cities. The application of TRACE delivers a set of 27 Key Performance Indicators (KPI) for the city of Ternopil.

Details of the benchmarking of Ternopil's KPIs are provided in [Chapter 3](#), while the following table provides a summary of observations by sector.

**Table 1: Summary benchmarking of KPIs of Ternopil with selected peer cities**

Sector	Selected KPI		Comparison of Performance with better performing cities	Theoretical EE potential
<b>City wide energy</b>	Annual Primary energy consumption per capita	41.4 GJ/capita	Medium performance Peer cities: Skopje and Bratislava.	50%
	Annual Primary energy consumption per GDP	13.9 MJ/USD GDP	Low performance Peer cities: Tbilisi and Belgrade	50%
<b>Public Transport</b>	Specific energy consumption of Public Transport	0.5 MJ / passenger km	Medium performance Peer cities: Belgrade and Sarajevo	35% to 50%
<b>Solid Waste</b>	Annual Waste production	Approx. 500 kg/capita	Low performance Peer cities: Sofia and Pristina	40%
	Solid Waste recycled	1 %	Very low performance	50-70%
<b>Water supply and waste water</b>	Energy Density of Potable Water Production (	0.67 kWh <sub>e</sub> /m <sup>3</sup>	Low performance Peer cities: Banja Luca or Vienna.	50%
	Energy Density of Wastewater Treatment	0.86 kWh <sub>e</sub> /m <sup>3</sup>	Very low performance	50-60%
<b>District Heat</b>	Heat Loss from DH Network	12 %	Medium performance: Peer cities: cities in Western Europe	40-50%



Sector	Selected KPI		Comparison of Performance with better performing cities	Theoretical EE potential
<b>Street lighting</b>	Annual Electricity consumed per lit road	7.7 kWh <sub>e</sub> /m	High performance Peer cities: Tbilisi or Vienna	40-50%
<b>Municipal public buildings</b>	Annual Heat Consumption	163 kWh <sub>th</sub> /m <sup>2</sup>	Low performance	50-60%

The benchmarking demonstrates that the majority of performance **indicators ranks low** (unfavorable) in terms of specific energy consumption, in particular for the sectors:

- **heat consumption in public buildings,**
- energy density for potable **water production and waste water** treatment,
- specific energy consumption for **street lighting,**
- specific energy consumption of the **public transport** fleet, and
- Cross-sector: preprimary energy consumption per GDP and per capita,

This indicates a theoretical energy saving potential for the above sectors and KPIs is in the **range of 30 to 50%.**

Additional potentials for increase of the city performance are with the reduction of **waste volume** per capita and an increase of the share of waste **recycling.**

### City authority Control

Due to various legal and regulatory frameworks and various types of ownership the City administration has different levels of control and degree of influence on end consumers of municipal energy and utilities. This relates to budget control, regulatory and enforcement power.

The CA remains in full control over the sectors of municipal public buildings and street lighting.

In addition the CA retains a certain degree of influence on the end energy consumer sectors of water supply and wastewater, district heating, waste management and public transport.

**Table 2: Ternopil City authority's level of budget control and enforcement power on urban infrastructure sectors' energy consumption**

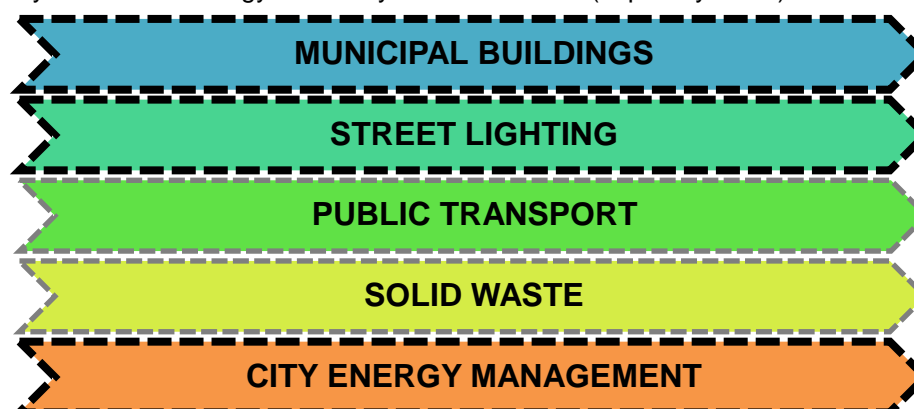
Sector	City authority level of power		
	Regulatory	Budget control	Influence and enforcement
Public buildings	HIGH	HIGH	HIGH
Street lighting	HIGH	HIGH	HIGH
District heating	MEDIUM	MEDIUM	MEDIUM
Public transport	HIGH	MEDIUM	HIGH
Potable water supply	LOW	MEDIUM	MEDIUM
Wastewater	LOW	MEDIUM	MEDIUM
Waste	HIGH	MEDIUM	HIGH
Power supply	LOW	LOW	LOW
Gas supply	LOW	LOW	LOW
Private transport	LOW	LOW	LOW
Residential buildings	LOW	LOW	MEDIUM

### Prioritized sectors and main priorities

Sectors found to warrant a prioritized analysis are very much determined by the

- ✓ theoretical energy efficiency potential - "Relative Energy Intensity"
- ✓ level of spending for energy in the sector of municipal energy and
- ✓ the City authority's level of control

The Priority sectors for Energy Efficiency Intervention are (in priority order):



*Cross sector priority*

Lower priority is given to the sectors District Heating and Water&Waste water because of the committed and ongoing energy efficiency investment programs funded by IFI projects.

Final energy consumer sectors which are controlled by individual or commercial entities are not considered in the TRACE assessment, as the City Authority has no control and influence on their energy performance or energy budget spending. At this point, the following sectors are set aside and not pursued further, as they are individual or commercial controlled.

- Private vehicles
- Power supply
- Gas supply
- Commercial sector/buildings
- Public, non-municipal buildings
- Residential sector
- Industrial sector

This does not necessarily mean that no energy efficiencies are to be developed in these sectors. It simply indicates that, when compared to other sectors, they are unlikely to produce as compelling energy efficiency savings potential or are unlikely to be achievable by the CA.

### Consideration of ongoing and committed investment programs and plans

The city of Ternopil and its utilities are implementing currently a number of investment programs funded by international donor programs, such as:

*In the district heating sector:*

- Ternopil District Heating Project supported by EBRD and E5P grant;
- District heating reconstruction program, funding by IBRD

*In the water supply & waste water sector*

- Ternopil Vodokanal project «Rehabilitation and Upgrade Water and Wastewater Facilities - 2014», funded by IBRD

Related components of those investment programs will **not** be considered in the list of recommended EE measures as they are already committed or under implementation, but they will deliver energy savings in the target year 2020 compared to the baseline year 2013.

The City of Ternopil has elaborated a comprehensive Municipal Energy Plan (MEP) for 2012 to 2016 and Sustainable Energy Plan (SEAP). The EE investment recommendations of these plans have been

screened and incorporated into the list of EE recommendations for the follow-up EE Transformation program.

### **EE measures recommended for analysis in the EE Transformation Program**

Based on the above justification of sectors, the discussion and preliminary decision at the Decision Workshop the list of EE measures comprise in total 18 EE measures, of which 11 are investment measures.

Recommended EE investment measures are categorized in short-term and long-term measures according to their preliminary implementation period, until 2020 and after 2020.

#### **A) Short term EE Investment measures: Implementation period 2016 to 2020**

Title	Components, extend	Indicative costs	Preliminary EE
<b>Municipal Public Buildings (PB)</b>			
Retrofit Program / thermo-modernization of Municipal educational and medical facilities by municipal and loan sources	Total approx. 258,402 sqm building area including building shell, piping, including IHS on demand	Approximately 28 million USD	Annual savings of up-to 27 GWh, primary energy natural gas saving
Retrofit Program / thermo-modernization of Municipal educational and medical facilities under EnPC scheme (ESCO or municipal EE fund)			
Replacement of indoor lighting for all municipal public buildings	(T5 with reflector or LED), all buildings to 10 kWh/m2 for lighting	Approximately 0.6 million USD	Annual savings of 0.8 GWh, electricity
<b>Street Lighting (SL)</b>			
Street Lighting Audit and Retrofit Program (replacement by high performing bulbs)	Approx. 2,100 bulbs(only for Mercury and conventional), including public space lighting on demand	Approximately 0.7 million USD	Annual savings of 0.5 GWh, electricity
<b>Solid Waste (WS)</b>			
Intermediate Transfer Stations including sorting, including Waste Infrastructure Planning (separate container sorting)	Construction of one facility, capacity to be analyzed	In the range of 8-12 million USD	Annual savings of up to 1 GWh, diesel

#### **B) Long- term EE investment measures: Implementation period 2020 to 2025**

Title	Components, extend	Indicative costs	Preliminary EE
<b>Municipal Public Buildings (PB)</b>			
Renewable energy individual heat generation for municipal education and medical facilities	To limited extend, only if DH supply is not appropriate, including heat, pumps, biomass, Solar water heating is an option for (3-4) public swimming pools	Approximately 5 to 8 million USD	Annual savings of 10-20 GWh, gas
<b>Street lighting</b>			
Street Lighting timing, dimming and management Program, integration of rehabilitation of electric supply system and Poles of SL (wiring, switches) in order to enable control	Including step-by-step rehabilitation of power supply network to enable control, timing and dimming  Limited extend for selected streets only	Approximately 0.5 million USD	Annual savings of 0.5 GWh, electricity

Title	Components, extend	Indicative costs	Preliminary EE
<b>Municipal public transport</b>			
Promotion of Public Transport, increase attractiveness targeting to lower private motorized transport mode	making the public transport more attractive (information system, clean, punctual, new bus stops), <i>Details in EE transformation program</i>	Up to 0.3 million USD	Annual savings of up to 3 GWh, gasoline in individual transport
Public Transportation Development for new district	with electric trolley busses	Up to 6 million USD	Annual savings of up to 1 GWh, gasoline in individual transport
<b>Solid Waste (WS)</b>			
Landfill Gas Capture Program and power generation unit (use of green tariff, approach PPP operator)	<i>Details in EE transformation program</i>	Up to 10 million USD	<i>To be analyzed</i>
Waste Pyrolysis Project	for heat generation (approach of PPP operator)	In the range between 3-5 million USD	<i>To be analyzed</i>

**C) Short term NON-INVESTMENT MEASURES: Implementation period 2016 to 2020**

Title	Components, extend	Indicative costs	Preliminary EE
<b>Municipal Public Buildings (PB)</b>			
Energy Audits and feasibility study for Municipal educational and medical facilities	Audit program for 80 to 100 buildings	Approx. 0.3 million USD	Results in PB - 02/03
<b>Municipal Energy Management</b>			
Awareness raising and EE promotion programs for all sectors (water, energy, waste reduction)	events, competitions, awards, print media, media campaigns	In the range of 0.1-0.2 million USD annually	Not primary for municipality
Institutional and Capacity building program Establishment Energy Management system including Monitoring and Verification (target tracking)	Including Municipal Building Inventory, Benchmarking and Energy Performance Monitoring Program municipal buildings	Approx. 0.2 million USD	n/a
Technical guideline and procedure for equipment and service purchasing and granting concessions	comprising e.g. life-cycle cost assessment, Performance Standards for private bus operators, Procurement for New Street Lights, equipment in public facilities, Mandatory Building Energy Efficiency Codes for Existing and new Buildings	In the range of 0.1 to 0.2 million USD	n/a
Preparation of Energy Performance contracting , preparation of contracting frame and procurements of ESCO services	preparatory energy audits, tender documents	In the range of 0.1 million USD annually	Resulting from investment projects
EE Strategy and investment plan resulting in Capital investment planning	<i>Details in EE transformation program</i>	In the range of 0,05 million USD	Resulting from investment projects

**C) Long term NON-INVESTMENT MEASURES: Implementation period 2020 to 2025**

Title	Components, extend	Indicative costs	Preliminary EE
<b>Municipal Energy Management</b>			
Establishment of Municipal EE fund (financing instrument to provide loans)	<i>Details in EE transformation program</i>	Approx. 2 million USD	Results in PB - 02

EE Measures not to be considered as priority, because investment programs has already been committed.

District heating	Water and Waste water
<ul style="list-style-type: none"> <li>- Performance increase of boiler-houses by rehabilitation</li> <li>- Fuel switch for heat generation - gas to biomass</li> <li>- District heating network rehabilitation, pipeline replacement</li> <li>- Solar heating plant (long-term)</li> <li>- Hydraulic balancing of the DH system</li> <li>- Installation of cogeneration plant for coverage of own demand</li> <li>- Implementation of SCADA system</li> <li>- Replacement of circuit pumps and equipment with VSD</li> </ul>	<ul style="list-style-type: none"> <li>- Improve Efficiency of Pumps and Motors in water supply and WWTP</li> <li>- Active Leak Detection and Pressure Management Program for potable water system</li> </ul>

## Energy Efficiency Recommendations Matrix

		First costs	
		< 1 million USD	> 1 million USD
Primary Energy Saving Potential	< 1 GWh/year	<ul style="list-style-type: none"> <li>• Replacement of indoor lighting for all municipal public buildings</li> <li>• Street Lighting Audit and Retrofit Program</li> <li>• Street Lighting timing, dimming and management Program, integration of rehabilitation of electric supply system and Poles of SL</li> <li>• Promotion of Public Transport, increase attractiveness targeting to lower private motorized transport mode</li> <li>• Energy Audits and feasibility study for Municipal educational and medical facilities</li> <li>• Awareness raising and EE promotion programs for all sectors</li> <li>• Institutional and Capacity building program - Establishment Energy Management system including Monitoring and Verification</li> <li>• Technical guideline and procedure for equipment and service purchasing and granting concessions</li> <li>• Preparation of Energy Performance contracting , preparation of contracting frame and procurements of ESCO services</li> <li>• EE Strategy and investment plan resulting in Capital investment planning</li> <li>• Establishment of Municipal EE fund</li> </ul>	<ul style="list-style-type: none"> <li>• Waste Pyrolysis Project</li> <li>• Intermediate Transfer Stations including sorting, including Waste Infrastructure Planning (separate container sorting)</li> </ul>
	> 1 GWh/year		<ul style="list-style-type: none"> <li>• Retrofit Program / thermo-modernization of Municipal educational and medical facilities</li> <li>• Renewable energy individual heat generation for municipal education and medical facilities</li> <li>• Public Transportation Development for new district</li> <li>• Landfill Gas Capture Program and power generation unit</li> </ul>



## 2 Introduction and Background to the Rapid Assessment Framework

The Tool for Rapid Assessment of City Energy (TRACE) is a central component of the Energy Efficient Cities Initiative (EECI), launched by the Energy Sector Management Assistance Program (ESMAP) in collaboration with the Urban Anchor. TRACE was piloted in 2010 and first deployed in 2012.

The purpose of TRACE is to identify technical and institutional measures that will improve the energy efficiency of the municipal infrastructure across the following sectors:

- 1) Municipal Buildings
- 2) Public Street Lighting
- 3) Power and district heat supply
- 4) Transportation (public and private)
- 5) Potable water supply and waste water treatment
- 6) Municipal Solid Waste

The organizational management practices with respect to energy efficiency of the City Authority (CA) that span all of the sectors above are also considered. Details are provided in the city background report.

The ultimate aim of TRACE is to identify ways in which energy efficiency can be improved by the CA and therefore reduce their expenditure on energy.

Sectors that will directly save the CA money and over which it has direct control are labelled as 'City Authority'; while sectors that do not necessarily affect the CA's energy expenditure, relate to energy use principally in the private sector, and on which the CA may have limited influence are labelled as 'City Wide.' In such instances, the TRACE process identifies how these issues may be addressed through engagement, representation and other means.

## 3 Benchmarking of the current Energy Performance of the city

### 3.1 Introduction on Energy Performance Benchmarking for the city of Ternopil

The benchmarking component of the TRACE tool is intended to assess the energy performance of the city compared to other peer cities.

The following peer cities have been selected from TRACE database for the benchmark of Ternopil:

- |  |                                |
|--|--------------------------------|
| - Baku, Azerbaijan   | - Sarajevo, Bosnia-Herzegovina |
| - Banja Luka, Bosnia-Herzegovina   | - Skopje, Macedonia            |
| - Beijing, China   | - Sofia, Bulgaria              |
| - Belgrade, Serbia   | - Tbilisi, Georgia             |
| - Bucharest, Romania   | - Warsaw, Poland               |
| - Gaziantep, Turkey  | - Yerevan, Armenia             |
| - Pristina, Kosovo   |                                |
| - Ukrainian cities of Odessa and Kiev (for limited available benchmark data) |                                |

The selection of peer cities is based on a similar level of the Human Development Index (HDI) and continental climatic conditions as well as a location in (Eastern) Europe to enable an appropriate comparison.

The criteria of the size of population has not been applied for the benchmarking, as the size of population of the city of Ternopil at 0.2 million people ranges at the lower end of the cities of the TRACE database; the number of peer cities would be too small.

KPI data for the chosen peer cities is used as a principal factor in sector prioritization in the TRACE tool.

The Key Performance Indicators for the city of Ternopil have been calculated and aggregated based on data and information received from the City Authority of Ternopil as well as interviews with stakeholders of the administration and utilities of municipal services. Data collection and interviews took place in November 2014. The availability and quality of city data and information of the city context is satisfying. Specific data on of sectors have been collected. No proxies have been used.

It was agreed with the City Administration and the World Bank team to apply data of the year 2013 as baseline data for the TRACE assessment and the following EE assessment.

For each sector, a number of Key Performance Indicators (KPIs) have been derived to indicate energy performance of the sector.

