ENERGY PLAN OF CAPITAL CITY OF PRAGUE (2013-2033)

ANNEX 10 STRATEGY OF TRANSITION TO LOW-CARBON ECONOMY IN PRAGUE

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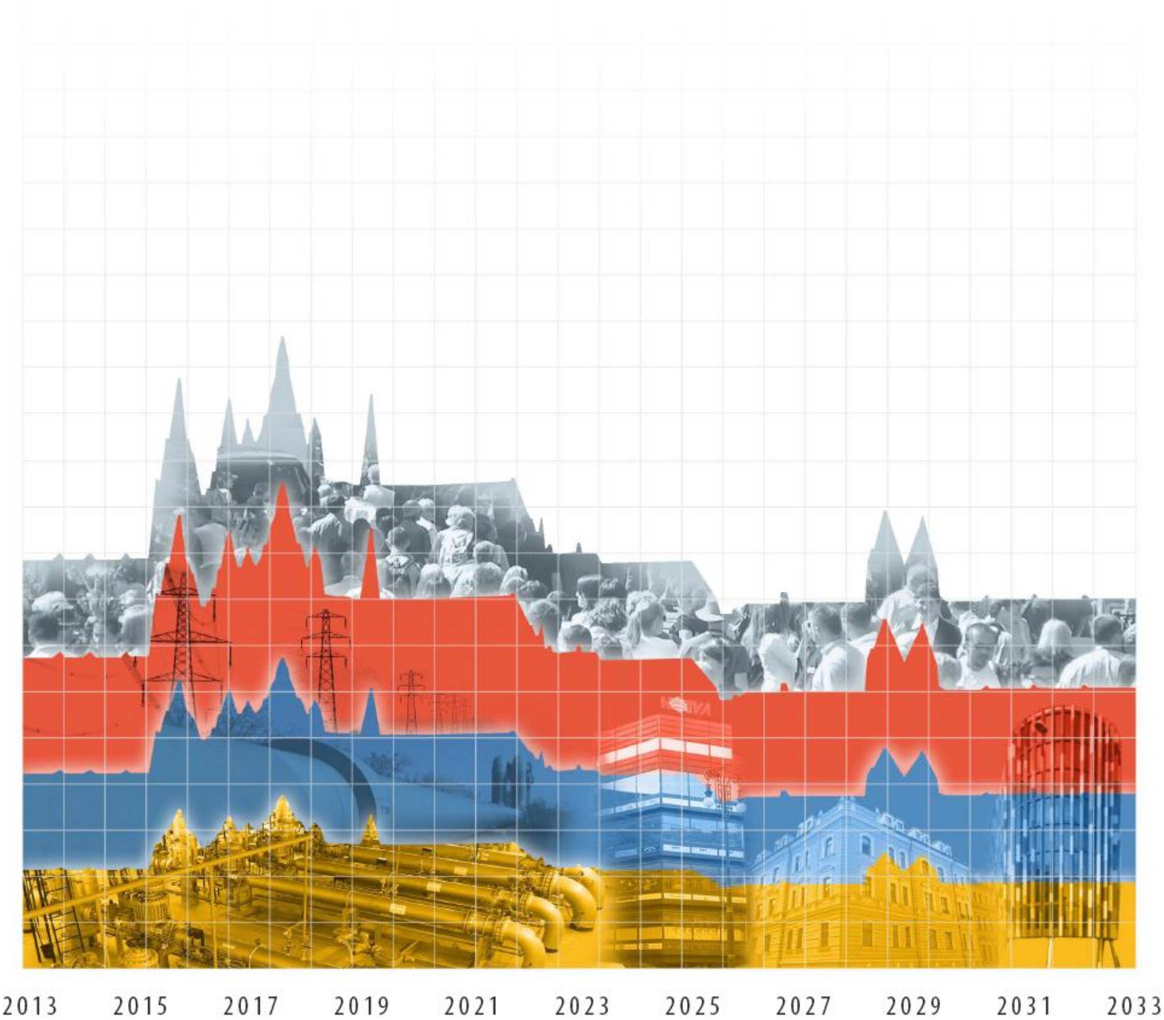

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1 | Introduction

The strategic objectives of the Energy Plan of the capital city of Prague (hereinafter "**EPP**" only) for the next twenty years (2013-2033) **are to support the reliability of energy supply while promoting efficiency in its use as much as possible in accordance with sustainable development**.

Priorities of effective and sustainable development can be understood at two levels - **economic and ecological**. From the **economic** point of view, effectiveness should be understood as the desire to eliminate ineffective energy use (economically unproductive) and sustainable development as the ability to pay the costs associated with the use of energy in the long run without any negative impacts on quality of life or the economy – in other words, **economically efficient use of energy**. For measures in which, by their nature, the economic efficiency criteria cannot be met, yet they can significantly contribute to the achievement of other the strategic objectives pursued, the solution (and that is one of the activities of the EPP) is to seek other sources of funding including winning grants from various support programs in order to implement such measures.

Through the lens of **ecology** to be economic is – with the respect to the environmental impacts – understood to use energy to the extent just really necessary; then in conjunction with sustainable development with the preferences of more environmentally friendly sources preferably capable of recovery (so-called renewable or secondary) from sources whose potential is to be exhausted (i.e. of fossil origin). Monitoring key indicator here is the amount of air pollutants emitted by energy use, directly or indirectly causes. Besides topical negative-acting pollutants, such as emissions of particulate matter, oxides of nitrogen, sulphur and other pollutants are also monitored emissions of so-called greenhouse gases contributing to climate change.

AS far as Prague is concerned, the emissions of carbon dioxide (CO_2) are especially relevant and **this Annex No 10 is dedicated to the proposal of the strategy – or better – specific measures how to decrease the emissions of this gas caused in relation to energy use within the city**.

The principle of "low carbon" development strategy is a gradual shift away from production of energy by combustion processes using fossil fuels. Nevertheless, the reduction of emissions of gases contributing to global climate change (i.e. mainly CO_2 but also methane, etc.) only by covering the energy needs through deliveries of already refined forms of energy (electricity, heat) from sources located outside the City, is so not an option.

The reason is that the amount of primary energy (in the form of fuel) necessary for covering the City's needs from these "external sources" of electricity or heat could be finally higher than what it would be if the energy needs were covered by burning fuel directly in the area concerned.

The situation in Prague is interesting as a significant percentage of its electricity and heat supplies nowadays come from external sources located outside the City. For that reason, in order to get an objective comparison, it is necessary to take into account the entire production chain and to integrate it into the total balance.

In Chapter 10 of Main report **three possible scenarios in the next two decades** were outlined. They differ from each other in the extent to which they reflect factors affecting end energy consumption as well as the ways of covering the City's energy needs.

The fundamental determinants are the continuing trends, reinforced by the progressive scenarios (referred to as a PROAKTIV and PROAKTIV +) with the support of additional measures such as those proposed for the implementation of the EPP, which are in detail introduced in Chapter 12 of the Main Report.

When designing measures included into the implementation, the effort was to define such a development principles appropriate balancing the sub-goals in favour of greater overall social benefit. Any low-carbon strategy measures in a greater or lesser extent contribute, in a larger or smaller extent, to the reduction of greenhouse gas emissions.

Below, it is outlined in more detail to what extent and at what possible costs the designed measures can contribute to the reduction of greenhouse gases.

The proposed measures are divided into those regarding the source and distribution parts (energy production and supply), and those affecting end consumption in various sectors (the civil sector, transportation, the tertiary sector, industry and other sectors).

2 | Low-carbon measures in production and energy supply

2.1 | Fuels

All types of fuel when used through burning (more specifically through conversion of the chemical energy in the fuel into heat using rapid oxidation of carbon compounds and other flammable substances at a sufficient temperature) are inevitably burdened with CO_2 as the main product of the combustion process.

Low carbon fuels are defined as those that release less CO_2 emissions per unit of heat into the atmosphere. Of all fossil fuels, methane and natural gas show the lowest emission factor (less than 56 kg/GJ of heat in the fuel measured through its calorific value). Fuels produced from renewable sources (i.e. biomass, mostly of wood origin) have an emission factor of zero; sometimes even fuels from secondary sources are similarly evaluated. For example, municipal waste typically contains at least 50% of biodegradable components, which are considered a renewable resource, and thus its emission factor per unit of fuel is very close to natural gas.

More efficient conversion of the fuels' chemical energy into heat contributes to further reduction of CO_2 emissions produced by the use of fuels. Achieving such higher efficiency is possible by replacing outdated and less efficient combustion heat sources with modern ones with higher efficiency. Considering the dominance of natural gas in the fuel base, the most significant reduction of CO_2 emissions can be brought about by just replacing existing furnaces burning natural gas with more efficient ones (condensing heat technology).

Therefore, the following specific measures should significantly contribute to the reduction of CO_2 emissions in Prague.

2.1.1 | Eliminating the use of solid fossil fuels in unsuitable heat sources by replacing them with low-carbon alternatives

Brief description: Nowadays, solid fossil fuels are burned in Prague mostly in two largest sources of REZZO 1 (Heating Plant Malešice II and Cement Mill Radotín), and in a number of unspecified small stationary sources of REZZO 3, specifically in houses or blocks of flats. While in the first group the sources producing pollutant emissions are very well monitored and the natural development keeps leading to further major reductions (in addition to the assumed long term plan of gradual termination of their operations), the regulations for the second group are currently being prepared. One of the possible tools is supposed to be the requirement for mandatory inspections, (revisions) resulting from the Clean Air Act, that all of these resources have to meet by the end of 2017. Moreover, after Jan 1 2022, it will only be allowed to operate those solid fuel combustion sources whose manufacturer, prior to marketing, has verified and guaranteed specifications meeting certain minimum requirements (the emission class or - in other words - emission limits).

The purpose of this measure is to require these inspections in the future consistently (by local authorities) as well as to motivate resource owners, through subsidies, to make their equipment "green" in advance, and not to wait until they have to meet the environmental specs and failure is punishable by law.

Projected effects: Through the "Clean Energy Praha" programme, more than 15 thousand solid fuel burning sources have been replaced with more environmentally friendly ones and allotted subsidies since 1994. However, the energy report of 2011 suggests that in Prague - according to expert estimates based on the 2011 Population and Housing Census in the housing sector – more than 300 thousand GJ per year are produced by burning solid fossil fuels. That suggests that there are at least several thousand combustion sources consuming annually about 15 thousand tons of coal of various kinds (lignite graded, lignite briquettes, etc.) in total. **The removal of the remaining solid fuel burning sources would represent a CO_2 reduction of up to about 30 thousand tonnes a year** on condition that all new sources were purely those that use renewable resources. However, since the most common alternative is the conversion to natural gas combustion sources or heat pumps, the actual reduction will definitely be significantly lower **(max. 50-60%).**

Terms of realization (costs of achieving total elimination): It is proposed to continue with the "Clean Energy Prague" co-financing programme for replacing old non-ecological combustion sources (preferably solid fuel) with new, more ecological ones, and for emphasising the need to implement environment friendly sources in the coming years. A typical co-financing contribution of CZK 25 thousand per application, multiplied by potential 10 thousand applications would mean a further total subsidy of CZK 250 million. Naturally, the total investment costs are estimated to be at least twice or 3 times higher.

2.1.2 | Increasing the efficiency of natural gas use in Prague through development of condensing technology

Brief description: Increasing the energy efficiency of the use of natural gas in combustion sources in Prague by gradual replacement technology for more efficient (i.e. condensation, able to use more energy in the fuel).

Projected effects: It is theoretically achievable to reduce the current natural gas consumption in Prague by several per cent (e.g. 5%), which corresponds to CO_2 emission reduction over 90 thousand tons/year on condition 100% of natural gas furnaces are replaced with condensing technology,

If only a partial model substitution is realized, that is of furnaces with a total capacity of 300 MW corresponding to modernizing 12-15 thousand heat producing devices in houses and apartments in most of the island district heating systems on the left bank of the river with the same total output, it is possible to expect a reduction in CO_2 emissions by more than 10 thousand tons/year.

Terms of realization (costs of achieving): The replacement of furnaces of the model capacity of 300 MW would require 0.5 to 1.5 billion CZK depending on the device size and additional modifications to reduce the return water temperature. A maximum financial subsidy per a device would be up to 20-25% of total costs.

2.2 | Heat energy and co-generation – CHP technology

The development of combined heat and power (CHP) in addition to prioritizing low carbon fuels contributes to the reduction of CO_2 emissions. Instead of the traditional production of electricity in condensing power plants and of heat in heating plants the same amount of electricity and heat can be produced by the common process called co-generation to consume less primary energy and therefore emitting less CO_2.

Nowadays, Prague uses this economical utilisation of fuel to a significant extent, through the Prague Heating Plant System, which is supplied to a significant degree by heat from the CHP source EMĚ I (Power Plant Mělník I). This originally conventional power plant was reconstructed in the 90s of the last century into a partially heating mode of operation, which now makes it possible to produce, according to the valid assessment methodology harmonized throughout the EU, almost 50% of electricity in the regime of high performance power and heat generation. In practice, this means savings of about 15% of fuel per year, which corresponds to CO_2 emission reduction of around 300 thousand tons/year or over 33 tons CO_2 per a TJ of heat supplied to Prague.

However, there is still an unused heat production capacity in the Mělník heating plant as well as heat saving measures on the heat supplying heat pipe-line between Mělník and Prague. Utilizing those could further strengthen positive effects of cogeneration.

In addition, the use of heat from the second major energy source close to Prague, Kladno Power Plant, could bring similar benefits. Compared with EMĚ I, it only has less than one fifth of the EMĚ I thermal output in cogeneration mode, but it turns out to be large enough to cover most of the heat supply for the island district heating systems in the southwest of the city, Liboc/Ruzyň and Veleslavín. The condition, however, is the construction of a heat pipe-line. In addition, Kladno power plant allows to burn fossil fuels in combination with fuels of renewable origin up to 10% of its heat capacity, which means that there is a potential for further CO_2 emission reductions.

For both promising sources of "high-efficiency cogeneration" it is necessary to point out that the use of heat helps to primary energy savings indeed, but mainly on condition the fuel is lignite (in comparison to being used for the production of an identical amount of electricity and heat in separate sources that generate electricity and heat separately).