**Figure 3: Key city statistics of 2013**

No	Indicator	Unit	Value
1	Population	people	218,600
3	Municipal area (same as metropolitan area)	km <sup>2</sup>	59
2	Population Density	People/km <sup>2</sup>	3,705
4	Primary Energy Consumption	GWh	2,727
5	Employment rate	%	90 %
6	Human Development Index (HDI) <sup>2</sup>		0.734
7	Total city budget	USD	99,095,378
8	Municipality expenditures for energy in public buildings	USD	8,077,902 8% of budget
9	Energy Spending (for sectors: municipal public transport, municipal buildings, street lighting, waste, water and waste water services)	USD	17,787,250 18% of budget
10	GDP (2013) <sup>3</sup>	USD	708,246,620

The Economic and political framework for implementation of energy efficiency in the city of Ternopil is outlined in the section on the city background.

The following sections graphically present the data collected and give a benchmarking comparison to other cities around the world. A selection of benchmarking graphs is presented that most accurately reflect the energy use characteristics of the city. The data applied for the benchmarking are justified in the context in the city of Ternopil in detail in the section of city background.

TRACE calculates the theoretical EE potential by comparing the KPI of Kyiv with the KPI of better performing cities (with lower specific energy consumption). This allows a rough statement on the performance of Kyiv compared to the set of peer cities.

A high rank with a performance indicator pertains to a favorable effect on energy efficiency, i.e. comparatively low consumption is judged to achieve a HIGH rank.

### 3.2 City Wide Energy Efficiency Benchmarking

**Figure 4: Key Performance Indicators for City Wide Energy**

Key Data			Key Performance Indicators (TRACE)	
Primary Energy Consumption per Capita	11,506	kWh/capita/annum	Electricity consumption (kWh <sub>e</sub> /capita)	1686.59
Primary Electricity Consumption per Capita	1,687	kWh <sub>e</sub> /capita/annum	Electricity consumption (kWh <sub>e</sub> /GDP)	0.61
Thermal Energy Consumption per Capita	2,613	kWh <sub>T</sub> /capita/annum	Primary energy consumption (MJ/capita)	41.42
Primary Energy Consumption per & GDP	3.85	kWh/USD	Primary energy consumption (MJ/GDP)	13.86
Energy Supply Cover	100	%		

<sup>2</sup> Source: UN Human Development reports; <https://hdr.undp.org/en/data>; Value for Ukraine 2013

<sup>3</sup> Source: Statistic Institute of Ukraine: [http://www.ukrstat.gov.ua/operativ/operativ2008/vvp/vrp/vrp2008\\_r.htm](http://www.ukrstat.gov.ua/operativ/operativ2008/vvp/vrp/vrp2008_r.htm)  
Calculated on the basis of Ternopil region GRP

The city of Ternopil ranks low for the performance indicator of Primary Electricity Consumption per capita in comparison with the peer cities with similar level of HDI. The theoretical energy saving potential for the city of Ternopil amounts to approximately 20 % to achieve a level of the better performing cities, such as: Tbilisi and Baku.

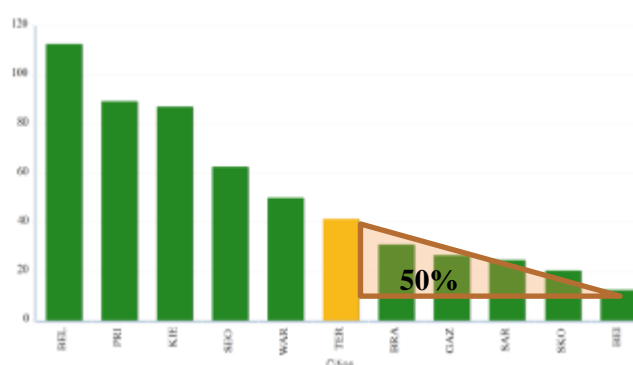
**Figure 5: Primary Electricity Consumption (kWe / GDP)**



The city of Ternopil ranks low for the performance indicator of Primary Electricity Consumption in kWe / GDP in comparison with the peer cities with similar level of HDI. The theoretical energy saving potential for the city of Ternopil amounts to approximately 30 % to achieve a level of the better performing cities, such as: Yerevan, Pristina and Belgrade.

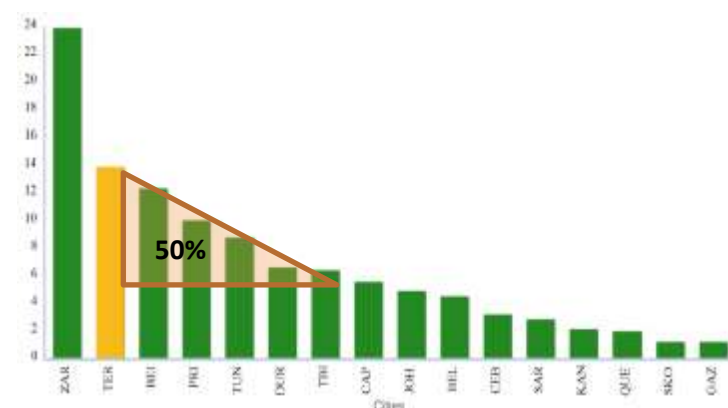
The city of Ternopil ranks medium for the performance indicator of Primary Energy Consumption per capita in comparison with the peer cities with similar climatic conditions. The theoretical energy saving potential for the city of Ternopil amounts to approximately 50 % to achieve a level of the better performing cities, such as: Skopje, Bratislava and Bratislava.

**Figure 6: Primary Energy Consumption (GJ / capita)**



The city of Ternopil ranks low for the performance indicator of Primary Energy Consumption per USD of GDP in comparison with the peer cities with similar characteristic on HDI. The theoretical energy saving potential for the city of Ternopil amounts to approximately 50 % to achieve a level of the better performing cities, such as: Tbilisi or Belgrade. Reason for this low performance is the low level of economic output of Ternopil. The improvement of that indicator depends heavily on the GDP development.

**Figure 7: Primary Energy Consumption (MJ / USD GDP)**



### 3.3 Transportation sector Benchmarking

**Figure 8: KPI and key data for transport sector**

Key Data		Key Performance Indicators (TRACE)	
Public transportation fuel consumption (MJ)	167 691 499	Total Transportation Energy Use Per Capita, MJ/capita	9806.4
Private transportation fuel consumption (MJ)	1 975 986 847	Public Transport Energy Consumption, MJ/passenger km	0.467
Public transportation passenger kilometers	359 149 000	Public Transportation Mode Split, %	0
Private transportation passenger kilometers	958 410 000	Private Transport Energy Consumption, MJ/passenger km	4
Transportation Mode Split (private motorized, public motorized, walk/cycle)	49 trolleybus	Metres of High Capacity Transit per 1000 People, m/1000 people	26
	219 bus		
	687 taxi	Transportation Non-Motorized Mode Split, %	2.062
	63 894 private transport		

There is no high capacity transit in Ternopil, such as metro and light rail.

The comparison with climate conditions of peer cities is not appropriate.

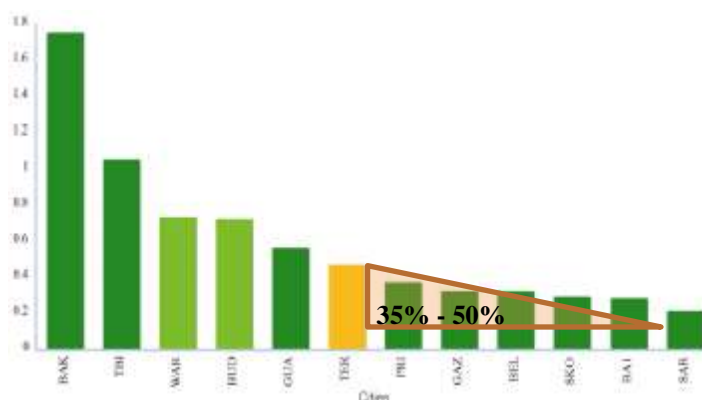
**Figure 9: Total Transportation energy use per capita (MJ/capita)**



The city of Ternopil ranks low for the performance indicator of Transportation energy use per capita in comparison with the peer cities with similar characteristic on HDI. The theoretical energy saving potential for the city of Ternopil amounts to approximately 50 % to achieve a level of the better performing cities, such as: Banja Luka and Skopje. However, the geographical extend and economic performance drives the demand of mobility and thus transports energy demand.

**Figure 10: Public Transport MJ / passenger km**

The city of Ternopil ranks medium for the performance indicator of Public Transport MJ / passenger km in comparison with the peer cities with similar characteristic on climate. The theoretical energy saving potential for the city of Ternopil amounts to approximately 35% to 50% to achieve a level of the better performing cities, such as Belgrade and Sarajevo respectively.



**Figure 11: Public transport mode split (%)**

The city of Ternopil ranks low for the performance indicator of Public transport mode split in comparison with the peer cities with similar characteristic on climate. There is the theoretical potential to increase the share of public transport use by 100% to achieve a level of the better performing cities, such as Belgrade and Sarajevo, at a level of 50%.

The share of non-motorized transport in Ternopil is low at a level of less than 5% of passenger km.

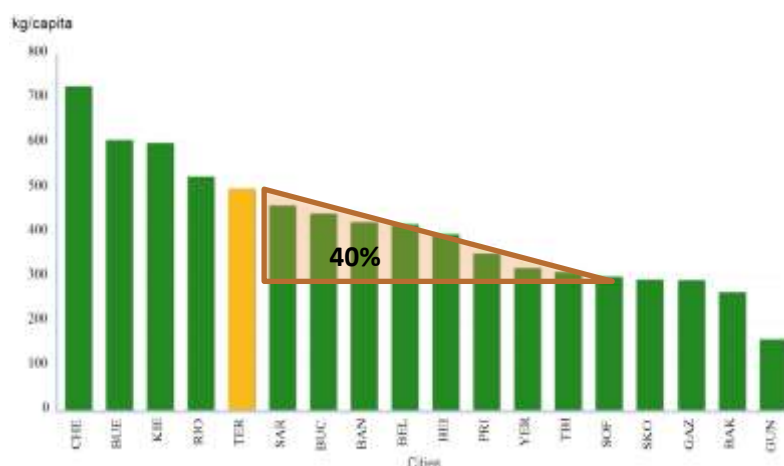
The specific energy consumption for private transport per passenger kilometre is in Ternopil at the central level of the peer cities.

### 3.4 Solid Waste Sector Benchmarking

**Figure 12: KPI and key data for solid waste sector**

Key Data		Key Performance Indicators (TRACE)	
Amount of solid waste generated within the municipal boundary (tonne)	108 910	Waste per capita (kg/capita)	498.22
Amount of solid waste that is recycled (tone)	695	Capture rate of solid waste	100
Amount of solid waste that goes to landfill (tone)	108 215	% of solid waste recycled	0.64
Amount of solid waste generated within the municipal boundary (tone)	108 910	% of solid waste that goes to landfill	99.36

The capture of solid waste amounts to almost 100% which all goes to the landfill. The very low percentage of waste recycled is according to official figures. In fact there is unofficial/illegal collection of recyclable fractions of the municipal waste which is processed for commercial sales.

**Figure 13: Waste per Capita (kg / capita)**

The city of Ternopil ranks low for the performance indicator of Waste per Capita in comparison with the peer cities with similar HDI characteristic. The theoretical potential to reduce the specific amount of waste at the city of Ternopil amounts to approximately 40 % to achieve a level of the better performing cities, such as: Sofia and Pristina.

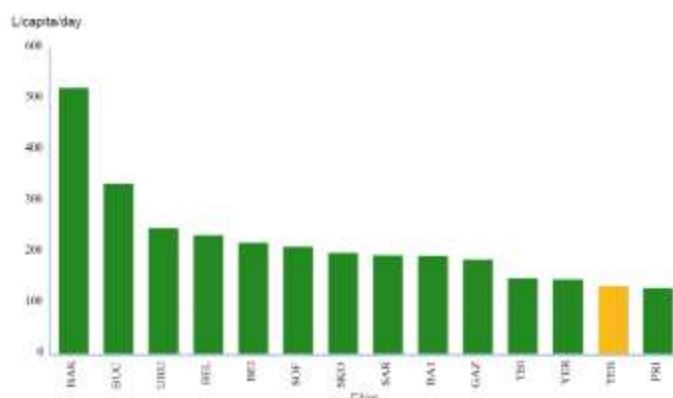
### 3.5 Water & Wastewater Sector Benchmarking

**Figure 14: KPI and key data for water and waste water sector**

Key Data	Key Performance Indicators (TRACE)
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Key Data		Key Performance Indicators (TRACE)	
Total amount of water sold (m <sup>3</sup> )	11 397 100	Water consumption L/capita/day	133.15
Energy consumed to produce potable water (kWh <sub>e</sub> )	11 712 900	Energy density of potable water production (kWh <sub>e</sub> /m <sup>3</sup> )	0.67
Total amount of potable water produced (m <sup>3</sup> )	17 362	Energy density of wastewater treatment (kWh <sub>e</sub> /m <sup>3</sup> )	5
Energy consumed to treat wastewater (kWh <sub>e</sub> )	15 773 700	Percentage of non revenue water <sup>4</sup>	46
Total amount of treated wastewater (m <sup>3</sup> )	18 401	Electricity cost for water treatment (potable- and wastewater) as a percentage of the total water utility expenditures	0.86
Energy expenditures of the water utility for potable water and wastewater treatment, \$	3 919 902		
Total expenditures of a water utility	8 515 589		
Number of households with potable water service	83 992		
Number of households with connection to the public sewage system	80 759		
Average water rates (\$/m <sup>3</sup> )	0.75		

**Figure 15: Water Consumption (l / capita / day)**



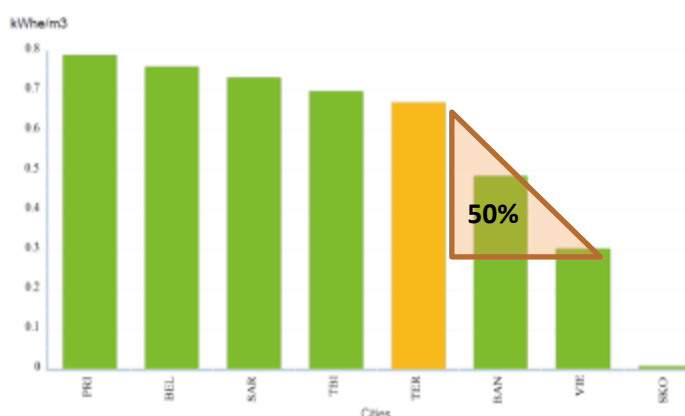
The city of Ternopil ranks high for the performance indicator of Water Consumption per capita in comparison with the peer cities with similar HDI characteristic. There is little theoretical potential for the city of Ternopil to decrease the consumption.

<sup>4</sup> Technical water losses amount to approximately 30%, but the sewage system collects rain water and waste water from other external sources. The TRACE model lacks precision for this KPI.

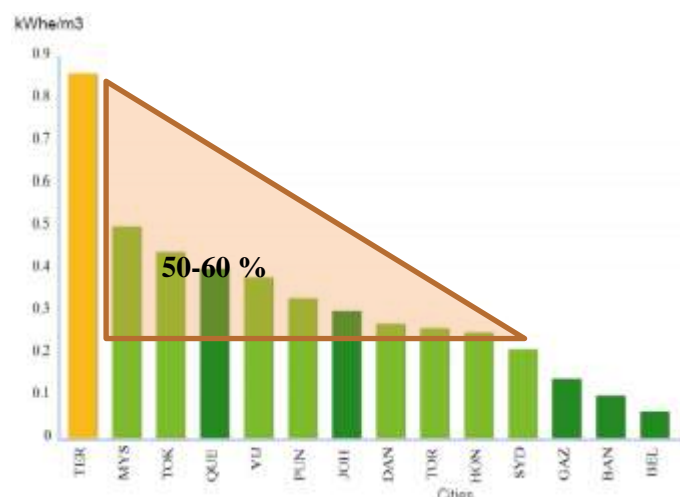


The city of Ternopil ranks medium for the performance indicator of Energy Density of Potable Water Production in comparison with the peer cities with similar characteristic on climate. The theoretical energy saving potential for the city of Ternopil amounts to approximately 50 % to achieve a level of the better performing cities, such as Banja Luca or Vienna. However, this indicator highly depends on the conditions of availability of fresh water resources.

**Figure 16: Energy Density of Potable Water Production (kWhe / m3)**



**Figure 17: Energy Density of Wastewater Treatment (kWhe / m3)**



The city of Ternopil ranks lowest for the performance indicator of Energy Density of Wastewater Treatment in comparison with all cities in TRACE comparisons. The energy saving potential for the city of Ternopil amounts to approximately 50 % to achieve a level of the better performing cities. The percentage of non-revenue water of a city needs to be considered for the evaluation of this indicator

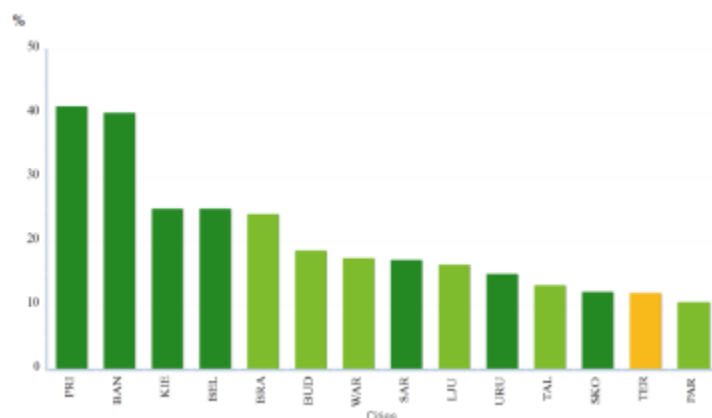
In Ternopil a high percentage of supplied potable water is revenue to the sewer and a of that a high percentage of collected wastewater is processed in the water treatment plant, both close to 100%, which consequently leads to high energy consumption and costs for the treatment. Peer cities with low level of treatment and collection rates have lower energy demand, but high environmental pollution.

The electricity cost for water treatment (potable and wastewater) as a Percentage of Total Water Utility Expenditures are at 45% thereby ranking highest in comparison with peer cities due to the above mentioned situation. Similar observations have been made for the energy density of waste water treatment at the high level of 0,86 kWh per m<sup>3</sup>.