However, as in Prague the substitute fuel for separate heat generation is now rather natural gas with the CO_2 emission factor significantly lower compared to lignite (about 56 kg/GJ in NG as opposed to about 100 kg/GJ in lignite), it cannot be denied that purely in terms of the total balance of CO_2 emissions it would be preferable not to use heat from the power plants and to meet Prague's heat needs from local sources burning natural gas instead.

In reality, the heat supplied from EMĚ I requires a certain amount of lignite to be produced, which ultimately means that the heat generation is inevitably associated with CO_2 emissions (calculations indicate about 75 kg / GJ, i.e. about 20% more in comparison to burning natural gas).

However, this view ignores the fact that while lignite is of domestic origin and at affordable prices, natural gas is not and must be imported into the country. From this point of view, it is economically desirable to use lignite in high-efficiency cogeneration mode. It is preferable, even at the cost of slightly degraded ecological balance, to the exhaustible mineral resources remaining unused because of higher fuel imports from abroad.

However, natural gas is generally the ideal fuel for low-carbon production of electricity and heat. Therefore, using NG is also listed as one of the measures for reducing CO_2 emissions in Prague - ideally as a complementary alternative to heat generation using natural gas in the district heating systems in the city (along with the supply from the sources above, high-efficient CHP).

2.2.1 | Increasing the supply of heat from highly efficient CHP power station EMĚ I (Power plant Mělník I)

Brief description: The annual potential supply of heat from EMĚ I may reach even over 16 thousand TJ/year, i.e. about 6.5 to 7 thousand TJ more than the current supply. Spare capacity currently ranges from 250 TJ/month in the period from November to February through 600 ÷ 900 TJ at the beginning and end of the heating season (March – June and September – October) to 1,000 - 1,200 TJ per month in the summer period after the heating season. Although it is not realistic to expect that this power could be used in the summer (if we exclude the possibility of the still uneconomical construction of a central supply of cool for air-conditioning), it is conceivable that, through better management in the winter and in the transition periods of the year, the supplied amount could be increased by thousands of TJ per year. However, higher utilization of heat supply from EMĚ I would require extensive investments into its redistribution throughout Prague Metropolitan District Heating System (PMDHS).

Projected effects: If we manage to use some of the spare capacity in the winter and in transition periods of the year, it is conceivable that the supply from EMĚ I can increase further by min. 1.0 to 1.5 thousand TJ per year. The realization of the measure would increase the amount of primary energy savings (according to the harmonized evaluation methodology prescribed by Regulation 453/2012 Sb.) 300 to 500 TJ / year, which corresponds to a CO_2 emission reduction of **30 to 50 thousand tonnes per year**.

Terms of realization (costs of achieving): Increasing the heat supply from EMĚ I can be partly realized by completing gradually the connection of the former island district heating system in Holešovice to the Prague metropolitan district heating system by 2020. Extending the transmission capacity of some network arteries distributing heat to the south of the city appears to be another means of better utilization of the EMĚ I heat. The estimated required investments into this measure amount to 0.5 to 1 billion CZK. In addition to the intensification of the operations, a growth in the number of new customers currently planning new investments into construction of new or reconstruction of existing heat sources near the Prague metropolitan district heating system can also contribute to further heat supply increase. Connecting to Prague metropolitan district heating system could be made mandatory or better required as a priority if the investors cannot prove that they are capable to meet their heat needs in an economically more advantageous and more environmentally friendly way. In other words, extensive growth under these conditions appears to be desirable and de facto with no additional cost borne either by the investor or public budgets.

2.2.2 | Introducing the use of heat from high-efficiency CHP power station EK I -Power Plant Kladno (construction of a interconnecting heat pipeline between Kladno and Prague)

Brief description: The Power Plant Kladno is another prospective source of heat for Prague. Using its newly built block B7 with usable heat output of 100 - 150 MW (completed this year) for supplying heat to left-bank parts of the city could bring similar effects to those of the heat supplied from EMĚ I through the Mělník – Prague interconnecting heat pipeline. However, to achieve this, it is necessary to construct a hot water pipeline about 18 km long which would connect to the main heat arteries and a network of heat pipes connecting individual PT boiler rooms located in the town parts of Liboc and Veleslavín (sources Dědina and Veleslavín), Řepy (ŘOK 1-5), Stodůlky (SOK 1 and 2), Lužiny (LOK 3-6), New Butovice (NBOK 13, 17, 18) and Velká Ohrada (VOOK 8). This measure is more precisely described in Annex 4 (chapter on the Power Plant Kladno project and heat supply Kladno - Praha). At the same time, if the individual owners were interested, it would also be possible to connect other consumers who currently operate their own heat sources (typically commercial and office buildings in Zlicin, Stodůlky, Řeporyje, New Butovice etc.).

Projected effects: Judging by the current level of supply of heat from the above listed CHS heat sources and considering possible further development in reducing energy consumption for heating through thermal insulation of residential buildings connected to these sources, the amount of useful heat supply from the Kladno power station can be estimated at 1 thousand TJ/year to the customers currently connected to the central heating plus up to 250 TJ/year for additional customers currently operating their own sources of heat in the area. Effects quantified in primary energy savings, **possibly in CO_2 emissions**, **would be similar to those of EMĚ I (i.e. in the amount of tens of thousands of tonnes per year)**.

Terms of realization (costs of achieving): Realizing this plan would require estimated investments in the range of 2 to 2.5 billion CZK. However, this is money whose amortization/repayment appears possible, but only in the long term (15-20 years) if it was not to adversely affect the prices of heat (constant real marginal cost/depreciation should not be higher than CZK 150 - 200/GJ).

A basic prerequisite for the implementation is concluding a long-term contractual relationship between the owner of the island district heating systems (Prague Water Supply) and the owner of Kladno resources (Alpiq Generation CZ). However, as no intensive negotiations have been taking place yet, the city could play the role of an initiator of this contract and possibly get involved in financing the project. Any help – especial financial - would lead to reduction of heat prices for consumers currently connected to island district heating systems.

2.2.3 | Transformation of district heating systems in Prague to the CHP heating station mode

Brief description: High-efficient cogeneration heat production mode can also be established on the territory of Prague. In the existing economic conditions and provided subsidies, it seems as the most appropriate to focus on the island (isolated) district heating systems burning natural gas as fuel to generate heat. The transformation can be achieved by adding a cogeneration heat source of power based on internal combustion engine principles with an output up to 5 MW.

Projected effects: Assuming an installed model electric output of 50 MW (or similar thermal output), the cumulative effects on primary energy savings and subsequently greenhouse gas emissions of CO_2 would reach over 20 thousand tons/year compared to the current situation (production of identical amounts of electricity and heat from natural gas in separate ways).

Terms of realization (costs of achieving): Taking a typical specific investment performance of 20 thousand CZK/kW of electric output, it would be necessary to invest an amount of about CZK 1 billion. Furthermore, it would be necessary to include the subsidies guaranteed to CHP operators (so-called green bonus for high-efficient CHP) in order to stimulate higher CHP application. These subsidies, paid as an additional bonus over electricity and heat market prices, significantly affect profitability and if they did not exist, the generation of electricity and heat in district heating systems from natural gas would be uneconomical due to low current prices of electricity and heat.

2.3 | Electricity

The following additional low carbon strategy measures were proposed in the field of production and distribution of electricity.

2.3.1 | Modernizing current transformers in the distribution network by replacing them with new ones meeting the requirements for "eco-design" (lower losses)

Brief description: Recently proposed European legislation is planning to tighten the regulations for percentages of transformation losses in newly manufactured power and distribution transformers in two steps: from 2015 respectively 2021. Modern designs will allow the newly installed transformers to reach about 15 - 25% lower losses than those that are typically installed nowadays. It is proposed to impose these standards on newly installed transformers in Prague in advance.

Assumed effects: At the present replacement rate of 70 - 80 units of HV/LV transformers in Prague a year, the effect of giving priority to more efficient ones is about 2 - 3 MWh/piece, which means 140 - 240 MWh/year corresponding to CO_2 emission reduction of 80 to 140 tonnes/year. Assuming a 6-year acceleration of this development, it would mean total reductions of 500 to 1,000 tonnes a year.

Terms of realization (costs of achieving): The proposed tightening of the standards should be in effect from 2014 or, at the latest, from 2015, but it should require loss percentages valid from 2021. All newly acquired/installed transformers, especially those for the voltage levels of HV/LV, would have to meet the technical specifications that are planned to become mandatory from 2021. The extra cost of more efficient transformers can be estimated at 50 thousand CZK/pc or 21 - 24 million CZK in total in 6 years of applying stricter standards. The return on extra costs can be expected within 15 - 20 years as the average life-span of a transformer is typically up to 40 years.

2.3.2 | Reducing technical and non-technical losses in the distribution system and wasteful use of electricity at end customers by creating an intelligent distribution network

Brief description: In the next 10-20 years electric power grids will need adapting to new trends, both in electricity production and use (because of an increasing number of decentralized electricity sources, anticipated electrification of transportation, etc.).

A prerequisite for this is enhancing of the distribution network gradually with advanced monitoring and controlling elements that will allow operators to respond quickly to sudden changes caused by unexpected production or consumption of energy in order to keep it balanced and as economical as possible. Technology development will soon require connections to each customer and energy producer that enable on-line monitoring at the point of connection. At the same time it is necessary to maintain rapid communication for exchanging data and commands to any (automatic or manual) change in the amount of energy produced or consumed in the next period.

Projected effects: In addition to better system management, it will be possible to eliminate technical and non-technical losses in the distribution system and to reduce wasteful use of electricity at end customers. The overall effect is estimated in percentage units of current consumption (1 - 2%), which, for Prague, represents a reduction of 60 to 120 GWh/year or tens of thousands of tons of CO_2 emissions per year for the emission factor typical of electricity supplied from a transmission network which large power stations are connected to.

Terms of realization (costs of achieving): The necessary first step is the installation of intelligent meters capable of remote management and two-way communication at all points of connection (in Prague, there are about 750 thousand of them). The cost per a supply point can be estimated at several thousand CZK, which means a total investment of several billion. However, the money does not have to be (and cannot be) spent at once, but can be spread over time (and only part of the costs would be additional costs because the modernization is currently being implemented anyway, even though not to a sufficient extent).

2.4 | Renewable and secondary energy sources (alternative energy sources)

2.4.1 | Increasing recuperation of waste heat (or possibly electricity)

Brief description: The principle of this measure is to increase energetic use of waste by extending ZEVO (waste liquidating plant) Malešice and to replace a part of heat currently produced in the heating plant Malešice II or EMĚ I with heat produced from waste in the ZEVO. The measure can help to further improve the CO_2 emission factor, which is closely associated to the heat supply from the PTS (Prague Heat Plant System). It is possible to raise the capacity by about 75 thousand tonnes/year (to 350 - 375 thousand tonnes/year) before 2020 and after 2020 by another 100 to 150 thousand tonnes (up to more than 500 thousand tonnes/year).

Projected effects: If the heat supply from ZEVO is increased by realistically reachable 650,000 TJ/ year through increasing its waste liquidating capacity by above mentioned 75 thousand tonnes / year, it will mean potential reduction in CO_2 emissions by 20 to 30 thousand tonnes / year calculated in comparison to heat produced by burning anthracite in Malešice II.

Terms of realization (costs of achieving): Increasing the processing capacity at ZEVO Malešice would require additional investment costs in the amount of CZK 0.5 to 2.5 billion (modernization of existing lines with the increase in their current processing capacity, the construction of the fifth line, strengthening the hot water pipe connected to PTS, the construction of a railway industrial track and other modifications).

2.4.2 | Utilizing biowaste to produce biogas for vehicles (collecting municipal waste) to replace currently used CNG

Brief description: Increasing energy recovery from waste by equipping ZEVO Malešice with new a bioreactor for processing sorted biowaste with a capacity of 10 to 15 thousand tonnes / year. The product of anaerobic fermentation of waste – biogas – could be used after refining (removal of impurities incl. CO_2) as motor fuel for Prague Services' municipal waste vehicles currently running on CNG.

Projected effects: Processing up to 15,000 tons of biowaste per year would allow producing about 700,000 Nm^3 of biomethane, which applied as 1:1 replacement of (compressed) natural gas means a reduction of about 1,400 tonnes of CO_2 per year. This amount of fuel could cover the annual needs of about 40 CNG burning waste collecting trucks that Prague Services already own.

Terms of realization (costs of achieving): The cost of bioreactor construction is estimated at CZK 100 - 150 million, depending on its capacity and design. If the prices of a biogas refining unit that enables it to be used as motor fuel and a "bioCNG" filling station with several racks are include, then the total cost will amount to CZK 150 to 200 million.

There is also a need for appropriate measures in order to ensure an increase in the yield of separate collections of sorted biowaste up to about 4 times as high as the current amount (in 2012 Prague Services managed to collect about 4,000 tons of biowaste, especially from catering companies and selected residential areas).

2.4.3 | Streamlining the sewage sludge processing at the Central Waste-water Treatment Plant Prague for possible heat supply to external customers

Brief description: Modifications to heat processing at Central Waste-water Treatment Plant Prague (hereinafter CWTPP) in order to generate heat usable at external customers (see project description in the Attachment)

Projected effects: If the basic step (installation of a working circuit with two heat exchangers and a suitable heat transfer medium) was implemented, it would be possible to deliver about 60,000 GJ of heat per year to external customers off CWTPP site. Additionally, a heat pump (using sludge residual heat or possibly discharged treated water heat) could supplement the system, which would result in increasing the amount of heat supplied to external customers to over 100 000 GJ/year. This would mean CO_2 emission reductions by several thousand tons per year (3 to 5 thousand tons CO_2/year) calculated in comparison to natural gas.

Terms of realization (costs of achieving): Feasibility tests of intended technology deployment for recovering heat from the sludge are a prerequisite. If the solution proved reliable, it would be necessary to invest the amount of CZK 20 to 25 milion in installing the recovery system and possibly several dozen million in the second phase (heat pump). The construction of a necessary heat pipeline connecting the plant to a suitable supply point would require several dozen million CZK (if the heat was brought to Juliska heating plant, the costs are estimated at a total of about CZK 60 million).

2.4.4 | Utilizing surplus biogas from the CWTPP to produce biofuels for vehicles currently using CNG

Brief description: Currently, the sludge facility at CWTPP disposes of surplus biogas by wastefully burning it in a flare. The gist of the proposed measure is to use the surplus biogas, refine it to natural gas quality and to be used it as biofuel in transportation.