### 3.6 Power & Heat Sector Benchmarking

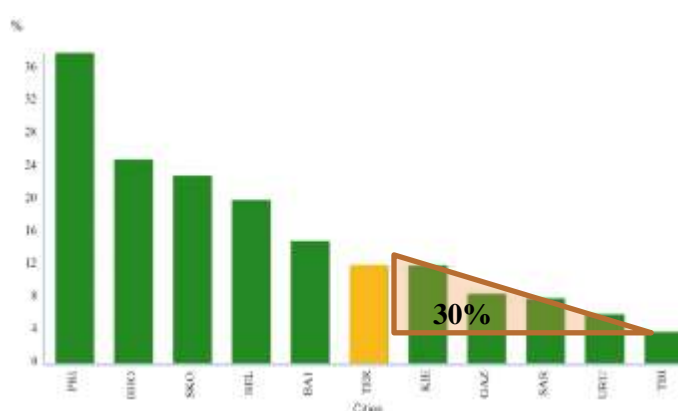
**Figure 18: KPI and key data for power and heat sector**

Key Data		Key Performance Indicators (TRACE)	
Technical T&D losses (kWhe)	49 115 000	Percent heat loss from network	11.82
Non-technical T&D losses (kWhe)	654 700	Percent total T & D losses	12.05
Number of households with authorized electrical service	83 343	Percent of T & D loss due to non-technical	1.33
Total electricity produced (kWh)	432 194 400		

**Figure 19: Heat Loss from DH Network in %**

The city of Ternopil ranks high for the performance indicator of Heat Loss from Network in comparison with the peer cities with similar climatic characteristic. A level of 12% heat losses is reported by the DH company and demonstrates, in fact, a good performance. Data for Ternopil need to be validated in the course of further assessment. The data of peer cities are not quite up-date and seem to contain estimations.

The city of Ternopil ranks medium for the performance indicator of power grid losses in comparison with the peer cities with similar characteristic. The theoretical energy saving potential for the city of Ternopil amounts to approximately 30 % to achieve a level of the better performing cities, such as power distribution networks in Western European cities at a level of 8% losses. The comparison with peer cities in the TRACE model is difficult, as they are not quite up-to-date and seem to be based on estimates and unknown assumptions.

**Figure 20: Losses from electricity Transmission & Distribution grid**

The Percent of Losses of the power Transmission & Distribution network due to Non-Technical Losses is in the city of Ternopil low. The collection rate, as reported by the power utility, is very high at a level of 99%.

A comparison with TRACE peer cities in particular with development countries is not appropriate.

### 3.7 Public Lighting Benchmarking

**Figure 21: KPI and key data for public lighting sector**

Key Data		Key Performance Indicators (TRACE)	
Total electricity consumption of street lights (kWhe)	2 672 100	Electricity consumed per km of lit roads (kWhe/km)	7 740.73
Total length of roads (km)	345.2		
Length of lit roads (km)	345.2	% of city roads lit	100
Number of light poles	8 248		
Total energy expenditure for street lights (\$)	176 539	Electricity consumed per light pole (by light point)	323.97
Average electric rates for street lights (\$/kWh)	0.066		

The specific electricity Consumed of Lit Roads in Ternopil with 7,700 kWh per km and the specific Electricity Consumed are with 324 kWh per Light Pole are low compared with peer cities. With the availability of new technologies such as LED the energy saving potential for street lighting increases to

40-50%<sup>5</sup>. The percentage of Lit City Roads is 100%, as reported by the municipal street lighting company.

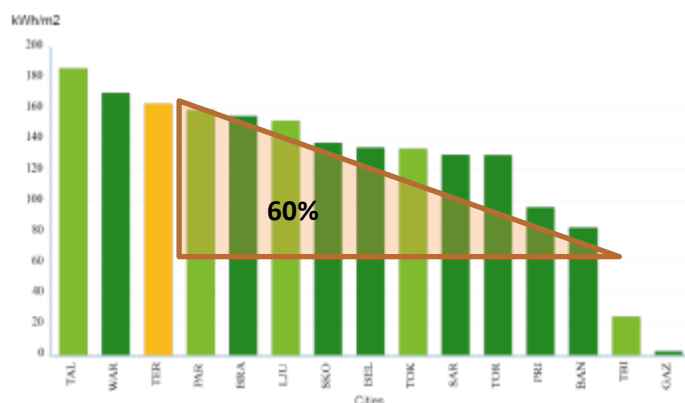
### 3.8 Municipal Buildings benchmarking

**Figure 22: KPI and key data for municipal public buildings sector**

Key Data		Key Performance Indicators (TRACE)	
Electricity consumption in municipal buildings (kWhe)	7 311 800	Municipal buildings electricity consumption (kWhe/m <sup>2</sup> )	19.45
Fuel consumption in municipal buildings (kWht)	61 334 417		
Total energy expenditure for municipal buildings (\$)	8 077 902	Municipal buildings fuel consumption (kWht/m <sup>2</sup> )	163.16
Municipal buildings, floor area (m <sup>2</sup> )	375 919		
Municipal buildings, average \$/kWh	0.09	Municipal buildings energy spend a percent of municipal budget	8.15
Commercial buildings, average \$/kWh	0.35		
Residential buildings, average \$/kWh	0.02		

The specific electricity consumption in Municipal Buildings is with approximately 20 kWh per sqm low compared with all peer cities.

**Figure 23: Municipal Buildings Heat Consumption (kWht / m<sup>2</sup>)**

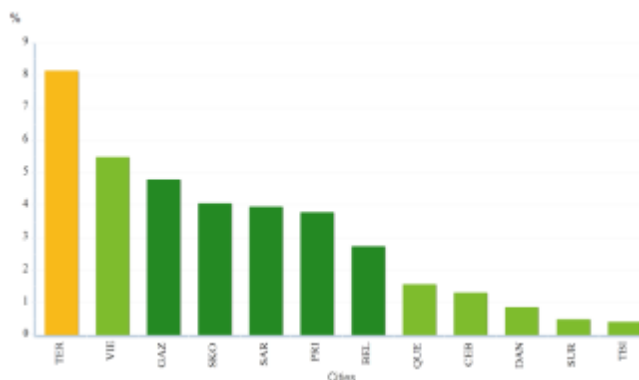


The city of Ternopil ranks low for the performance indicator of Municipal Buildings Heat Consumption in comparison with the peer cities with similar climatic characteristic. The theoretical energy saving potential for the city of Ternopil amounts to approximately 50 to 60 % to achieve a level of the better performing cities, such as Banja Luka and Western European cities. The average level of best practice for this indicator of 60 kWht/sqm could be applied. A comparison with cities listed in the TRACE model is not very appropriate due to the limited number of data and uncertain assumptions and sources on figures.

<sup>5</sup> It is assumed that LED technology replacement is not (or not widely) included in KPI of TRACE peer cities.

**Figure 24: Percentage of Municipal Budget spending for energy in municipal buildings**

The share of spending of energy in municipal buildings amounts to approximately of the 8% Municipal Budget of Ternopil. This is very high compared with peer cities. A direct energy saving potential cannot be derived from this indicator. This indicator is for average performing cities in western Europe at a level of 2 to 3 %.



### 3.9 Summary of Ternopil city benchmarking

In comparison with peer cities of the TRACE database the majority of performance indicators ranks low in terms of specific energy consumption, in particular for the sectors of

- preprimary energy consumption per GDP and per capita,
- **heat consumption in public buildings,**
- energy density for potable **water production and waste water treatment,**
- specific energy consumption for **street lighting,**
- energy use per capita for total **transport**
- specific energy consumption of the **public transport fleet**

The theoretical energy saving potential for the above sectors and KPI is in the **range of 30 to 50%.**

Additional potentials for increase of the city performance are:

- the reduction of **waste volume** per capita and an increase of the share of waste **recycling**
- an increase of the **share of public transport** mode to reduce private, individual transport energy consumption.

The results of the benchmarking comparison provide an indication for the prioritization of sectors with high energy saving potential.

## 4 Identifying Priority Sectors

The purpose of TRACE is to rapidly assess energy use in a city in order to identify and prioritize sectors, and indicate specific energy efficiency interventions.

Therefore it has been analyzed which sectors offer the highest Energy saving potential that are both achievable due to the control and impact by the CA and financially viable.

The process for identifying priority sectors considers three main issues:

- > the **proportionate spending on energy** in each sector either at a municipal level or for the entire city (public and private);
- > the **relative energy intensity** of the sector, based upon the results of the benchmarking exercise and the consultant's professional opinion having reviewed each sector; and
- > the **degree of control or influence** that the city government has over each sector or components of a particular sector, budgetary control being considered the most important factor.

### 4.1 Spending for energy in the city

Annual Budget of City in 2013	99 095 378 USD
<b>City Government Energy Spend</b>	
Energy Spending (for sectors: municipal public transport, municipal buildings, street lighting, waste, water and waste water services) in 2013	17 787 250 USD
Of which energy spending for municipal buildings	8,077,902 USD 8% of budget
Energy Spend as Percentage of Annual Budget	18%

A detailed analysis of the sectors is available in the city background report.

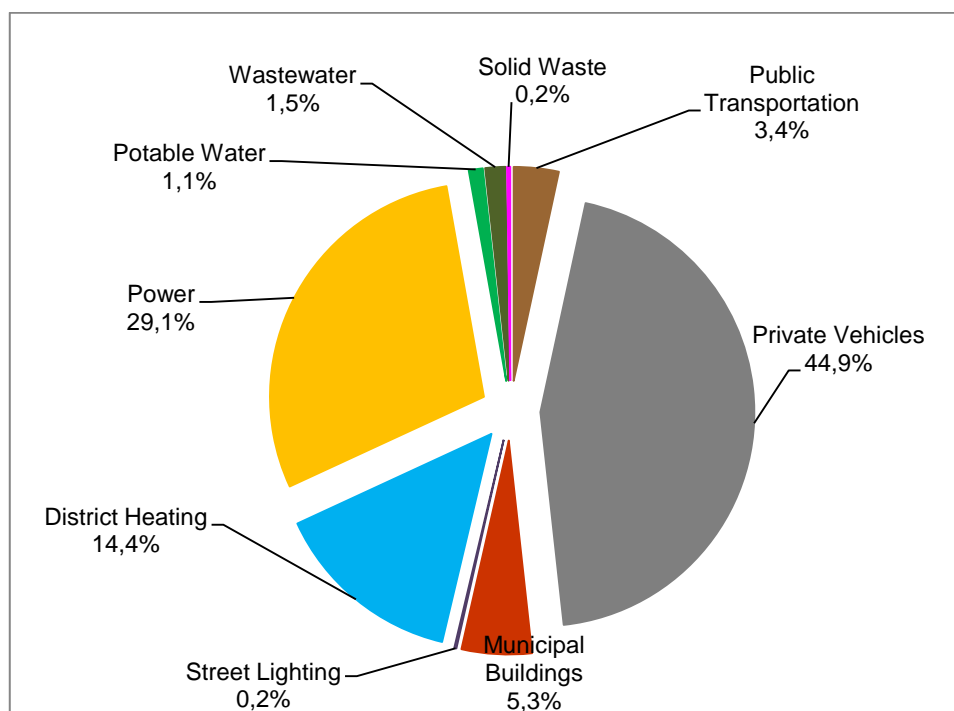
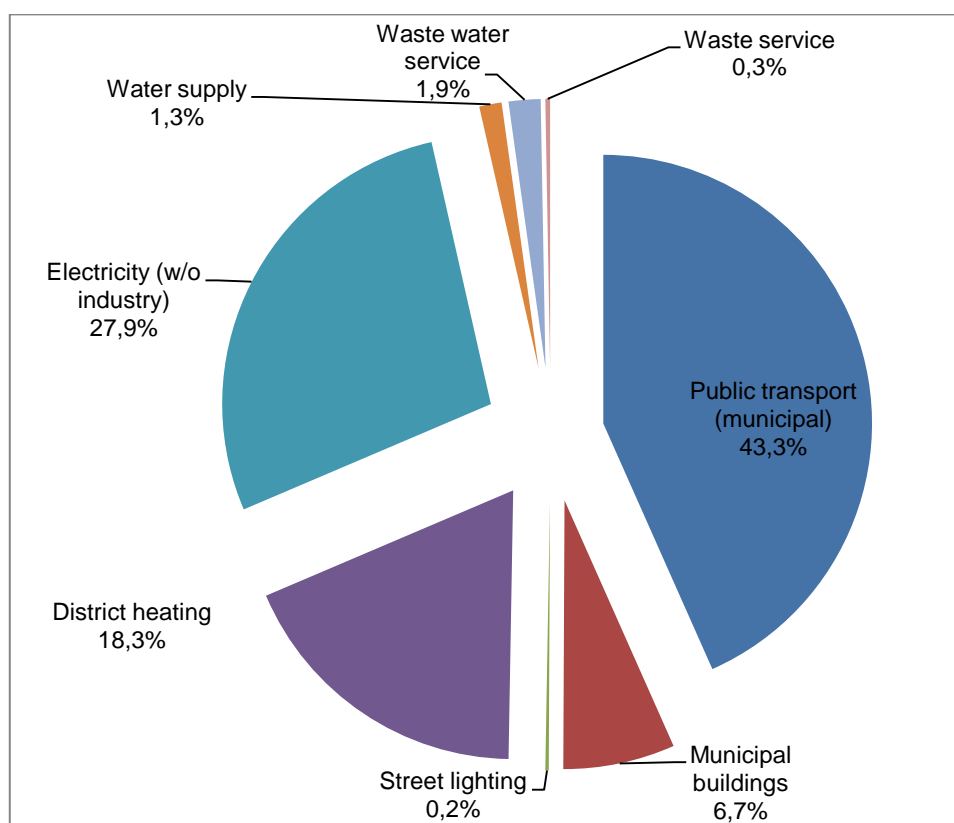
### 4.2 Relative Energy Intensity

The indication of the Relative Energy Intensity (REI) is based on the results of the benchmarking exercise and provides the theoretical potential for energy saving.

**Figure 25: Comparison of sectors by spending for energy, REI and EE potential**

Sector	Energy Spend (in million USD including VAT)	Theoretical Energy Savings Potential = Relative Energy Intensity	EE potential by implementation of the recommended set of measures
Public, municipal buildings	8.1	50-60%	77%
Street Lighting	0.2	40-50%	35%
District Heating	22.0	30%	16%
Public Transportation	5.2	20-35%	6%
Waste	0.4	30-50%	48%
Potable Water	1.6	30%	33%
Wastewater	2.3	30-50%	
Electricity sector	33.4	3%	0%
Private Vehicles	66.7	20%	1%

The spending for energy in Ternopil, without private transport sector, amounted in 2013 to a total 73.2 million USD, including private vehicles 139 million USD.

**Figure 26: Costs of energy in Ternopil (in million USD, year 2013, total 139 million USD)****Figure 27: Municipal spending for energy in Ternopil in 2013, without private transport sector (Total 17.8 million USD)**



### 4.3 City authority level of control, influence and enforcement power

The **level of regulatory power, budget control and influence** / enforcement power of the Ternopil City Authority on the energy sector and urban infrastructure is summarized as follows.

**Figure 28: Ternopil City authority level of budget control and enforcement power and urban infrastructure sectors` energy consumption**

Sector	City authority level of power		
	Regulatory	Budget control	Influence and enforcement
Public buildings	HIGH	HIGH	HIGH
Street lighting	HIGH	HIGH	HIGH
District heating	MEDIUM	MEDIUM	MEDIUM
Public transport	HIGH	MEDIUM	HIGH
Potable water supply	LOW	MEDIUM	MEDIUM
Wastewater	LOW	MEDIUM	MEDIUM
Waste	HIGH	MEDIUM	HIGH
Power supply	LOW	LOW	LOW
Gas supply	LOW	LOW	LOW
Private transport	LOW	LOW	LOW
Residential buildings	LOW	LOW	MEDIUM

The CA remains in full control over the sectors of **Municipal public buildings** and **street lighting**.

In addition the CA retains a certain degree of influence on the end energy consumer sectors of **water supply and wastewater disposal, district heating, waste management and public transport**.

The energy consumption of the **private, individual transport** can be influenced by the CA to a certain extend only, for example by attracting passengers to shift to the public transport mode of mobility and by smoothing inner-city traffic flow.

A cross-sector horizontal area of EE activities is the **Municipal Energy Management**, which is 100 % controlled by the CA.

The Municipal Authority of Ternopil has **limited control** and influence on

- A) the end consuming sectors of: Residential sector, commercial and industrial sector, private transport, non-municipal public buildings,
- B) the power generation and distribution sector,
- C) Gas distribution.

### 4.4 Prioritization of sectors

Consequently the EE recommendations for those sectors with limited control by the CA should receive lower/low priority.

The areas listed below will be the 7 sectors selected for detailed analysis and development of appropriate EE recommendations on the frame of TRACE.