Projected effects: The amount of surplus biogas at CWTPP stands at about 1 million Nm^3 per year. As biogas typically contains more than 60% of methane, it is theoretically possible, after deducting the loss in refining it to natural gas quality, to obtain 600,000 Nm^3 of "bioCNG" a year. This is an amount of fuel that is sufficient to cover the annual fuel consumption of several dozen buses (about 30) or a few hundred cars. This measure can potentially generate CO_2 emission reduction of about 1,200 tonnes of CO_2 per year if it replaces compressed natural gas or nearly 1,600 tons of CO_2 per year if conventional fuels (petrol, diesel) are substituted.

Terms of realization (costs of achieving): Implementing the measure would require the installation of equipment for biogas refinement near to natural gas quality as well as further distribution of the fuel. The distribution options are either delivering it to a nearby gas network or putting it into cylinders or other pressure vessels that would be transported to other locations (e.g. to CNG filling stations, where vehicles could be filled with it). Naturally, profitability is decisive. Investment costs are estimated at CZK 40 to 60 million depending on capacity of the technology and the selected mode of transportation of the gas for end use.

2.4.5 | Expanding high-efficiency heat pump installations

Brief description: At the core of this measure there is active search for and implementation of such heat pump applications that can achieve highly efficient operations (these can be defined as having an average annual COP of 4 or more). This efficiency can be mainly reached by using secondary sources of heat. The most promising way appears to be the use of sewage heat energy obtained with the help of heat collectors placed into the sewage pipe network; other options are surface and ground water (especially along the Vltava River) and also extracting heat from the ground with collectors integrated in concrete constructions of underground structures (tunnels, metro stations, etc.).

Projected effects: Installing proposed heat pumps with high coefficients of performance with a total heat producing capacity of 10 to 30 MW could bring CO_2 reductions of about 1 - 3 thousand tonnes/ year (if the heat replaces heat from burning natural gas).

Terms of realization (costs of achieving): A high-COP heat pump installation of the considered 10 to 30 MW heat producing capacity would require an estimated investment of between CZK 400 and 1,200 million if it is calculated with the average investment cost of CZK 40,000/kW of thermal output. However, there is a prerequisite for a successful implementation of this measure: coordinated actions of all parties involved - the owners and managers of the infrastructures concerned as well as heat end users. This solution appears to be most suitable for new construction sites (e.g. the development zone in Bubny-Holešovice or D-line metro stations).

2.4.6 | Supporting the development of photovoltaic power installations on buildings

Brief description: Photovoltaics has by far the largest energetic potential of all renewable sources. At the same time, this technology is developing dynamically, which leads to decreasing technology prices, increasing performance and yield and to reducing negative effects of solar power stations on distribution systems' reliability and the quality of distributed energy. Therefore, it is proposed to make good use of these positive developmental changes and to actively support installations of photovoltaic power plants in Prague, both on residential and non-residential buildings.

Projected effects: The overall energetic potential is estimated at up to 300 MW_{peak} of electric power in optimal conditions – at peak performance. It is realistic to assume that installations of 100 to 200 MWp can be put in operation within the next 10 - 20 years. This would enable to produce 100 to 200 GWh of electricity with de facto zero pollutant emissions. It would represent indirect CO_2 reductions of **50 to 100 thousand tonnes/year.** (Calculated with the current average ratio of sources in the electricity power system of the Czech Republic.)

Terms of realization (costs of achieving): At current prices, the installation of 100 to 200 MWp would require an investment of CZK 5 - 10 billion over the next 3 - 5 years but, considering price developments, the costs may only be half of the projected sum. Investors can bear these costs without any subsidies, but there is a weak point: using surplus electricity at times when more power is produced than demanded. Unless a cheap way of accumulating/storing electricity is invented, the growth in FVE can significantly slow down in the years to come. In the context of Prague and its inhabitants, it does not seem reasonable. By increasing the installed capacity in photovoltaic applications it is possible to reduce power peaks during the summer. Therefore, it is proposed to apply a more accommodating approach of the concerned authorities to permitting these sources (both in terms of installations and permissions to connect from the distributor), if the sources are balanced with existing power-consumption. It is also proposed, with the help of PREdi or PRE Group, to initiate an intensive search for a suitable product enabling temporary "storage" of surplus electricity with an option to re-deliver it to the customer who produced it.

3 | Low-carbon measures in end energy consumption

3.1 | Transportation

3.1.1 | Enhancing the usability of recuperated energy of the Metro

Brief description: In particular, Metro operations hide significant potential for energy savings. Its use is limited by the established rules of operation, by required technical standards or by low economic efficiency in general. These unrealized measures include changes in the timetable of trains (for technical and operational reasons), even though they would permit the use of recuperated braking energy, upgrading platform lighting systems (because of the required electrical wiring replacement), installation of inverters for possible conversion of energy recovered from train braking to AC and its use in non-traction subway appliances or the use of co-generation units for thermal needs on Prague Public Transport Company (PPTC) premises. The same applies to the installation of super capacitors (that could use accumulated energy from braking for subsequent acceleration) in tram cars as it still remains much too costly.

So, the most promising measure appears to be replacing iron supply rails with aluminium ones. Aluminium has about three times higher conductivity than iron. Therefore, electrical sections could be longer and the probability of another metro car being close enough to use the recuperated energy for acceleration would be higher.

Projected effects: The effects are estimated at about 30 GWh of electricity savings per year (about 28% of the current traction electricity consumption), if the supply rails of all metro lines were replaced (currently about 60 km in total, 66km after the implementation of the A-line extension). At the current electricity prices of about CZK 2/kWh, this would result in savings of more than CZK 60 million/year and more than 17,000 tons CO_2/year (using emission factor corresponding to the electric energy source ratio in the electric power supply of the CR).

Terms of realization (costs of achieving): The realization of this measure would mean investment costs at the amount of about CZK 650 million; technical or other additional conditions are not known and included. Considering the DPP budget, an investment subsidy would be helpful.

3.1.2 | Utilizing heat pumps in heating new D-line metro stations

Brief description: On the new subway line "D", there are ten stations in total. If their way of heating has not been definitively decided, there is an opportunity to heat or cool them with heat pumps. Inspired by models abroad (e.g. U2 underground stations in Vienna), we could build a network of flexible heat collecting pipes both in the foundations and the tube body itself with minimal extra costs. These would later form the primary circuit of a heat pump. In winter, the recovered heat (from the ground and internal heat sources) could be used for metro station space heating and in the summer, it would significantly contribute to its cooling. The pumps would work very efficiently and therefore with low operating costs. Along with acceptable investment costs, this concept of heating/cooling could be economically advantageous as well as environmentally friendly.

Projected effects: Typical values of thermal potential range from 10 to 30 W/m2 in the tunnel area. Lower values are characteristic of the "cold" tunnels (without internal heat gains) or tunnels in unsuitable subsoil, but they are typically higher in tunnels with high internal heat gains and in clay subsoil. The achievable cooling capacity is about a third lower. The necessary heat output is estimated at 100 - 150 kW for one station. For all new station it is conceivable to install about 1 MW of thermal power, which can generate about 1 - 2 thousand MWh of heat/cold a year with related CO_2 **emission reductions of 200 to 300 tons** per year compared to heat production by conventional means.

Terms of realization (costs of achieving): Before this proposal can be realized, it is necessary to carry out a detailed study in order to verify the suitability of this solution at each station and to quantify the potential costs. The investment costs of heat pumps typically reach CZK 30-40 thousand/kW of installed capacity (in total about 30-40 million CZK for all the stations - size of 1 MWt). If the proposal was realized, it would not only bring an environmentally friendly alternative, it would also be economically competitive to heat sources using natural gas.

3.1.3 | Implementing automatic energy consumption monitoring in selected facilities of the public transportation system

Brief description: A system enabling automatic monitoring of all types of energy consumption would allow to significantly improving the level of energy management thus minimizing wasteful use of energy.

Therefore, in the proposed Energy Plan, it will be recommended to include selected supply points (e.g, all Metro stations) in the in the pilot project "Smart Prague". The core of the measure would lie in equipping selected supply points in buildings and facilities directly or indirectly owned by the City with modern primary, possibly even secondary, electricity or heat meters. Meters enable sending on-line readings, which would be collected, analyzed and stored in an integrated information system (following the initiative "Together for Prague").

Projected effects: Estimated effects are now difficult to quantify, however, practice suggests that a consistent "energy management" can bring energy savings of several percent of the consumption. If this managed to reduce electricity consumption in the service facilities of the Metro and the tramway network (i.e. non-traction facilities), it could save gigawatt hours of electricity and hundreds of gigajoules of heat from district heating or from gas a year **(equivalent to potential CO_2 reductions of thousands of tonnes per year).**

Terms of realization (costs of achieving): Prior to realization, it is necessary to identify all suitable supply points and to fit them out with measuring devices that are capable of remote data readings and of transferring the data to a central place for analysing, reporting and final archiving. Typical costs of a modern measuring unit may be in thousands of CZK. If they were at every subway station or at all surface facilities, their number would be about 200. The total costs would be estimated at CZK 3 - 4 million (including appropriate software - either licensed or developed).

3.1.4 | Support for the introduction of vehicles with environmentally friendly engine

Brief description: Prague can actively promote the implementation of environmentally friendly engine systems and alternative fuels by motivating or by committing its own organizations and city companies to prioritizing environmentally friendly vehicles. Apart from the first-generation liquid biofuels, whose environmental benefits are questionable, there only exists one, realistic and technologically and economically tested alternative for reducing CO_2 emissions and that is the use of biogas extracted from biowaste. That is why this fuel is nowadays classified as advanced biofuel and states will be motivated to prefer it to the first-generation biofuels and to gradually extend its use.

As Prague can produce this biofuel in its own facilities at costs that can be even lower than the prices of today's conventional fuels (petrol, diesel), it is recommended to continue replacing conventional cars and trucks with ones that use CNG and can use biogas without difficulty.

Projected effects: For both production sources in Prague (CWTPP and the bioreactor at ZEVO Malešice), the potential biofuel production in the form of "bioCNG" reaches about 1.3 million Nm^3 in total. The production may be even higher (e.g, if the yield of biowaste from sorted-out waste collections rises or if the production of biogas at CWTPP increases after streamlining sludge processing). This amount would be sufficient for the operation of several hundreds of passenger cars or several dozen heavy trucks. The result would be a reduction in CO_2 emissions of 2.5 to 3 thousand tonnes / year (depending on the type of fuel being replaced).

Terms of realization (costs of achieving): There are two prerequisites for implementing this proposal: production and support for distribution. The former requires the installation of biomethane producing facilities; the latter offers two alternatives: either to take price measures in order to make bio-CNG financially more attractive than CNG and distribute it at current CNG filling stations or to support the construction of a new distributing infrastructure (most economically by adding bio-CNG dispensers at existing CNG stations). Support for the new construction would have to be combined with purchasing other CNG-burning vehicles with the proviso that they would use bio-CNG as fuel of choice. Induced costs would depend on the number of vehicles acquired and potential need to build a petrol station at which bio-CNG would be dispensed. If we consider purchasing 50 more trucks or buses, the extra costs would amount to CZK 40 - 50 million. Construction costs of a fast filling station of the standard capacity with two dispensers (up to 1 million Nm^3) would be between CZK 5 and 7 million. For a larger number of dispensers and a higher fuel capacity that might be needed, for example, for a fleet of buses, the costs would be 2 to 3 times higher.

3.1.5 | Introducing electro mobility within the public bus transportation system in Prague

Brief description: City bus public transportation is generally regarded as one of the most promising areas in which vehicles with emission-free electricity-driven engines could replace conventional buses in the not too distant future. Public Transport Company of Prague (hereinafter DPP) has been testing various prospective types of electric vehicles in everyday Prague traffic in order to gain valuable data about their intended operation in Prague public transportation. The current tests suggest that the most promising solution, both technically and economically, seems to be purchasing and operating (more affordable) vehicles, although with a lower battery capacity, but capable of high performance on route as well as of fast recharging at terminals. Maximum range of these vehicles could be 30 to 50 km with ongoing recharging. The use of a pantograph system for recharging appears to be a suitable technology as it is an open standard, field-proven, relatively inexpensive and as it allows quick recharges. Recharging points would use the existing infrastructure of power supply lines for the trams or the Metro (by constructing overhead lines near converter stations). Assuming tram network power infrastructure is used, there is a possibility of partial reuse of recuperated energy from braking, i.e. if energy surplus can be stored in temporary stationary supercapacitators. This concept could be beneficial not only environmentally but also economically and it could justify preferring electric buses to those with diesel engine by the Public Transport Company. Prospectively, electrobuses could constitute a significant part of the DPP fleet (several hundred buses) on condition they are proved to be economically advantageous. **Only a long-term pilot project, the details of which are outlined in the Annex, can verify the feasibility of this measure.**

Projected effects: At this point, it is only possible to model the estimated effects theoretically. Energy consumption of an electrical bus when it is self-driven could be about 1 kWh/km. Including energy for heating in winter or cooling in summer, it can be an annual total of 50% more (i.e. 1.5 kWh/km), which is just about 40% of the energy consumed by a diesel bus with a conventional engine. In addition to the economic benefits due to lower costs of operation (estimated savings of about CZK 5/km), in terms of CO_2 emission reduction this would mean 100% at the tank-to-wheel level, which corresponds to CO_2 production decrease of about 1 kg/km. For a vehicle with an average mileage of 50 - 60 thousand km a year, local reductions in CO_2 emissions would amount to about 50 - 60 tonnes / bus / year. The main benefit would be the elimination of other pollutants from combustion (emissions of NOx, SPM, HCO). **When evaluating reductions in CO_2 emissions at a global level with the Czech Republic's energy source portfolio, the effect of this measure is insignificant and cannot be clearly quantified.** However, if a fraction of the consumed electricity came from tram or the Metro braking energy, or if the national energy source portfolio changed in favour of zero-emission or renewable sources in the future, CO_2 reductions at the global level would be easier to quantify and they could reach tens percent of the theoretical values of annual savings per a bus (i.e. up to tens of tonnes / bus / year).

Terms of realization (costs of achieving): Realizing the pilot operation project, which involves the construction of two recharging stations (at a selected depot and at one of the terminals) and possibly a stationary storage super capacitor for the use of recuperated energy and the purchase of at least one electric bus of the above mention type, is a sine-qua-non. The total cost of the pilot project can be estimated very roughly at CZK 10 to 20 million in dependence on the scope of implementation. The costs of the pilot project would be significantly decreased if the vehicle(s) was either lent or rented for long-term testing by the manufacturer interested in this business opportunity.