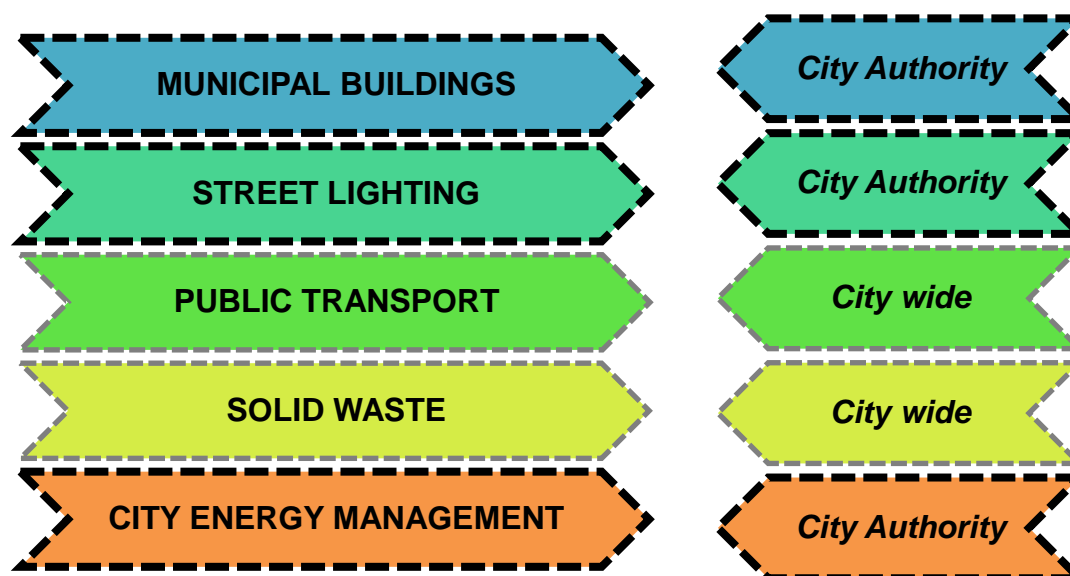
The level of use of the energy of a respective sector indicates in addition the degree of influence of the City Administration.

City wide energy means that the energy is spent for private, commercial and public entities, while City Authority means the energy is spent for areas or services, the City Authority has a jurisdiction.

The CA remains in full control over the sectors of municipal public buildings and street lighting.

In addition the CA retains a certain degree of influence on the end energy consumer sectors of water supply and wastewater, district heating, waste management and public transport. The classification of the level of control has been confirmed by the city leaders during the decision workshop.

The Priority sectors for Energy Efficiency Intervention are (in order):

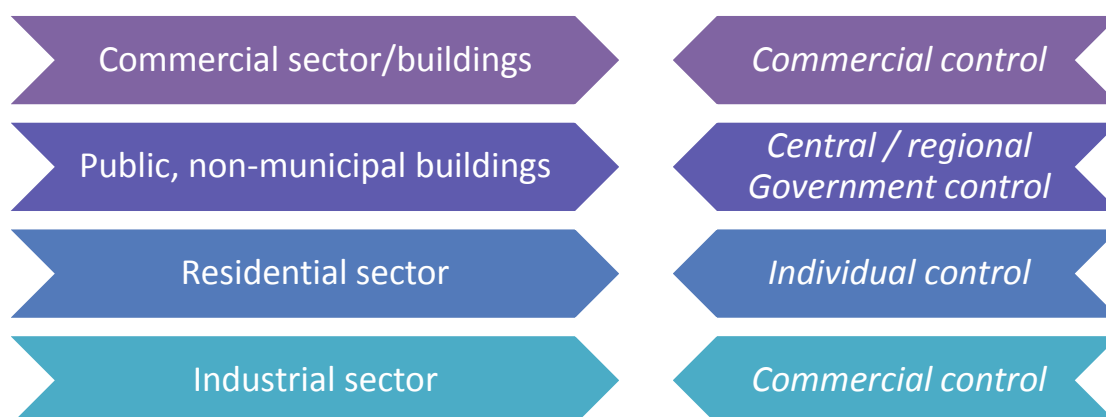


*Cross sector priority*

Considering EE interventions in those sectors have the potential to reduce municipal budget spending for energy, multiplication and replication and to strengthen the degree of CA control.

Lower priority is given to the sectors District Heating and Water&Waste water because of the committed and ongoing energy efficiency investment programs funded by IFI projects.

**Final energy consumer sectors which are controlled by individual or commercial entities are not considered in the TRACE assessment**, as the City Authority has no control and influence on the energy performance or energy budget spending. At this point, the following sectors are set aside and not pursued further.



This does not necessarily mean that no energy efficiencies are to be developed in these sectors. It simply indicates that, when compared to other sectors, they are unlikely to produce as compelling energy efficiency savings potential or are unlikely to be achievable by the CA.

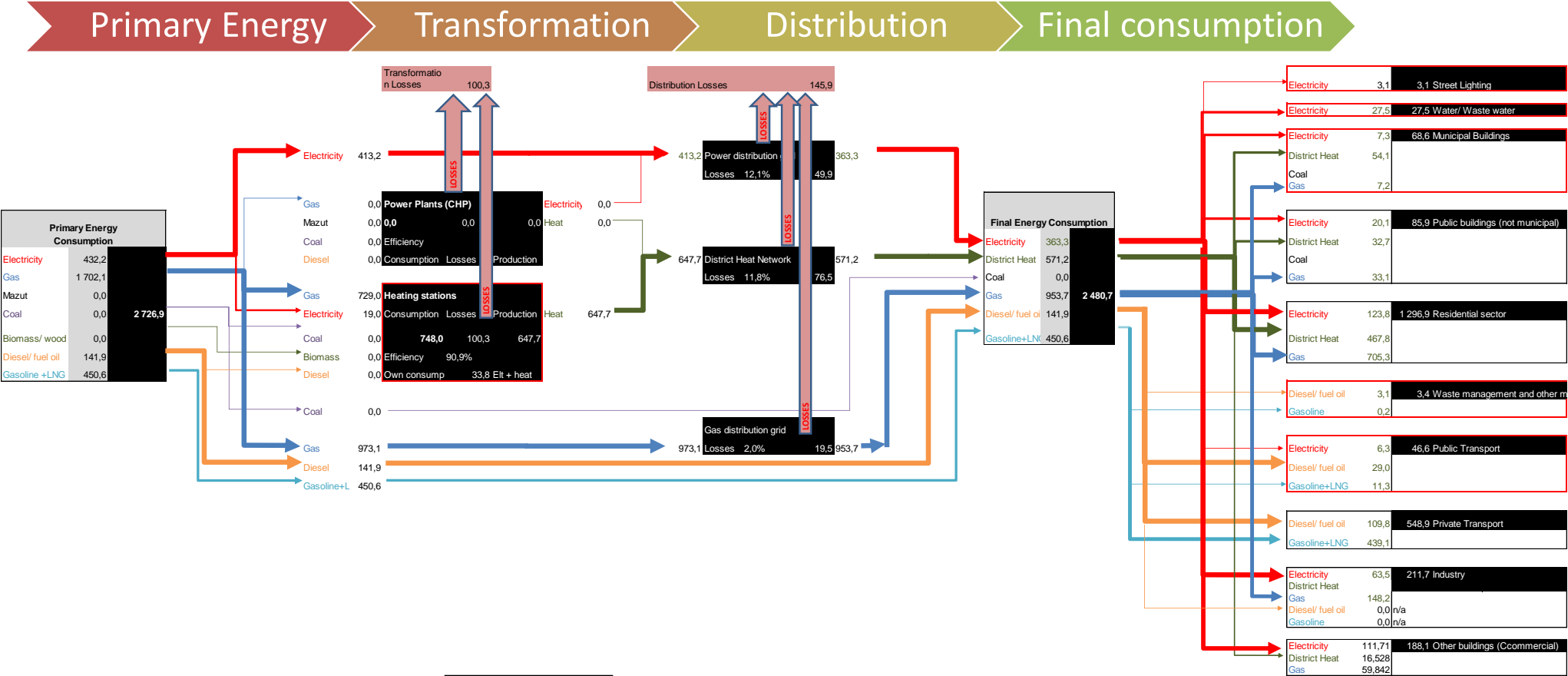
## 5 Brief Review of Sectors

A detailed analysis of the sectors is available in the city background report.

### 5.1 City wide energy

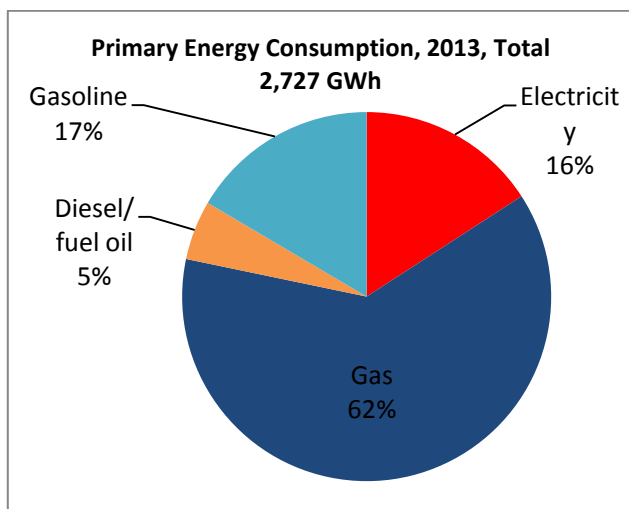
The Energy balance of Ternopil has been analyzed for the year 2013 and is presented graphically in a Sankey type Energy flow chart. The **city controlled areas** are marked with a red box. The energy flow of the city follows the logic of supply: Primary Energy → Transformation of Energy → Distribution → Final consumption.

Figure 29: Energy balance and Energy flow chart of Ternopil, 2013 (in GWh)

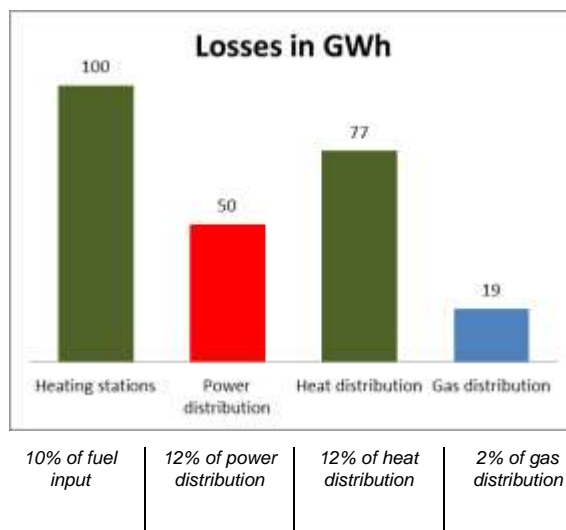


Ternopil's primary energy consumption amounts to 2,727 GWh in 2013 with highest consumption of natural gas of almost two third. The majority of gas is utilized in boilers of the central heating system to generate district heat for various end consumers. There are no power generation or heat and power cogeneration facilities operated in the city of Ternopil.

**Figure 30:** Primary energy consumption by energy carrier



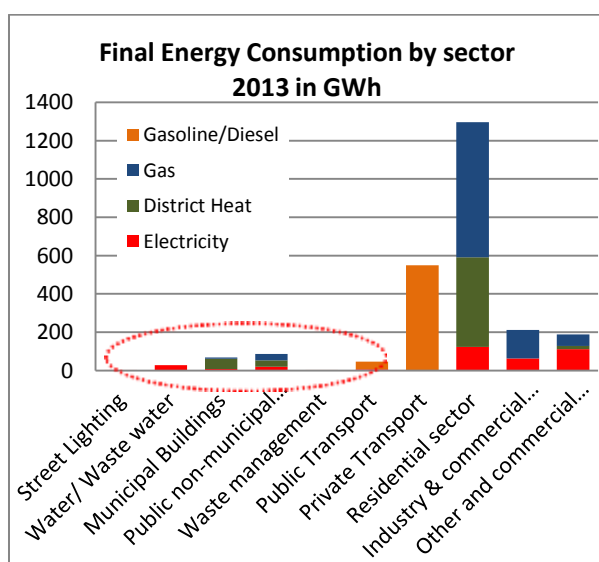
**Figure 31:** Losses in the energy transformation and distribution



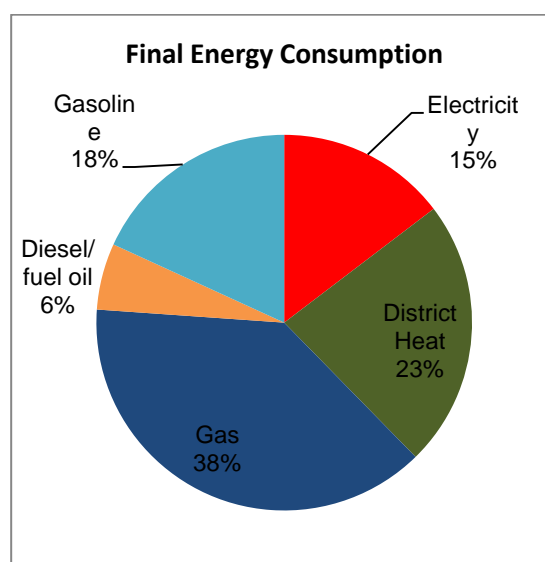
There are no shortages of energy supply registered in 2013. All households, public and commercial customers are connected to energy distribution systems and supplied with energy according to their needs.

The residential sector is the largest energy consumer with above 50 % of the city's **final energy consumption** as it is typical for all Ukrainian cities. This is followed by the private transport sector of 22% and industry and commercial sector (including other buildings) of 16%.

**Figure 32:** Final energy consumption by sector

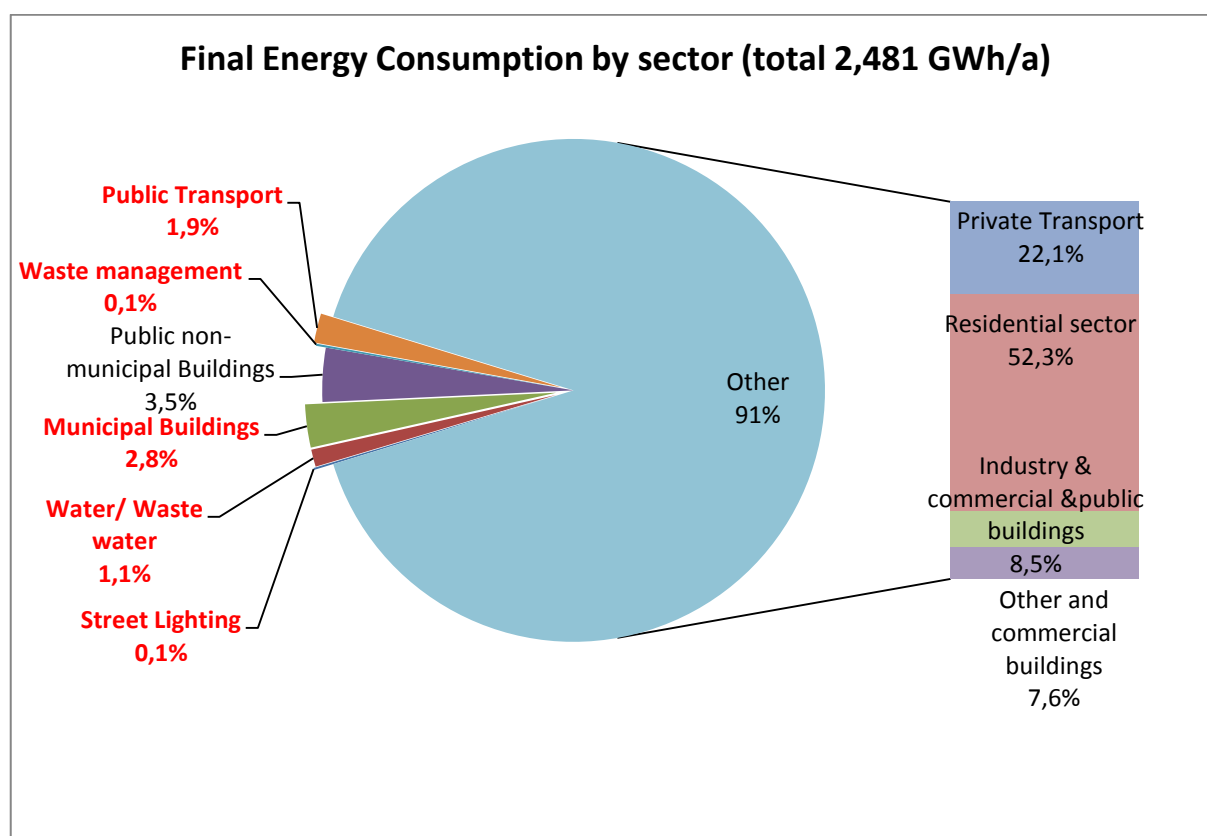


**Figure 33:** Final energy consumption by energy carrier



Natural gas and district heat are the dominant types of the final energy consumption, in particular in the residential sector.

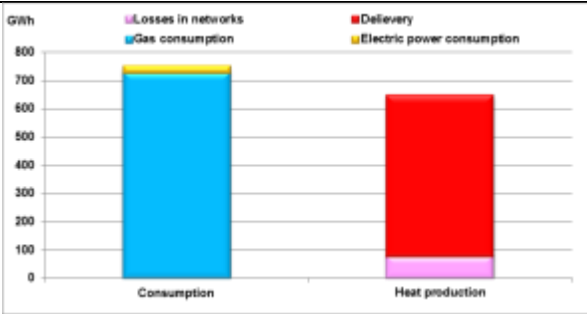
The final energy consumption of the sectors under control and influence by the city administration amounted in 2013 to 149.2 GWh which represents 6% of the overall city final energy consumption.

**Figure 34: Final energy consumption by sector, 2013 in %**

## 5.2 Heat generation and distribution - city wide

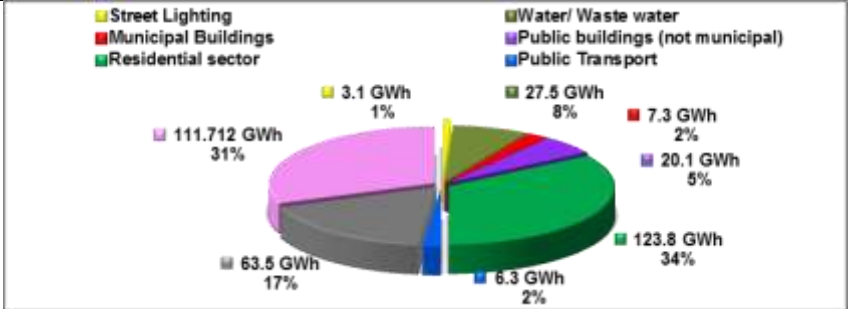
Operators of facilities/ utilities:	The communal enterprises “Ternopilmiskteplokomunenergo” provides space heat and domestic hot water services to customers of the central heating system.
Level of CA control or influence:	The CA as a key shareholder has control over MU “Ternopilmiskteplokomunenergo” and maintains influence on operation, performance and financing.
City energy spent and energy use:	<p>Individual heating stations of residential, commercial, non-municipal public and other buildings is not considered in this section, but the consumption is shown in the energy balance.</p> <p>The DH company operates 38 boiler-houses, with a total installed capacity of 646.278 Gcal/h (751.6 MW). Much of boilers are outdated and physically worn out which leads to the reduction to an operational capacity to one third, at a level of 215 Gcal/h. Approximately 85% of the boilers have exceeded their operation life time.</p> <p>The production capacity of the heating company amounts for space heat delivery at 191.359 Gcal/h and for hot water supply 22.703 Gcal/h.</p> <p>The heat networks length is 148.5 km. The heat losses in the DH network amount to 12%, caused by hydraulic losses, network water loses and heat losses in the pipelines</p> <p><b>Figure 35: Comparison of fuel consumption and heat energy production</b></p>



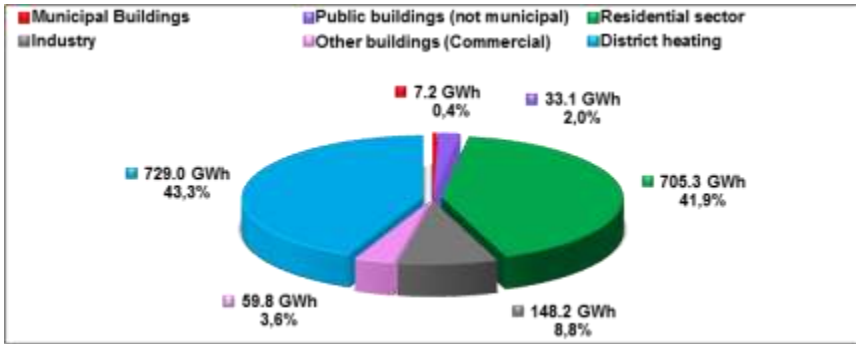
	 <p>The energy input / gas consumption for the heat production is with the amount of 139 m<sup>3</sup>/Gcal. The electricity consumption for heat production and distribution is high (37.5 kWh/Gcal). The main reasons for the high specific electricity consumption are: disconnection of consumers from the centralized heating system with 34% customers already lost; technically outdated equipment; lack of hydraulic balancing at the consumer sites.</p>
Condition of main equipment and EE potential:	<p>The DH network was constructed in the 1970–80 years; today 62% of the DH network components are older than 15 years. The majority of the heat networks are laid in reinforced concrete troughs which are impassable channels. Thermal insulation of pipes made mainly by mineral wool and glass wool mats and is partly damaged.</p> <p>Recently the government obliged the DH companies to decrease the gas consumption by 30%, as defined by the Resolution of Cabinet of Ministers of Ukraine 09.07.2014 № 296 "Some issue of providing natural gas population, enterprises, institutions and organizations by the end of the heating season 2014/15 year".</p> <p>Gas tariffs for heating companies that produce heat for households shall increase during 2014-2017 in steps by 34%, 40%, 20% and 20%.</p>

### 5.3 Power distribution - city wide

Operators of facilities/ utilities:	Electric power supply is carried out by JSC "Ternopiloblenergo" whose activities comprise electricity purchase, transmission and distribution to consumers in the region.
Level of CA control or influence:	<p>The power distribution system is not subject of municipal control or the municipal budget. Energy efficiency measures are under the responsibility of JSC "Ternopiloblenergo".</p> <p>The electricity tariffs are regulated by the National Commission for State Energy and Public Utilities Regulation of Ukraine.</p>
City energy spent and energy use:	<p>In 2013 city electricity consumption in Ternopil was 363.2 GWh, including population consumption - 33%, other consumers - 25%, industry - 18%, municipal utilities - 17% and public buildings -7%.</p> <p>All households are connected and supplied by the power utility.</p> <p><b>Figure 36: Structure of city electricity consumption by consumers groups</b></p>

	
Condition of main equipment and EE potential:	<p>Ternopil power supply is operated through 6 substations at 110/10 kV with a total capacity of 197 MVA. The length of the power electric networks is as follows: cables 10 kV and 0.4 kV – 643 km, Overhead lines 10 kV and 0.4 kV - 158 km. For the power distribution 320 closed-transformer substations with a total capacity 174 MVA exist. Consumer network has 168 closed-transformer substations with total capacity – 114 MVA.</p> <p>The technical transmission and distribution losses amount of 49 GWh which represents 12% of transmission energy.</p> <p>During the period 2009-2014 the power utility has undertaken a number of investments to up-grade the system performance: cable and sub-station replacement, improvement of metering.</p>

#### 5.4 Gas distribution - city wide

Operators of facilities/ utilities:	<p>The gas supply in Ternopil is operated by “Ternopilmiskgas”. As of 1st January 2011 76,005 apartments in Ternopil have been supplied by natural gas, which is mainly used in multi-apartment buildings for cooking and preparation of domestic hot water. Gas supplied to individual houses is used in addition for the individual production of space heat.</p>
Level of CA control or influence:	<p>The gas distribution system is not subject of municipal control or the municipal budget. Energy efficiency measures are under the responsibility of JSC " Ternopilmiskgas".</p> <p>The gas distribution tariffs are regulated by the National Commission for State Energy and Public Utilities Regulation of Ukraine.</p>
City energy spent and energy use:	<p>In 2013, the city gas consumption amounted to 179.5 million m<sup>3</sup> (1,702 GWh). The structure of gas consumers is: district heating company 44%, residential sector 42%, industry 9%, public buildings 2% and other consumers 3%.</p> <p><b>Figure 37: Structure of city gas consumption by consumers groups</b></p> 
Condition of main equipment and EE potential:	<p>“Ternopilmiskgas” operates 1,390 km of gas pipelines. Based on expert estimation, the technical losses in the gas distribution network amount to 2%.</p>

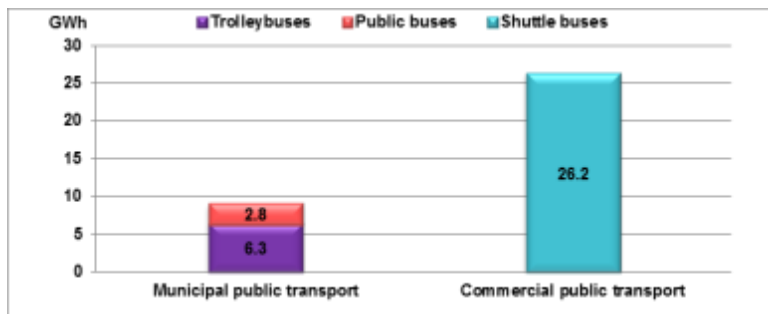
	During the period 2009-2014 the gas utility has undertaken a number of investments to up-grade the system performance: reduction of leakages and losses, improvement of metering.
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## 5.5 Private Transport - city wide

Operators of facilities/ utilities:	The transport energy consumption is dominated by private, individual vehicles. While the transport mode split referring to passenger-kilometers is estimated with 50–60% urban public transport, 5-10 % walk and cycling, 30-40 % individual, private cars.																		
Level of CA control or influence:	The licensing of vehicle operation is performed by Ukrtransinspektsiya (State land transport security Inspectorate of Ukraine). The CA as no control and limited influence on the individual transport means.																		
City energy spent and energy use:	<p>Private vehicles of individual motorized transport are with 92% the largest consumer of fuel and energy in city transport sector in 2013 .</p> <p>The overall passenger turnover amounts to 1,317.6 million passenger km per year. With a total energy consumption of 595 GWh per year. The split of energy consumption for all transport is: 1% electricity, 24% diesel, 74% gasoline and 1% LPG.</p> <p><b>Figure 38: Share of energy consumption of transport sector</b></p> <table border="1"><thead><tr><th>Transport Mode</th><th>Share (%)</th><th>Energy Consumption (GWh)</th></tr></thead><tbody><tr><td>Private vehicles</td><td>92%</td><td>548.9</td></tr><tr><td>Taxi</td><td>2%</td><td>11.3</td></tr><tr><td>Shuttle buses</td><td>4%</td><td>26.2</td></tr><tr><td>Public buses</td><td>1%</td><td>2.8</td></tr><tr><td>Trolleybuses</td><td>1%</td><td>6.3</td></tr></tbody></table>	Transport Mode	Share (%)	Energy Consumption (GWh)	Private vehicles	92%	548.9	Taxi	2%	11.3	Shuttle buses	4%	26.2	Public buses	1%	2.8	Trolleybuses	1%	6.3
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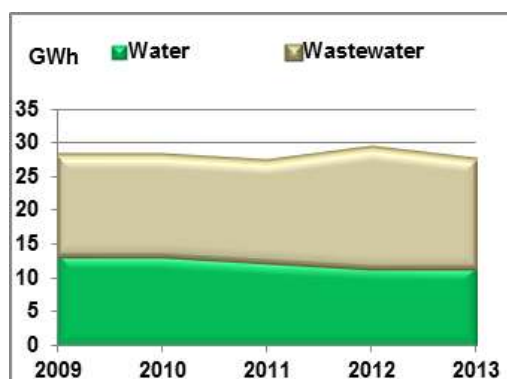
## 5.6 Public Transport Sector - City wide and City Authority

Operators of facilities/ utilities:	<p>The city public transport service is operated by:</p> <ul style="list-style-type: none"> <li>Transport companies with the CA as the main shareholder: "Ternopilelektrotrans", company with additional liability "Taxopark", OJSC TOP "Ternopilavtotrans-16100", which are operating 42 vehicles (9 trolleybus and 33 bus).</li> <li>Commercial transport companies: MC "Miskavtotrans", PJSC "Ternopil ATP - 16 127", LLC "Mens - Auto", LLC "ATK" Etalon ", LLC" Nazar - Trans ", LLC "Mega - Service", PE "Ternvoyazh"</li> </ul>
Level of CA control or influence:	<p>The CA maintains budget control and influence on the 3 municipal public transport companies.</p> <p>Commercial and private transportation services providers and taxi operators must register their vehicles in accordance with Ukrainian laws, to have relevant license and license card for each vehicle equipped according to established specifications.</p> <p>The local authority has full regulatory influence on the transport carriers of municipal ownership but also to a certain extent to commercial transport companies.</p>
City energy spent and energy use:	In Ternopil 45 million people (rides) were served by public transport services in 2013 including: trolleybuses - 37% municipal buses - 6%, minibuses - 57%. Preferential transportation is provided by all city

	<p>trolleybuses.</p> <p>The total number of inner-urban public transport vehicles comprise 268 units, comprising: 49 trolleybuses, 21 municipal buses, 198 shuttle buses).</p> <p><b>Figure 39: City transport fuel and energy consumption (excluding taxi and private transport) in 2013</b></p>  <table><caption>Data for Figure 39: City transport fuel and energy consumption (excluding taxi and private transport) in 2013</caption><thead><tr><th>Transport Type</th><th>Vehicle Type</th><th>Energy Consumption (GWh)</th></tr></thead><tbody><tr><td rowspan="2">Municipal public transport</td><td>Trolleybuses</td><td>6.3</td></tr><tr><td>Public buses</td><td>2.8</td></tr><tr><td>Commercial public transport</td><td>Shuttle buses</td><td>26.2</td></tr></tbody></table>	Transport Type	Vehicle Type	Energy Consumption (GWh)	Municipal public transport	Trolleybuses	6.3	Public buses	2.8	Commercial public transport	Shuttle buses	26.2
Transport Type	Vehicle Type	Energy Consumption (GWh)										
Municipal public transport	Trolleybuses	6.3										
	Public buses	2.8										
Commercial public transport	Shuttle buses	26.2										
Condition of main equipment and EE potential:	<p>There is the opportunity to introduce higher vehicle emission standards in the process of providing new or the extension of licenses for public transportation.</p> <p>The energy consumption of the private, individual transport can be influenced by the CA to a certain extend only, for example by attracting passengers to shift to public transport mode of mobility and by smoothing inner-city traffic flow.</p>											

## 5.7 Potable Water and Wastewater– city wide

Operators of facilities/ utilities:	<p>Water supply and waste water services are provided by the municipal utility "Ternopilvodokanal". It is a city wide service to all customer groups.</p> <p>The number of users of potable water (residential, public and commercial) is 80,759 of which 96% are connected to the waste water collection and treatment system.</p>																					
Level of CA control or influence:	<p>The CA as a key shareholder has control over MU "Ternopilvodokanal" and maintains influence on operation, performance and financing.</p>																					
City energy spent and energy use:	<p>Annual water consumption in the city is 11.4 million m<sup>3</sup>.</p> <p><b>Figure 40: . The water consumption Structure in the city, million m<sup>3</sup></b></p> <div><table border="1"><thead><tr><th>Category</th><th>Consumption (million m<sup>3</sup>)</th><th>Percentage (%)</th></tr></thead><tbody><tr><td>Utilities</td><td>0.1</td><td>1%</td></tr><tr><td>Residential buildings</td><td>9.1</td><td>80%</td></tr><tr><td>Public buildings</td><td>0.7</td><td>6%</td></tr><tr><td>Industrial enterprises</td><td>0.8</td><td>7%</td></tr><tr><td>Others</td><td>0.7</td><td>6%</td></tr><tr><td>Unlabeled</td><td>0.1</td><td>1%</td></tr></tbody></table></div> <p>The annual volume of sewage to be treated (including waste water from other sources and collected rain water) is 18,4 million m<sup>3</sup>.</p> <p>For the operation purposes of the water supply and wastewater system 27.5 GWh of electricity have been consumed in 2013, of which 43% for water supply and 57% for wastewater.</p> <p>Average specific electricity consumption for water supply is 0.675 kWh / m<sup>3</sup> and for wastewater – 0.857 kWh / m<sup>3</sup>.</p>	Category	Consumption (million m <sup>3</sup> )	Percentage (%)	Utilities	0.1	1%	Residential buildings	9.1	80%	Public buildings	0.7	6%	Industrial enterprises	0.8	7%	Others	0.7	6%	Unlabeled	0.1	1%
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**Figure 41: Electricity consumption of MU "Ternopilvodokanal" on water and wastewater service**

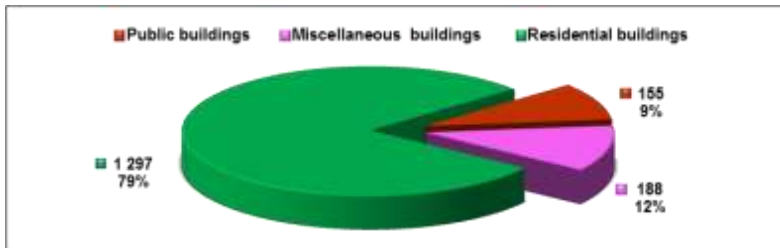
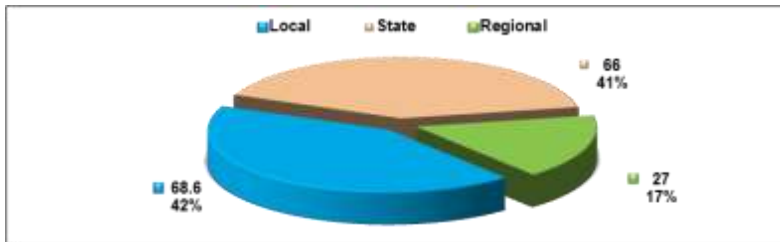
Condition of main equipment and EE potential:	<p>The total length of the water supply network is 342 km.</p> <p>Technical losses in water supply amount to approx. 38%.</p> <p>In 2013 the number of water network leakages was 324. The length of water supply network that need to be replaced is 183.6 km, which is 54% of the total water supply pipeline length.</p> <p>The length of waste water treatment network that need to be replaced is 135 km, which is 54% of the total waste water treatment pipeline length.</p> <p>Demand for energy saving by:</p> <ul style="list-style-type: none"> <li>• Implementation of energy efficient pumps and fans</li> <li>• improved metering of water consumption at residential sector</li> </ul>
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## 5.8 Waste management – city wide

Operators of facilities/ utilities:	Solid waste collecting services are determined on a competitive commercial basis according to the Law of Ukraine. In 2013 services collection, transportation and disposal of solid waste in the city has been provided by companies "Altfater-Ternopil", PE "Ekotern", PE "Quarter-L".
Level of CA control or influence:	The CA as has limited control over the commercial waste collection companies, but maintains full responsibility on the landfill.
City energy spent and energy use:	<p>In Ternopil there are 86,891 households and approximately 2,000 companies and organizations which generate solid municipal waste.</p> <p>Total solid waste annual collection in Ternopil in 2013 is 485,900 m<sup>3</sup>.</p> <p>Recyclable fragments of the waste volume amount to 342,600 m<sup>3</sup>, i.e. 71 % of the total, of which paper 25 %, metal 5 %, plastic 6 % and biomass 35 %. Currently less than 1% of the waste annual volume is recycled. Due to lack of waste sorting and a transfer station all waste goes to the landfill, which will reach the absorption capacity in a short period of time.</p> <p>Special vehicles that collect and transport solid waste have consumed 300,040 liters of fuel in 2013</p>
Condition of main equipment and EE potential:	<p>According to the waste management programs of the city the following energy performance improvements are necessary: :</p> <ul style="list-style-type: none"> <li>• construction of a solid waste processing facility;</li> <li>• implementation of separate waste collection systems in residential sector;</li> <li>• reconstruction of partially completed facilities for sorting waste;</li> <li>• replacement and up-grading of waste collection trucks including</li> </ul>

- driver training;
- awareness campaigns for reduction and separation of waste.