3.1.6 | Introducing measures increasing the efficiency of the technical transport infrastructure

Brief description: In cooperation with the TSK hl. Prague several measures have been identified that would contribute to greater efficiency of transportation infrastructure on the territory of the capital city. One of them relates to using more efficient light sources in traffic lights reconstructions and to modernizing tunnel lighting. There are other measures increasing the efficiency of transportation technical infrastructure.

In a broader context, from the viewpoint of energy saving measures, measures for increasing road traffic flow can also bring some benefits. These include the introduction of advanced traffic management, e.g. increasing the number of traffic lights at intersections able to give absolute preference to public transportation vehicles (buses, trams), raising the number of preferential lanes for public transport, taxis, and other motor vehicles granted special priority or constructing additional P + R parking lots near the Metro terminal stations in order to encourage travellers to prefer means of public transport.

Projected effects: More information about the measures defined by TSK Praha could not be obtained and therefore it was not possible to competently determine the level of positive impact in terms of reducing CO_2 emissions. Therefore, we cannot publicize in the updated Energy Plan of the capital city of Prague; however, they will be quantifiable later.

Terms of realization (costs of achieving): The same applies to the definition of the terms of implementation.

3.1.7 | Giving priority to more economical and ecological forms of cargo transportation

Brief description The city of Prague has now introduced a system of regulated entry to the city center and to selected districts in its vicinity for heavy trucks and buses. The system is based on the need to apply for entry permission to the City Hall Department of Traffic Agenda prior to entering those areas. There is no legal right to obtain the permission (i.e. the request may be refused). Applications are assessed individually and the permissions have limited validity (short-term ones for a maximum of eight days and long-term ones for up to one year).

Currently, two zones of limited entry are defined. The first zone of regulation includes the area of the historical center, which means almost the entire territory of Prague 1 and a part of Prague 2 (between the streets Resslova, Žitná, Sokolská, Wilsonova). Permissions are obligatory for trucks over 3.5 tonnes and buses. To obtain the permission, the vehicle must comply with emission standard EURO IV (since January 1, 2013) and entries are limited in time (Mon - Fri 8 - 18 hours).

The second zone covers a broader area of Prague 4, 6 and 7 and the permissions are only required for vehicles over 6 tonnes.

In the context of this regulatory measure, it is appropriate to supplement it by a proposal of more environmentally friendly means of cargo transport in this area of the city.

Since rail vehicles (powered by electricity) are generally several times more efficient than vehicles with internal combustion engines, it seems useful to consider greater use of rail transport network for freight transport on the territory of Prague.

Some cities abroad integrate even urban tram network into their environmentally friendly freight transport strategies. Local transport companies have special tram cars capable of transporting selected sorts of items. These are used e.g. for the collection of bulky waste or for transporting larger quantities of goods from one place to another (e.g. from a logistics center on the outskirts of the city to a factory in the center).

Logistical centers, called urban consolidation centers (UCCs) abroad, are a tool for further reduction in the number of truck entries into densely populated areas. In those centers, shipments for different types of customers are collected and then transported to individual addressees by a fleet of environmentally friendly vehicles (e.g. vehicles with CNG or electric engines, etc.). Their acquisition and operation usually have to be subsidized from public sources. However, if the permissions to enter the area are strictly limited to very environmentally friendly means of transport, they can be economically self-sufficient.

Possible specific measures and proposals are identified in the Annex to this strategy plan.

Projected effects: At this stage, the possible specific measures and intentions are only defined conceptually and their potential benefits to the citywide CO_2 balance cannot be quantified; this will have to be done later.

Terms of realization (costs of achieving): The same applies to the definition of the terms of implementation.

3.2 | Households and tertiary sector

3.2.1 | Advanced renovations of residential buildings before 2020

Brief description: Over the last ten to fifteen years, the renovation of housing stock has progressed significantly, especially in prefabricated blocks of flats. However, a simple field survey shows that a considerable part of the housing stock in Prague is waiting for this renovation, especially in brick residential buildings and houses. The aim of the measure is to support such renovations, which will use the highest rational degree of measures for improving the efficiency of heating energy use.

Projected effects: Advanced building envelope renovations, which include replacing window panes and insulating non-transparent structures (roof, walls, possibly basements) to the recommended values of heat-insulating properties, enable to reduce energy demands for heating by 25 - 30% (i.e. typically 50 kWh/m^2 floor area per year). If we expect renovations in the range of 80 to 100 thousand dwellings (15 - 20% of the housing stock) before 2020, it corresponds to total savings of 1 to 1.2 PJ (1 x 10^{15} J) of heat energy, calculated with an average 85% efficiency of its production, **the total savings can reach 1.2 to 1 4 PJ of primary energy per year.**

With an average CO_2 emission factor per GJ primary energy of 75 kg this corresponds to an annual reduction in the greenhouse gas emissions of **90 to 105 thousand tonnes / year.**

Terms of realization (costs of achieving): Investment costs of such profound upgrading can only be estimated on the basis of previous experience of completed modernizations which shows an average cost about CZK 13,000/GJ of saved thermal energy. Costs of necessary structural repairs required because of neglected maintenance are not included in this amount. Total investment costs would amount to about **13 to 16 billion CZK**. If all necessary improvements including building envelope repairs and heat use efficiency measures were applied, it would be needed to gain financial support covering the envelope reparations. That means extra 20 – 30% of the above mentioned investment costs.

3.2.2 | Advanced renovation of residential buildings after 2020

Brief description: After 2020, significantly stricter energy saving requirements for new buildings and renovations will come into effect both in the Czech Republic and in the whole EU. However, it will probably be possible to renovate existing buildings without applying all hi-tech heating energy saving measures. Therefore, the essence of the proposed plan is to motivate such reconstructions of selected buildings that would achieve an above standard heat energy savings. That is reconstructions that include using hi-tech insulation materials as well as introduce controlled ventilation with exhaust air heat recuperation. Since air permeability of window panes in insulated buildings greatly reduces, it seems that the introduction of controlled ventilation is a desirable solution, because it contributes to both energy savings and the quality of inside air/environment.

Projected effects: With such advanced reconstructions of existing buildings, the reductions in heating energy consumption can realistically reach 40 - 50% of currently consumed energy (i.e. typically about 80 kWh/m^2 of floor area per year in absolute numbers). If we expect the renovation in the range of 120 - 140 thousand apartments after 2020 (20 - 25% of the housing stock), it corresponds to total savings of 2.5 to 2.8 PJ of heat energy per year; calculated with an average 85% efficiency of its production, the **total savings can reach 2.9 to 3.3 PJ of primary energy per year**.

With an average CO_2 emission factor of 75 kg per GJ primary energy, this corresponds to an annual reduction in the greenhouse gas emissions of **220 to 250 thousand tonnes/year**.