## 5.9 Building sector – City wide and City Authority

Operators of facilities/ utilities:	The total energy consumption of all buildings in Ternopil of various types of usage and ownership amounted to 1,640 GWh in 2013, representing 66% of the total city consumption.
Level of CA control or influence:	The buildings of the city are the largest final energy consumers, of which almost 80% goes to the residential sector. The CA has no control and limited influence on the energy consumption of the residential sector. Apartments in multi-storey buildings are privatized.
City energy spent and energy use:	<p><b>Figure 42: Energy consumption structure of overall buildings of different ownership, GWh</b></p>  <p><b>Figure 43: Structure of energy consumption of public buildings according to their ownership, GWh</b></p> 
Condition of main equipment and EE potential:	Through the installation of Individual Heating Stations (IHS) overheating of apartments can be reduced and better hydraulic balancing can be achieved. EE investments in improvement of the building performance and a decrease of the heat demand, e.g. building shell measures, remain challenging due to the ownership structure.

## 5.10 Municipal Buildings - city authority

Operators of facilities/ utilities:	The operator of the municipal public buildings are the departments of the CA: Department of Health and medical care, Department of Education and Science, Department of Culture and the Arts, Social Policy Management Department, Department of Family, Youth, Sports and Tourism;
Level of CA control or influence:	
City energy spent and energy use:	<p>In Ternopil there are 122 public municipal buildings with local budget funding with a total area is 375,900 m<sup>2</sup>.</p> <p>Municipal budget buildings can be divided into three types of budget funding: central government, regional and municipal buildings.</p> <p>Municipal budget buildings' fuel and energy consumption occupies approx. 4% among the total city buildings consumption</p> <p>The total amount of heat energy consumed in 2013 by municipal public</p>



	<p>buildings was 425,00 Gcal. Consumption of electricity is high at 11% of the total energy consumption. In 2013 7.3 GWh of electric energy was consumed by municipal public buildings.</p> <p>There is almost no supply of hot water from the district heating network for municipal public buildings.</p> <p>The gas consumption for heating and hot water preparation by individual boilers in municipal public building boilers amounted to 33 GWh per annum.</p> <p><b>Figure 44: The structure of fuel and energy consumption, GWh</b></p> <p>The specific heating energy consumption is in the range of 150-170 kWh / m<sup>2</sup>.</p>
Condition of main equipment and EE potential:	<p>The existing public buildings have been mostly built in the Soviet Union era in 1950-1970. They have large heat losses through the building envelope and require a significant amount of heat energy for space heating. Most buildings have received regular maintenance and repairs over 30 years.</p>

### 5.11 Public Lighting – City Authority

Operators of facilities/ utilities:	Operation, and maintenance of outside city lighting is carried out by municipal communal enterprise "TernopilniskSvitlo"
Level of CA control or influence:	CE "Ternopilnisksvitlo" is a legal entity in 100% ownership of the municipality. Thus the CA maintains full control and influence for the public lighting sector.
City energy spent and energy use:	<p>The total amount of electric energy consumption in 2013 was 3.126 GWh.</p> <p>The electricity consumption for street lighting during 2009 -2013 has been quite stable, while the costs for energy in the same period has almost doubled.</p> <p><b>Figure 45: Annual costs for street lighting</b></p>
Condition of main equipment and EE potential:	<p>For street lighting mainly incandescent lamps, arc mercury fluorescent lamps, and sodium-vapor tube lamps are used. Currently 73% of installed bulbs are efficient high-pressure sodium-vapor bulbs at a</p>



capacity of 150 W.

The operation hours of the street lighting are 3.743 h/year.

**Figure 46: Composition of street lighting by type and number of lamps**

Light bulbs type		Average capacity of light point (W)	Number of light points
Sodium lamp arc tube	DNaT	150	6,050
Arc mercury fluorescent lamps	DRL	250	2,138
Incandescent lamps	IL	100	56
LED lamps	LED		4
Total			8,248

The frequency for the replacement of conventional bulbs is 3 to 4 years. The annual cost for replacement and maintenance of conventional bulbs (equipment + installation) amounts to USD 39.200.

## 6 Energy Efficiency Recommendations

### 6.1 Methodology for evaluation, selection and ranking of EE measures

The long-list of recommendations for energy efficiency originate from various sources in the course of the compilation of data, information, consultation with stakeholders as well as the TRACE model.

Sources for EE recommendations have been:

- listed EE recommendations of the **TRACE model**,
- measures which have been recommended and analyzed in the **SEAP and Municipal Energy Plan** of the city of Ternopil
- recommended EE measures which have been identified during **interviews with city administration and local stakeholders, utilities**
- **best practice** EE recommendations from the expertise of the **consulting team**

In addition EE investment measures and investment programs which have been commenced in 2014, such as IFI funded projects (IBRD, EBRD) have been considered, as their implementation will provide EE benefits compared to the baseline of energy performance of the year 2013. Those EE measures and programs “on the way” are listed separately, because they are already prioritized.

A total set of 74 EE recommendations has been identified and preliminarily evaluated on their appropriateness. Those include also EE recommendations in the sectors which have been recommended as ‘low priority’, i.e. the power sector and private transport.

For that first selection the following **criteria on appropriateness** for the EE measure have been applied.

- a) Degree of **control and influence** of the Municipal Authority on the sector
- b) Degree of **competencies of the CA** or the stakeholder responsible for the implementation. Competencies of the CA comprise: Capacities of the utility or municipal staff to operate and maintain the project, equipment/ facility; Capacity to undertake project assessment, public procurement and implementation supervision; Experiences with similar previous projects; Available methods/equipment to verify energy savings. The assessment of the competencies follows the initial appraisal of the TRACE model
- c) **Ease of Implementation**
- d) Availability of the **local market** for the EE measure and maturity of the Ukrainian and local market for application, mainly related to absorption capacity for the technology and its operation
- e) Availability of a **supporting framework**, in terms of regulatory, legal and municipal policy
- f) Ability to achieve the **Economic Sustainability**; to establish and maintain the economic benefit in terms of revenues from the EE measure for the investor in the EE measure.

If one or more of the criteria b) to f) have been evaluated negatively, such as low or not guaranteed, the respective EE recommendation has been dropped for further consideration.

The Recommended EE measures are of **different type**, nature:

- **Type I: investment** measures, which comprise the investment and installation of EE technology and equipment and generate physical energy savings
- **Type P: preparation** measures which are non-investment but preparing the framework or conditions for the smooth implementation of investment measures, such as feasibility studies, regulation, implementation mechanisms. It is recommended to link and combine those type P measures with investment measures.
- **Type A: Accompanying** measures, which are non-investment or low investment, which are enabling EE at low-cost, such as awareness raising, information and increasing capacities.

It is recommended to link and combine those type A measures on demand with investment measures to ensure their proper implementation, monitoring and results.

The following **assumptions** have been taken for the preliminary assessment of EE recommendations/ EE measures

- *Investment costs* at the level of 2013 prices, including import duties (on demand), installation, using the currency exchange rate of December 31, 2013 (1 USD = 82, UAH)
- *Emission factors* for primary energy carriers
- *Payback* is preliminarily calculated on the basis of annually saved energy costs. For this purpose the 5-year average tariff of the respective final energy carrier is used for the period 2015 to 2020
- The *implementation period* of the EE measure starts in 2016, with delivery of EE benefits in the year 2017 the earliest. Each EE measure is completed in 2020. EE benefits become valid in the energy balance of 2020.

## 6.2 EE recommendations in the sector Municipal public buildings

The following set of EE recommendations meet the basic criteria of appropriateness and have been preliminarily assessed.

Code	Title of measure	Type	Comment/ additional information
PB-01	Municipal educational facilities Audit and Retrofit Program (schools, kindergartens, etc.)	<b>I-Investment</b>	258,402 sqm including building shell, piping (no EE on electricity consumption)
PB-02	Renewable energy individual heat generation for municipal education and medical facilities (schools, kindergartens, hospitals)	<b>I-Investment</b>	Biomass (woodchips/pellets) and heat pumps
PB-03	Municipal medical facilities Audit and Retrofit Program (hospitals, polyclinics, etc.)	<b>I-Investment</b>	73,660 sqm including building shell, piping (no EE on electricity consumption)
PB-04	Other municipal Building Audit and Retrofit Program (culture facilities, libraries, etc.)	<b>I-Investment</b>	30,162 sqm including building shell, piping (no EE on electricity consumption)
PB-05	Municipal administrative buildings Audit and Retrofit Program	<b>I-Investment</b>	13,688 sqm including building shell, piping (no EE on electricity consumption)
PB-06	Replacement of indoor lighting for all municipal public buildings	<b>I-Investment</b>	(T5 with reflector of LED), all buildings 10 kWh/m2 for lighting
PB-07	Municipal Building Inventory and Benchmarking and Monitoring Program	P-Preparation	
PB-08	Mandatory Building Energy Efficiency Codes for Existing and New Buildings	Accompanying	

There are no considerable EE investment programs on-going in the sector.

A number of other EE activities as listed in the TRACE model have not been put forward or have been integrated in the set of recommended EE measures.<sup>6</sup>

<sup>6</sup> TRACE model EE activities in this sector which have been rejected due to their low appropriateness (technology, framework, economic sustainability, capacities, and ease of implementation) are:

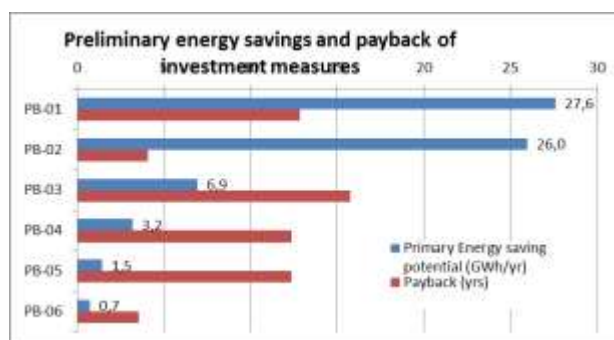
- Municipal Building Energy Efficiency Task Force, as it shall be included in the Energy Management sector
- Municipal Residential building Audit and Retrofit Program; as there are no considerable municipally owned residential buildings
- Computer PowerSave Project
- Solar Hot Water Program
- Green Building Guidelines for New Municipal Buildings, due to limited number of new construction expected
- Installation of IHS at schools and kindergartens, as this has been realized already for 90% of the related buildings (74 buildings)
- Green Building Guidelines for New Municipal Buildings, included in PB-06

The preliminary assessment of the recommended EE measures results into the following indicators. A first ranking of the EE measure has been undertaken on the highest energy saving potential.

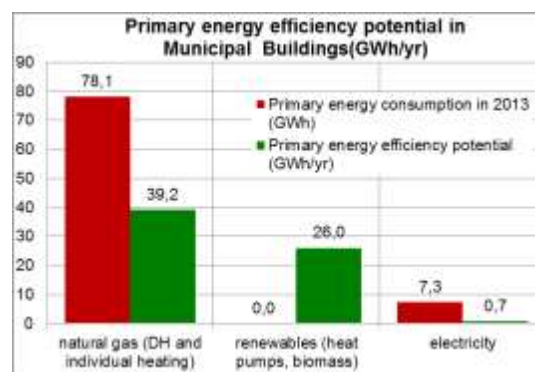
Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Saving of energy carrier	Emission saving (kt CO <sub>2</sub> /a)	Preliminary payback time (years) <sup>7</sup>
PB-01	Municipal educational facilities Audit and Retrofit Program (schools, kindergartens, etc.)	28,55	27,61	Primary-gas	5,6	12,87
PB-02	Renewable energy individual heat generation for municipal education and medical facilities (schools, kindergartens, hospitals)	5,30	26,00	Primary-gas	5,3	4,08
PB-03	Municipal medical facilities Audit and Retrofit Program (hospitals, polyclinics, etc.)	8,62	6,94	Primary-gas	1,4	15,78
PB-04	Other municipal Building Audit and Retrofit Program (culture facilities, libraries, etc.)	3,14	3,22	Primary-gas	0,7	12,37
PB-05	Municipal administrative buildings Audit and Retrofit Program	1,42	1,46	Primary-gas	0,3	12,37
PB-06	Replacement of indoor lighting for all municipal public buildings	0,59	0,73	Primary-electricity	0,8	3,55
PB-07	Municipal Building Inventory and Benchmarking and Monitoring Program	0,01	0,34	all Final energy of the sector	0,2	0,23
PB-08	Mandatory Building Energy Efficiency Codes for Existing and New Buildings	0,01	0,00	all Final energy of the sector	0,0	n/a

**Figure 47: Preliminarily calculated energy saving potential (primary energy, final energy gas and electricity) and payback time of recommended EE measures**

Primary energy savings and payback time by EE measures

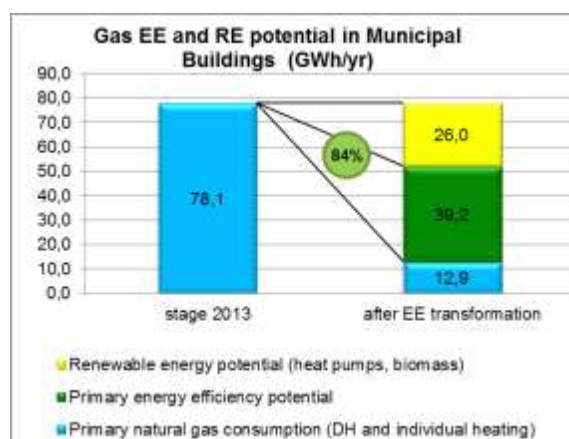


Primary energy savings by type of energy and RE

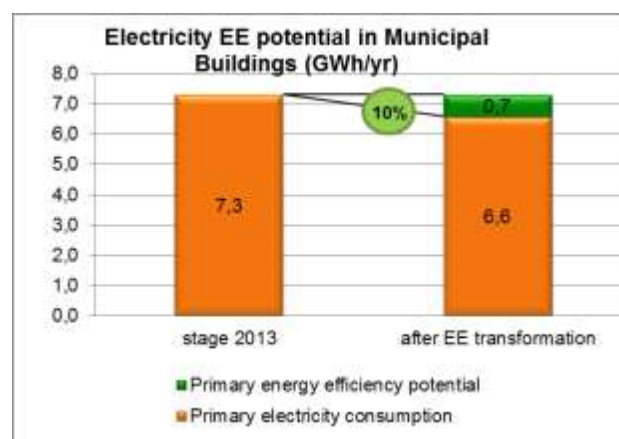


<sup>7</sup> The PBT is based on a rough estimate of the investment and it doesn't consider operation costs.

## Potential gas savings



## Potential electricity savings



The reduction of energy demand of municipal public kindergartens and various types of schools bears the largest potential to save district heating energy at a level of 26 GWh per year. The same level of savings of district heat can be achieved by the installation of individual heat generation units using renewable energy sources (such as heat pumps and biomass boilers).

This needs to be coordinated closely with the DH Company as a reduction of the heat load may result in negative effects for the DH system.

In addition substantial heat energy savings can be achieved by rehabilitation of administrative and medical buildings.

The indicative implementation frame of the pre-selected investment measures can be as follows:

Title of EE recommendation	Implementation perspective	Possible start in	Implementation Speed (years)
Renewable energy individual heat generation for municipal education and medical facilities (schools, kindergartens, hospitals)	short-term	2017	2 years
Replacement of indoor lighting for all municipal public buildings	short-term	2016	1 year
Municipal Building Inventory and Benchmarking and Monitoring Program	short-term		2 years
Municipal educational facilities Audit and Retrofit Program (schools, kindergartens, etc.)	long-term	2016	3 years
Municipal medical facilities Audit and Retrofit Program (hospitals, polyclinics, etc.)	long-term	2017	3 years
Other municipal Building Audit and Retrofit Program (culture facilities, libraries, etc.)	long-term	2017	2 years
Municipal administrative buildings Audit and Retrofit Program	long-term	2016	2 years
Mandatory Building Energy Efficiency Codes for Existing and New Buildings	long-term	2016	3 years

The **key stakeholders** for implementation of the recommended EE measures in this sector are:

- The municipal authority and the respective department in the CA, as the owner of the buildings
- The directors of the facility
- The users of the facility

### 6.3 EE recommendations in the sector street lighting

The following set of EE recommendations meets the basic criteria of appropriateness and has been preliminarily assessed.

Code	Title of measure	Type	Comment/ additional information
SL-01	Street Lighting Audit and Retrofit Program	I-Investment	Replacement of Mercury bulbs with LEDs, (approx. 2,100 mercury-vapour lamps of 566 kW), including replacement at public space lighting on demand
SL-02	Street Lighting timing, dimming and management	I-Investment	Combination of dimming and timing device for light points which will be replaced.

Code	Title of measure	Type	Comment/ additional information
	Program		
SL-03	Traffic Signal Audit and Retrofit Program	I-Investment	Replacement at 40 intersections
SL-04	Procurement Guide for New Street Lights	P-Preparation	Implementation of life cycle cost assessment

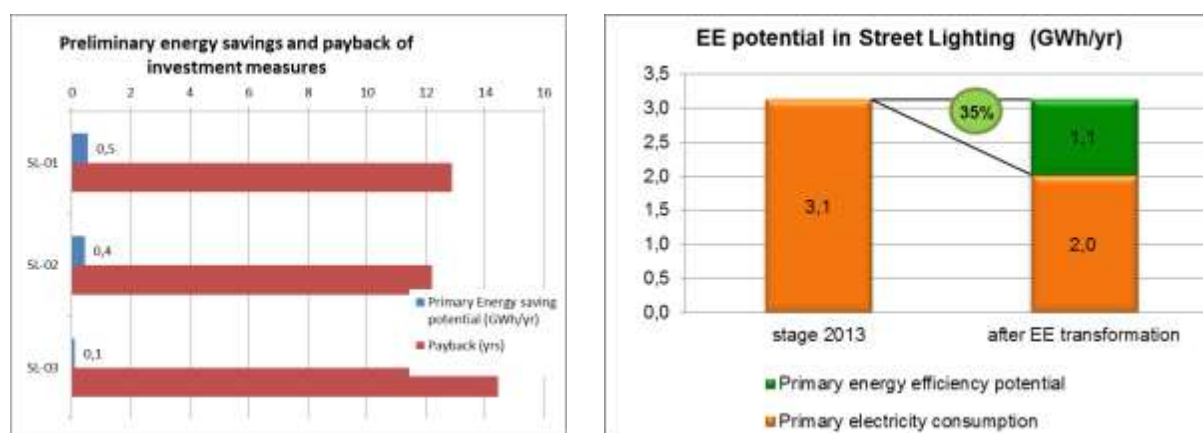
Presently there are no considerable EE investment programs in the sector.

A number of other EE activities as listed in the TRACE model have not been put forward or have been integrated in the set of recommended EE measures.<sup>8</sup>

The preliminary assessment of the recommended EE measures results in the following indicators. A first ranking of the EE measures has been undertaken on the highest energy saving potential. All energy savings in the street lighting sector are Primary energy electricity savings.

Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Emission saving (kt CO <sub>2</sub> /a)	Preliminary payback time (years)
SL-01	Street Lighting Audit and Retrofit Program (replacement with LED) <sup>9</sup>	0,69	0,55	0,6	10-12,87
SL-02	Street Lighting timing, dimming and management Program	0,54	0,45	0,5	12,19
SL-03	Traffic Signal Audit and Retrofit Program	0,16	0,11	0,1	14,45
SL-04	Procurement Guide for New Street Lights	0,00	0,00	0,0	0,00

**Figure 48: Preliminarily calculated Primary energy saving potential of recommended EE measures and payback time**



The indicative implementation frame of the pre-selected investment measures can be as follow:

<sup>8</sup> TRACE model EE activities in this sector which have been rejected due to their low appropriateness (technology, framework, economic sustainability, capacities, and ease of implementation) are:

- Integrated Public Lighting Assessment Program, as market and absorption capacity is low
- Street Signage Lighting Audit and Retrofit Program, no market
- Public Spaces Lighting Audit and Retrofit Program, integrated in measure SL-01

<sup>9</sup> Investments include replacement of electric network and poles Lighting Timing, dimming and management Program. It will be analyzed in more detail in the EE program/ profile.



Code	Title of EE recommendation	Implementation perspective	Possible start in	Speed of Implementation, years
SL-01	Street Lighting Audit and Retrofit Program	short-term	2016	1 year
SL-02	Street Lighting timing, dimming and management Program	short-term	2016	2 years
SL-03	Traffic Signal Audit and Retrofit Program	short-term	2016	1 year
SL-04	Procurement Guide for New Street Lights	short-term	2016	2 years

The key stakeholders for implementation of the recommended EE measures in this sector are:

- The City Authority including a cooperation with infrastructure planning department
- The Street lighting company
- Cooperation with the power utility Ternopilenergo is required

#### 6.4 EE recommendations in the sector district heating

The following set of EE recommendations meet the basic criteria of appropriateness and have been preliminarily assessed.

Code	Title of measure	Type	Comment/ additional information
DH-01	Performance increase of boiler-houses by rehabilitation	I-Investment	change of burners, economizers, replacements, reduction of own consumption
DH-02	Fuel switch for heat generation - gas to biomass	I-Investment	one biomass boiler of 8 MW
DH-03	District heating network rehabilitation, pipeline replacement	I-Investment	emergency replacement of 25% of distribution and transmission pipeline system
DH-04	Solar heating plant	I-Investment	assumed 2 MW for the DHW
DH-05	Hydraulic balancing of the DH system	I-Investment	
DH-06	Installation of cogeneration plant for coverage of own demand	I-Investment	2 small units (0.3-0.5 MW)
DH-07	Implementation of SCADA system	I-Investment	
DH-08	Replacement of circuit pumps and equipment with VSD	I-Investment	

On-going EE investment programs in the sector are as follows:

- EBRD project and IBRD project covering DH 02, DH – 03, DH-04, DH 07

A number of other EE activities as listed in the TRACE model have not been put forward or have been integrated in the set of recommended EE measures.<sup>10</sup>

The preliminary assessment of the recommended EE measures results in the following indicators. A first ranking of the EE measures has been undertaken on the highest energy saving potential.

<sup>10</sup> TRACE model EE activities in this sector which have been rejected due to their low appropriateness (technology, framework, economic sustainability, capacities, and ease of implementation) are:

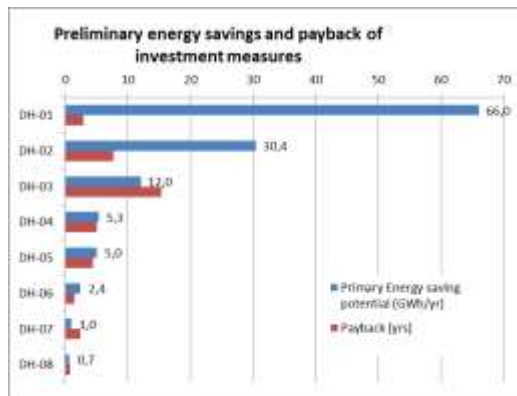
- District heating network rehabilitation, pipeline insulation and maintenance, as the remaining pipeline system of 75% of distribution and transmission is presumed to be in good performance.



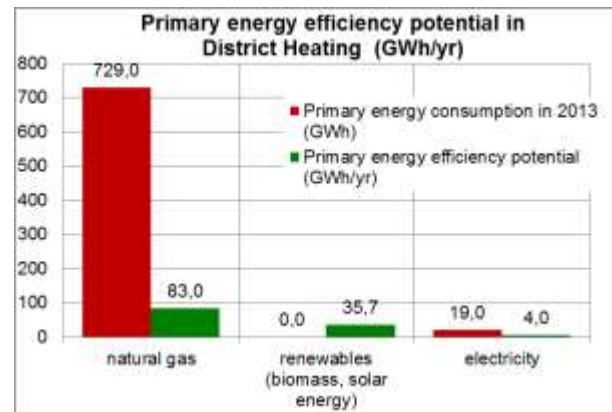
Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Saving of energy carrier	Emission saving (t CO <sub>2</sub> /a)	Preliminary payback time (years)
DH-01	Performance increase of boiler-houses by rehabilitation	11,25	66,00	Primary-gas	24,0	2,91
DH-02	Fuel switch for heat generation - gas to biomass	7,00	30,40	Primary-gas	6,1	7,68
DH-03	District heating network rehabilitation, pipeline replacement	6,88	12,03	Primary-gas	2,4	15,34
DH-04	Solar heating plant	1,56	5,33	Primary-gas	1,1	4,99
DH-05	Hydraulic balancing of the DH system	1,00	5,01	Primary-gas	5,5	4,46
DH-06	Installation of cogeneration plant for coverage of own demand	0,78	2,40	Primary-electricity	2,6	1,44
DH-07	Implementation of SCADA system	0,50	0,95	Primary-electricity	1,0	2,33
DH-08	Replacement of circuit pumps and equipment with VSD	0,10	0,67	Primary-electricity	0,7	0,69

**Figure 49: Preliminarily calculated energy saving potential (primary energy, final energy gas and electricity) and payback time of recommended EE measures**

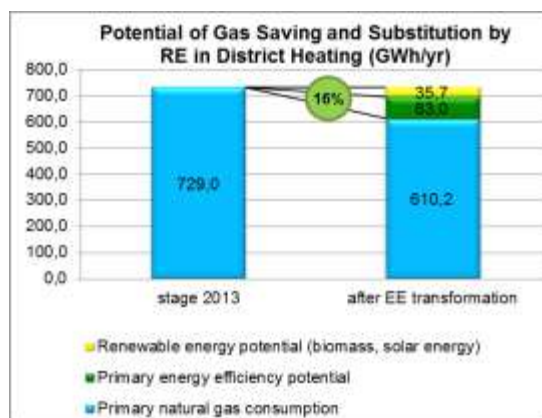
Primary energy savings and payback time by EE measures



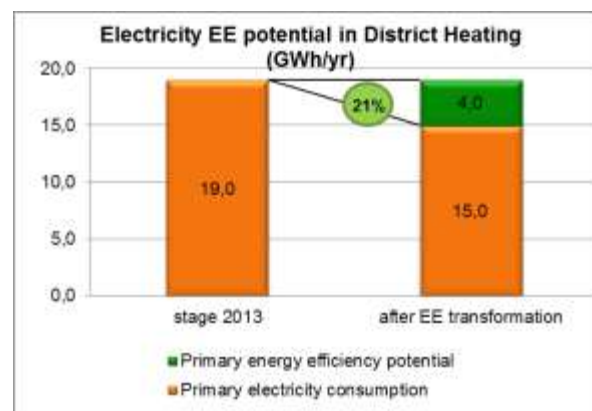
Primary energy savings by type of energy and RE measures



Potential gas savings



Potential electricity savings



The indicative implementation frame of the pre-selected investment measures can be as follow:

Code	Title of EE recommendation	Implementation perspective	Possible start in	Speed of Implementation, years
DH-01	Performance increase of boiler-houses by rehabilitation	short-term	2016	2 years
DH-02	Fuel switch for heat generation - gas to biomass	short-term	2016	1 year
DH-03	District heating network rehabilitation, pipeline replacement	short-term	2016	2 years
DH-04	Solar heating plant	long-term	2018	1 year
DH-05	Hydraulic balancing of the DH system	short-term	2017	2 years
DH-06	Installation of cogeneration plant for coverage of own demand	short-term	2017	2 years
DH-07	Implementation of SCADA system	short-term	2016	2 years
DH-08	Replacement of circuit pumps and equipment with VSD	short-term	2016	1 year

The key stakeholders for implementation of the recommended EE measures in this sector are:

- The municipal enterprise “Ternopilmiskteplokomunenergo”

## 6.5 EE recommendations in the sector public transport

The following set of EE recommendations meets the basic criteria of appropriateness and has been preliminarily assessed.

Code	Title of measure	Type	Comment/ additional information
TM-01	Promotion of Public Transport, improvement of attractiveness	I-Investment	making the public transport more attractive (information system, clean, punctual, new bus stops)
TM-02	Public Transportation Development for new district with innovative vehicles	I-Investment	(e.g. electric buses, bio CNG), for connection of new micro district K. (considering fast track lane)
TM-03	Fuel switch of municipal bus fleet from diesel to electric (trolley busses)	I-Investment	need to include the extension of electric overhead infrastructure
TM-04	Replacement of municipal diesel bus fleet to hybrid (diesel/electric)	I-Investment	all remaining
TM-05	Reconstruction of existing trolley bus overhead lines	I-Investment	including SCADA and system optimization
TM-06	Vehicle Emission Standards for private bus operators	P-Preparation	set limits for vehicle emissions (private mini-busses) for the granting of new operation licenses

Presently there are no considerable EE investment programs in the sector.

A number of other EE activities as listed in the TRACE model have not been put forward or have been integrated in the set of recommended EE measures.<sup>11</sup>

<sup>11</sup> TRACE model EE activities in this sector which have been rejected due to their low appropriateness (technology, framework, economic sustainability, capacities, and ease of implementation) are:

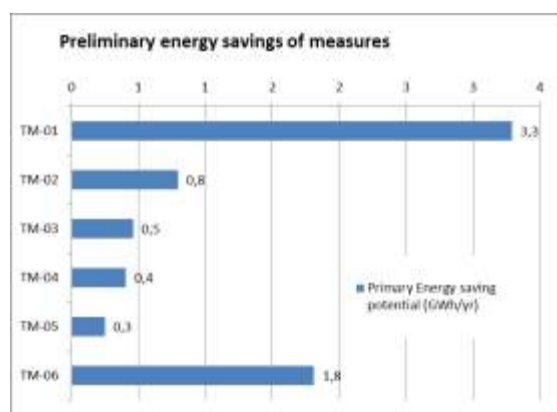
- Municipal Vehicle Fleet Efficiency Program, as there is the very low number of such very specialized vehicles
- Car parking Management
- Traffic Flow Optimization
- Traffic Restraint Measures
- Travel Planning

The preliminary assessment of the recommended EE measures results in the following indicators. A first ranking of the EE measures has been undertaken on the highest energy saving potential.

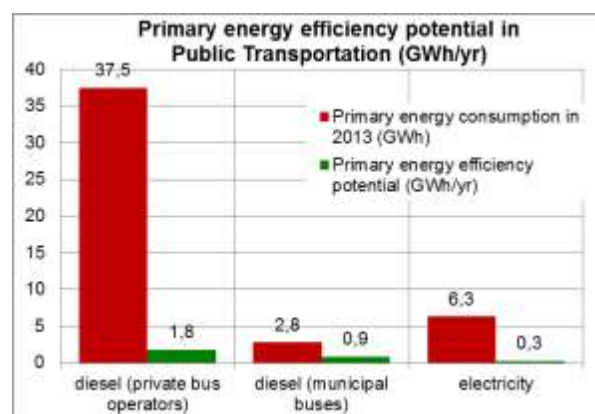
Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Saving of energy carrier	Emission saving (t CO <sub>2</sub> /a)	Preliminary payback time (years)
TM-01	Promotion of Public Transport, improvement of attractiveness	0,30	3,29	Gasoline	0,8	
TM-02	Public Transportation Development for new district with innovative vehicles	6,50	0,80	Gasoline	0,2	
TM-03	Fuel switch of municipal bus fleet from diesel to electric (trolley busses)	0,84	0,46	Diesel	0,1	22,64
TM-04	Replacement of municipal diesel bus fleet to hybrid (diesel/electric)	1,68	0,41	Diesel	0,1	20,34
TM-05	Reconstruction of existing trolley bus overhead lines	0,98	0,25	Primary-electricity	0,3	17,15
TM-06	Vehicle Emissions Standards for private bus operators	0,08	1,81	Diesel	0,5	0,22

**Figure 50: Preliminarily calculated energy saving potential (primary energy, final energy gas and electricity) and payback time of recommended EE measures**

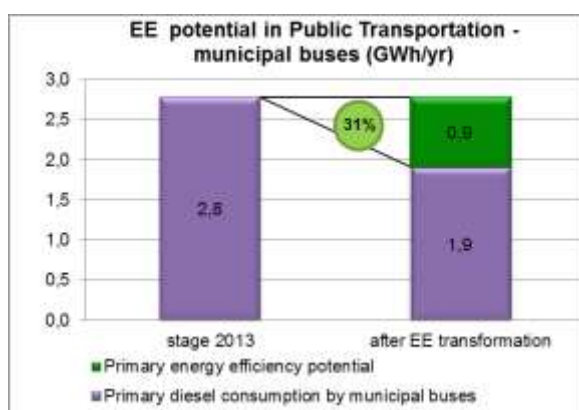
#### Primary energy savings and payback time by EE measures



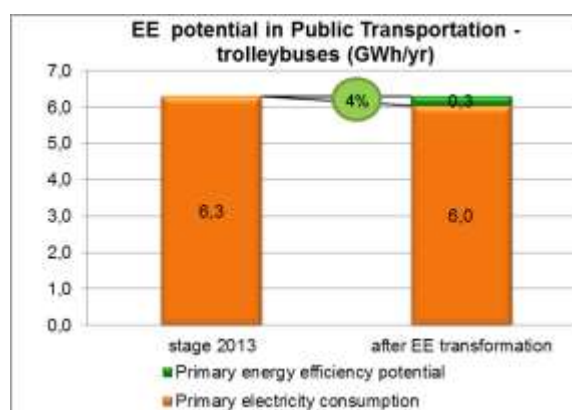
#### Primary energy savings by type of energy and RE



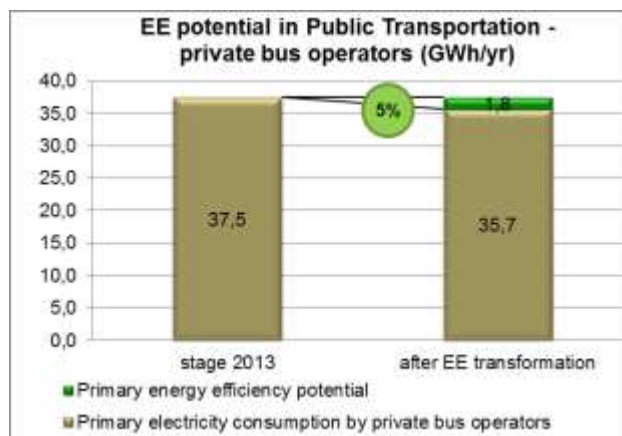
#### Potential diesel savings



#### Potential electricity savings



**Figure 51: EE potential by measures for commercial public transport companies**



The indicative implementation frame of the pre-selected investment measures can be as follow:

Code	Title of EE recommendation	Implementation perspective	Possible start in	Speed of Implementation, years
TM-01	Promotion of Public Transport, improvement of attractiveness	Long-term	2018	> 4 years
TM-02	Public Transportation Development for new district with innovative vehicles	long-term	2019	> 4 years
TM-03	Fuel switch of municipal bus fleet from diesel to electric (trolley busses)	short-term	2017	2 years
TM-04	Replacement of municipal diesel bus fleet to hybrid (diesel/electric)	long-term	2020	2 year
TM-05	Reconstruction of existing trolley bus overhead lines	short-term	2016	2 years
TM-06	Vehicle Emissions Standards for private bus operators	long-term	2018	3 year

The key stakeholders for implementation of the recommended EE measures in this sector are:

- a) Transport companies with the CA as main shareholder:
  - "Ternopilelektrotrans"
  - A company with additional liability named "Taxopark",
  - OJSC TOP "Ternopilavtotrans-16100", which are operating 42 vehicles (9 trolleybuses and 33 buses).
- b) Commercial transport companies: MC "Miskavtotrans", PJSC "Ternopil ATP - 16 127", LLC "Mens - Auto", LLC "ATK" Etalon ", LLC "Nazar - Trans ", LLC "Mega - Service", PE "Ternvoyazh",

## 6.6 EE recommendations in the sector water and waste water supply

The following set of EE recommendations meets the basic criteria of appropriateness and has been preliminarily assessed.

Code	Title of measure	Type
WW-01	Improve Efficiency of Pumps and Motors in water supply and WWTP (elements of the IBRD project), upgrading of WWTP and pumping stations of sewer system, improvement of performance of water supply network	I-Investment
WW-02	Active Leak Detection and Pressure Management Program for potable water system	I-Investment

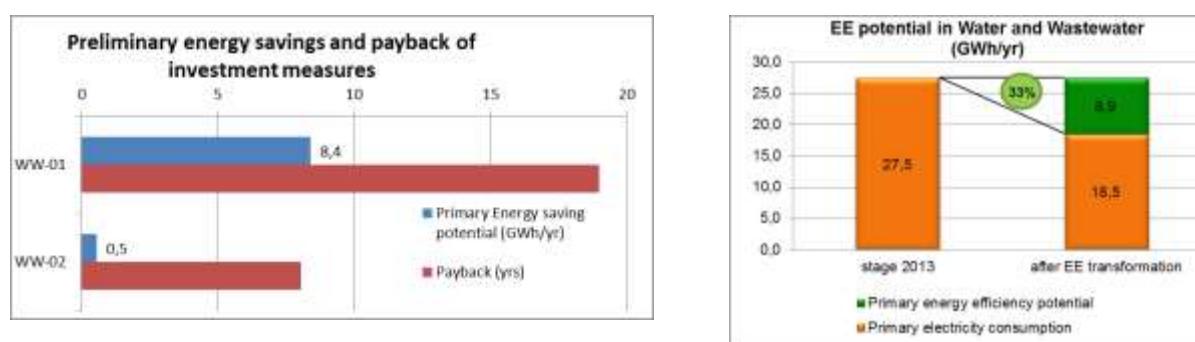
The above measure WW-01 is covered by the IBRD Ternopil Vodokanal project «Rehabilitation and Upgrade Water and Wastewater Facilities - 2014».

A number of other EE activities as listed in the TRACE model have not been put forward or have been integrated in the set of recommended EE measures.<sup>12</sup>

The preliminary assessment of the recommended EE measures results in the following indicators. A first ranking of the EE measures has been undertaken on the highest energy saving potential.

Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Saving of energy carrier	Emission saving (t CO <sub>2</sub> /a)	Preliminary payback time (years)
WW-01	Improve Efficiency of Pumps and Motors in water supply and WWTP	36,00	8,40	Primary-electricity	9,2	18,99
WW-02	Active Leak Detection and Pressure Management Program for potable water system	1,00	0,55	Primary-electricity	0,6	8,06

**Figure 52: Preliminarily calculated Primary energy saving potential of recommended EE measures and payback time**



The indicative implementation frame of the pre-selected investment measures can be as follow:

Code	Title of EE recommendation	Implementation perspective	Possible start in	Speed of Implementation, years
WW-01	Improve Efficiency of Pumps and Motors in water supply and WWTP	short-term	2016	2-3 years
WW-02	Active Leak Detection and Pressure Management Program for potable water system	long-term	2017	3 years

The key stakeholder for the implementation of the recommended EE measures in this sector the municipal utility "Ternopilvodokanal".

<sup>12</sup> TRACE model EE activities in this sector which have been rejected due to their low appropriateness (technology, framework, economic sustainability, capacities, and ease of implementation) are:

- Prioritizing Energy Efficient Water Resources
- Auditing and Retrofit of Treatment Facilities
- Use of waste water sludge for production of biogas
- Educational Measures
- Water Efficient Fixtures and Fittings
- Water Meter Program (individual at end consumer side)
- Improve Performance of System Networks
- Formation of Ring Main

## 6.7 EE recommendations in the sector waste management

The following set of EE recommendations meet the basic criteria of appropriateness and have been preliminary assessed.

Code	Title of measure	Type	Comment/ additional information
WS-01	Intermediate Transfer Station including sorting, recycling line and composting station	I-Investment	
WS-02	Waste Vehicle Fleet Maintenance Audit and Retrofit or replacement Program	I-Investment	20 units
WS-03	Fuel Efficient Waste Vehicle Operations	A-Accompanying	includes non-investment measures, training etc.
WS-04	Waste Infrastructure Planning (connected to landfill site, containers)	P-Preparation	

Presently there are no considerable EE investment programs in the sector.

A number of other EE activities as listed in the TRACE model have not been put forward or have been integrated in the set of recommended EE measures.<sup>13</sup>

The preliminary assessment of the recommended EE measures results into the following indicators. A first ranking of the EE measure has been undertaken on the highest energy saving potential.

Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Emission saving (t CO <sub>2</sub> /a)	Preliminary payback time (years)
WS-01	Intermediate Transfer Station including sorting, recycling line and composting station	9,00	0,84	0,2	52,76
WS-02	Waste Vehicle Fleet Maintenance Audit and Retrofit or replacement Program	0,85	0,76	0,2	5,56
WS-03	Fuel Efficient Waste Vehicle Operations	0,01	0,02	0,0	2,90
WS-04	Waste Infrastructure Planning (connected to landfill site, containers)	0,40	0,00	0,0	

Energy savings will mainly be realized on diesel fuel.

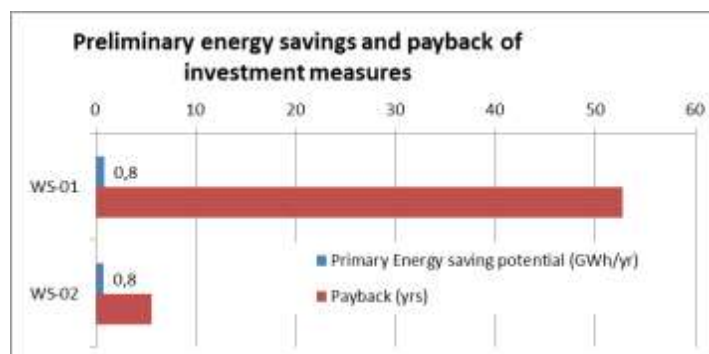
<sup>13</sup> TRACE model EE activities in this sector which have been rejected due to their low appropriateness (technology, framework, economic sustainability, capacities, and ease of implementation) are:

- Waste Composting Program, as this can be combined with the transfer station
- Landfill Gas Capture Program, due to low gas production potential
- EE in existing sorting and transfer facilities, not existing
- Waste to Energy Program, not appropriate
- Waste Collection Route Optimization shall be included in infrastructure planning

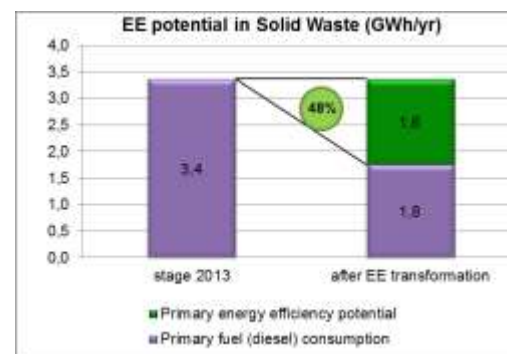


**Figure 53: Preliminary calculated Primary energy saving potential of recommended EE measures and payback time**

Primary energy savings and payback time by EE measures



Primary energy savings , diesel



The indicative implementation frame of the pre-selected investment measures can be as follow:

Code	Title of EE recommendation	Implementation perspective	Possible start in	Speed of Implementation, years
WS-01	Intermediate Transfer Station including sorting, recycling line and composting station	short-term	2016	2 years
WS-02	Waste Vehicle Fleet Maintenance Audit and Retrofit or replacement Program	short-term	2017	2 years
WS-03	Fuel Efficient Waste Vehicle Operations	short-term	2016	1 year
WS-04	Waste Infrastructure Planning (connected to landfill site, containers)	short-term	2016	1 year

The key stakeholders for implementation of the recommended EE measures in this sector are:

- The CA
- Waste services collection, transportation companies "Altfater-Ternopil", PE "Ekotern", PE "Quarter-L".

## 6.8 EE recommendations in the Municipal Energy Management

The following set of EE recommendations meets the basic criteria of appropriateness and has been preliminarily assessed.

Code	Title of measure	Type	Comment/ additional information
EM-01	Awareness raising and EE promotion programs for all sectors	P-Preparation	Events, competitions, awards, print media, media campaigns
EM-02	Capacity building programs	A-Accompanying	For operation staff EM, utilities
EM-03	EE Municipal task force	A-Accompanying	Extension of EM department
EM-04	Purchasing and service contracts	P-Preparation	procurement including life-cycle cost assessment
EM-05	Energy Performance contracting	P-Preparation	Focus on street lighting and municipal buildings
EM-06	EE Strategy and investment plan	P-Preparation	Including EE assessment
EM-07	Capital investment planning	P-Preparation	Preparation of pipeline for EE investments, financial structuring and fund raising

The preliminary assessment of the recommended EE measures results in the following indicators. A first ranking of the EE measures has been undertaken on the highest energy saving potential.

Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Emission saving (t CO <sub>2</sub> /a)
EM-01	Awareness raising and EE promotion programs for all sectors	0,08	to be analysed	n/a
EM-02	Capacity building programs	0,10	3,53	0,9



Code	Title of EE recommendation	Investment costs (M USD)	Primary EE (GWh/a)	Emission saving (t CO <sub>2</sub> /a)
EM-03	EE Municipal task force	0,12	0,10	0,0
EM-04	Purchasing and service contracts	0,01		
EM-05	Energy Performance contracting	0,05		
EM-06	EE Strategy and investment plan	0,02		
EM-07	Capital investment planning	0,05		

The indicative implementation frame of the pre-selected investment measures can be as follows:

Code	Title of EE recommendation	Implementation perspective	Possible start in	Speed of Implementation, years
EM-01	Awareness raising and EE promotion programs for all sectors	long-term	2016	3 years
EM-02	Capacity building programs	short-term	2016	3 years
EM-03	EE Municipal task force	short-term	2016	1 year
EM-04	Purchasing and service contracts	short-term	2017	2 years
EM-05	Energy Performance contracting	long-term	2017	3 years
EM-06	EE Strategy and investment plan	short-term	2016	1 year
EM-07	Capital investment planning	short-term	2017	3 years

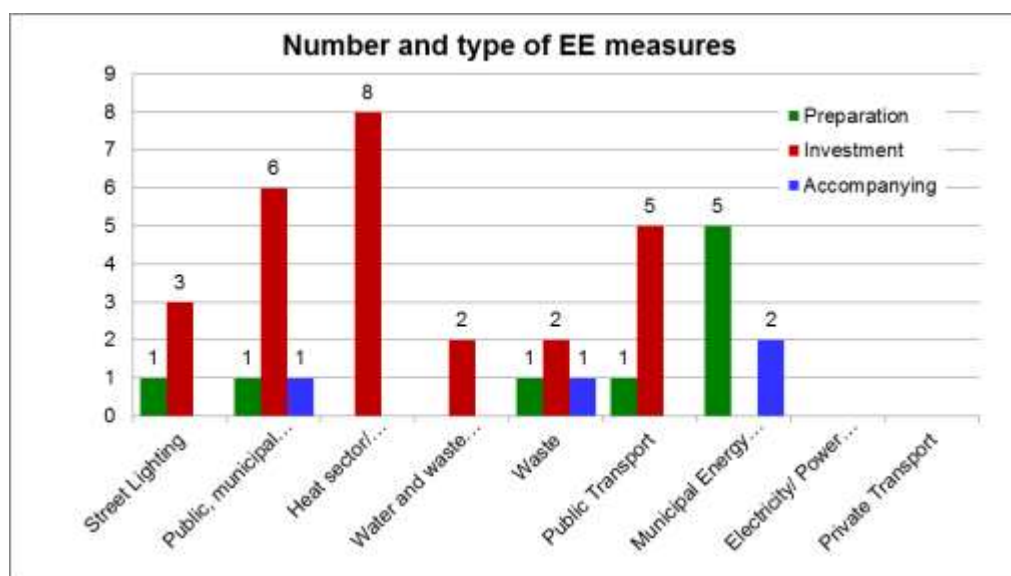
The key stakeholders for implementation of the recommended EE measures in this sector are:

- The CA and all energy users,
- Consultants
- Media
- National stakeholders

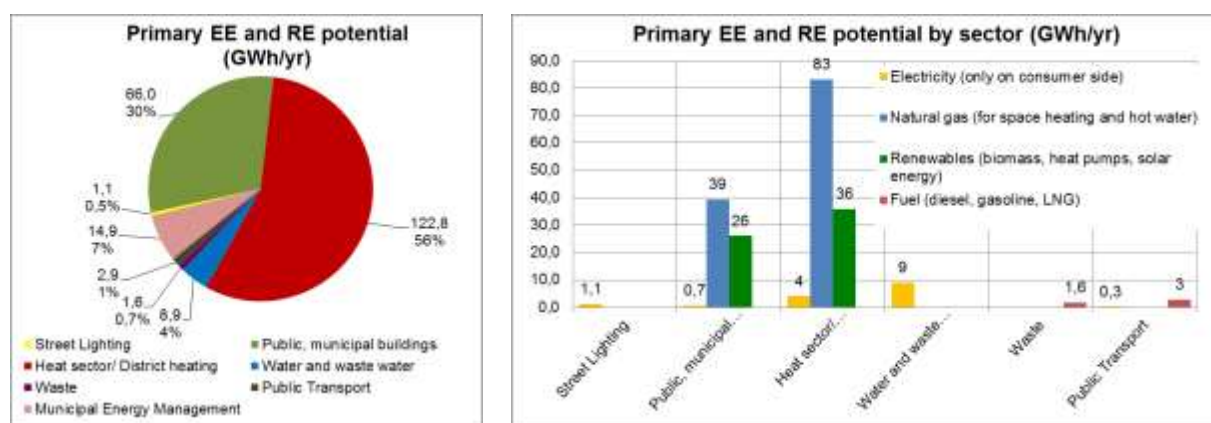
## 6.9 Summary of potential benefits by the pre-selected EE recommendations

From the above analysis it is recommended to consider 39 EE measures, of which 26 are investment type; 9 preparation and 4 accompanying measures.

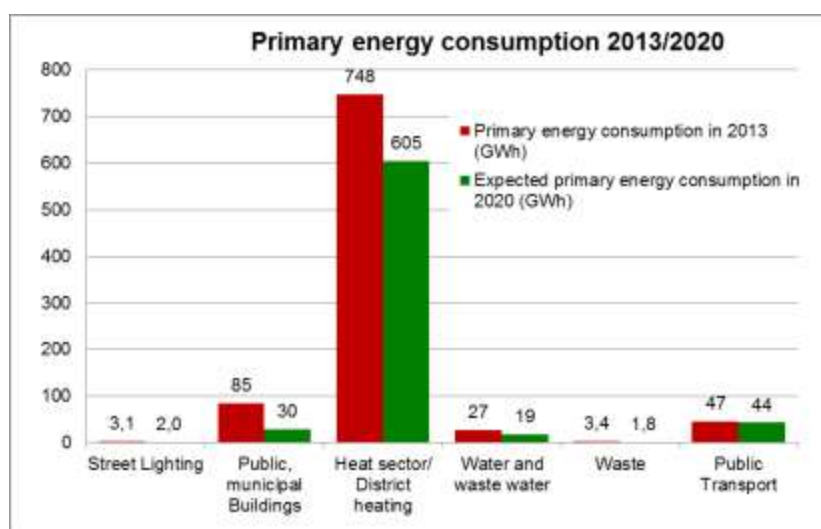
**Figure 54: Number and type of EE measures recommended by sector**



The overall primary energy savings by implementation of the 39 recommended measures will amount to annually in the range between 200 to 215 GWh of which energy saving in energy consumption amounts to 75% and the substitution of conventional primary energy by renewable energy at 25%.

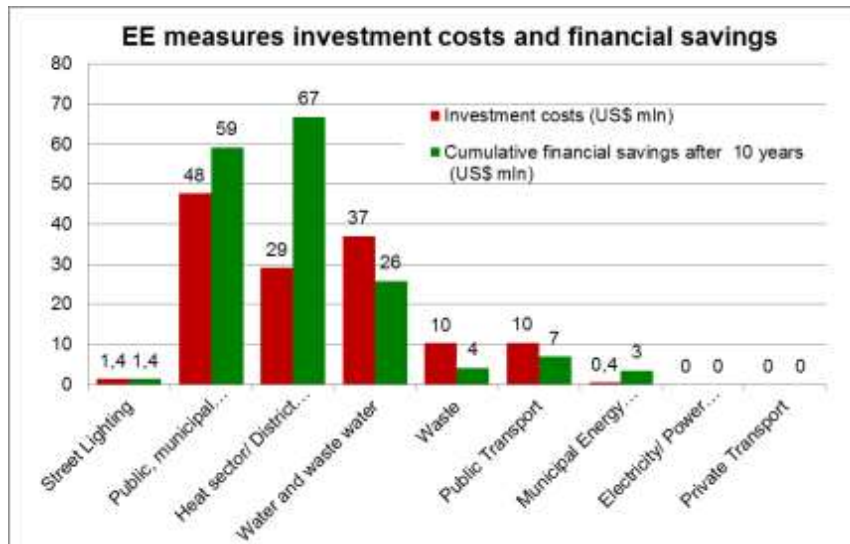
**Figure 55: Primary energy saving potential by sector and type of energy**

The implementation of the recommended EE measures until the year 2020 can reduce the primary energy consumption in the considered sectors by up to 20% (from 843 GWh in 2013 to approx. 680 GWh in 2020). This savings potential would represent only 8% of the overall city's primary energy consumption (including industry, commercial, residential sector, which are not considered in the analysis).

**Figure 56: Comparison of Primary energy consumption in the related sectors, of baseline year 2013 and forecast year 2020**

The overall investment costs for the implementation of the 39 measures would be in the range between 120 to 140 million USD, which can generate a 10-years cumulative saving of energy costs (considering a projection of energy tariffs) of up-to 170 million USD.

**Figure 57: Investment costs for EE recommendations and cumulative 10-years energy cost saving achievements (in million USD)**



The largest savings (90%) of primary energy can be achieved in natural gas by up to 180 GWh which represents a level of 19.5 million m<sup>3</sup> gas of annual savings.

**Figure 58: Primary energy saving and substitution by renewable energy potential (in GWh/year)**