Terms of realization (costs of achieving): Investment costs for such advanced upgrading can be only roughly estimated as they will be realized in the distant future in unpredictable conditions. Taking into account the lower investment costs of thermal energy savings through the introduction of controlled ventilation with heat recuperation on the one hand, and probable advances in technology on the other hand, investment costs can be estimated at the same level as the previous measure, i.e. about CZK 13,000/GJ of saved heat energy. Yet again, costs of necessary structural repairs required because of neglected maintenance are not included in this amount. The total investment cost would amount to **app. 33 to 36 billion CZK**. If hi-tech renovations to higher energy-efficiency standards are realized, it would be necessary to gain financial support covering the difference between the costs of the required and hi-tech reconstructions. That again means about 20 – 30% over the above mentioned investment costs.

3.2.3 | Hi-tech energy-efficient new buildings and constructions

Brief description: The current requirement Czech legislation put into operation after 2020, only the so called zero building does not mean that it is indeed a building with zero consumption. Czech requirement is relatively benevolent and allows investors the following mandatory parameters easy to breach. The aim is that new construction in Prague will achieve better energy efficiency than required by the new legislation by the year 2020 and thereafter.

The most promising locations for applying these requirements in advance seem to be the main development areas (Holešovice - Bubny, Smíchov Railway Station, Žižkov Railway Station, Rohanský Ostrov, etc.) that require changes in the City Land-Use Plan and therefore an approval from the City Authorities for their developments.

Projected effects: If we consider new developments of app 1,000,000 square meters and the difference in heat savings between currently required minimum standards and the hi-tech standards is estimated at 40 kWh/m^2/year, the calculation shows that about 140 to 150 TJ heat per year could be saved; calculated with an average 85% efficiency of its production, the **total savings can reach from 165 to 180 TJ per year**.

With an average CO_2 emission factor of 75 kg per GJ of primary energy, this corresponds to an annual reduction in the greenhouse gas emissions **of 12.5 to 13.5 thousand tonnes/year.**

Terms of realization (costs of achieving): The City Authorities will have to use their strong position resulting from the necessary changes in the City Land-Use Plan that require the City's approval in negotiations with the investors for hi-tech standard measures in construction. Additional costs of hi-tech standard construction are expected to be maximum 10% over construction costs in standard construction, i.e. about CZK 2.5 - 3 thousand/m^2 of floor area or a total **of CZK 2.5 - 3 billion.**

3.2.4 | Supporting renewable sources installations in residential areas from the Clean Energy Prague programme fund

Brief description: The measure is targeted to continue of support installations using renewable energy sources in residential areas of the programme "Clean Energy Prague".

Projected effects: Considering the current number of supported projects, it appears to be achievable to support every year a few tens to hundreds of devices, such as heat pumps, solar thermal and photovoltaic systems, in the future. It is proposed to subsidize another 10,000 applications within the period, which would bring an average reduction of one ton of CO_2/application/year, which means a total reduction in CO_2 emissions **of 10,000 tonnes per year**.

Terms of realization (costs of achieving): The subsidy is proposed to be granted at the current level (i.e. a maximum of CZK 20 to 25 thousand/application), which is sufficient to cover 15 - 30% of the total investment cost in dependence on the type of equipment installed and its size. For the proposed number of 10,000 applications the total subsidy would amount to approximately CZK 250 milion and the total investment costs to CZK 1 to 1.5 billion.

3.2.5 | Enhancing motivation to apply modern technologies to increase energy efficiency in the non-production sector entities

Brief description: The purpose of the measure is to encourage non-manufacturing sector subjects to develop and to keep internal programmes that are targeted at efficient energy management. The tool for this is the introduction of energy management systems according to standardized procedures (standards ISO 50001 or 16001), or other appropriate systems that implement efficient "energy monitoring and targeting."

Projected effects: High quality energy management can produce energy savings in the order of several percent of the current consumption. At the moment, it is impossible to summarize its total positive effects as the number of possible subjects involved is unknown. However, the target is to achieve the total amount of cumulative CO_2 emission reductions of 10,000 tonnes / year through implementing these systems.

Terms of realization (costs of achieving): It is proposed either to provide a financial incentive to subjects that have implemented the system or to prioritize those public contract bidders that have the system in operation. With the usual costs of measures reducing CO_2 emissions of CZK 500 to 1,500/tonne of CO_2, the total additional expenditure would amount to CZK 5 to 15 million.

3.3 | Industrial companies

3.3.1 | Enhancing motivation to apply modern techniques to increase energy efficiency in the industrial enterprises

Brief description The purpose of the measure is to encourage industrial entities to develop and to keep internal programs that are targeted to efficient energy management. The tool for this is the introduction of an energy management system according to standardized procedures (standards ISO 50001 or. 16001), or other appropriate system that implements efficient "energy monitoring and targeting."

Projected effects: High quality energy management can produce energy savings in the order of several percent of the current consumption. At the moment, it is impossible to summarize its total positive effects as the number of possible subjects involved is unknown. However, the target is to achieve the total amount of cumulative CO_2 emission reductions of 5,000 tonnes/year (lower than the non-manufacturing sector due to generally lower savings potential and also generally smaller size of this sector in Prague compared to other regions of the country).

Terms of realization (costs of achieving): It is proposed either to provide a financial incentive to subjects that have implemented the system or to prioritize those public contract bidders that have the system in operation. With the usual costs of measures reducing CO_2 emissions of CZK 500 to 1,500/tonne of CO_2, the total additional expenditure would amount to CZK 2.5 to 7.5 million.

4 | Prague city to take lead

4.1 | Utilizing the economic savings potential in all objects owned by the Capital City of Prague

Brief description The aggregate amount of the saving measures economic potential of payback period less than their expected life, Energy Plan estimates of about 157,000 GJ / year (see Appendix 2) at circa 170 selected objects with the highest energy consumption under the property of city management organizations or the city.

The savings could be achieved the most often by retrofitting of existing building systems covering the needs for heat, hot water or cold, and some appliances (e.g. pumps, lights), with a payback period of 5-10 years.

Further energy savings can be brought by action in the construction part (replacing window constructions, additional insulation of exterior walls, roofs and floors, etc.). The return on investment would be a little longer, but still shorter than the lifetime of the measures.

Saving measures may be actively implemented by object administrators themselves, but practice proved to determine for the implementation of modernization measures a clear responsibility for the outcome. For this reason, it is advisable to deal with at least part of the energy potential by EPC - the method of financing the saving measures from the guaranteed generated savings of operating costs (especially EPC method for the renovation of the housing stock is used successfully by cities like Berlin or London; see Appendix 8).

European legislation - Directive 2012/27/EU on energy efficiency encourages to the housing stock owned by public authorities renovation. According to this Directive, the 3% of the total floor area of heated or cooled buildings owned and in use of the central government institutions should be renovated annually within the years 2014-2020, to the level of minimum energy requirements according to applicable legislation. Member States should encourage other public entities to accept a similar renovation plan (see Article 5, paragraph 7 of the Directive).

Projected effects: The total potential energy savings in final energy consumption was quantified at nearly 157,000 GJ / year, which corresponds to the primary energy savings of 1.3 times this value (approximately 200,000 GJ / year) - depending on the heat source type.

With an average CO_2 emission factor is of 75 kg per 1 GJ of primary energy that corresponds to the annual contribution to the reduction of greenhouse gas emissions **of 12 thousand tons / year**. Reducing energy consumption will also bring savings in operating costs. Their total amount by taking the price CZK 300 of 1 GJ of primary energy corresponds to approx. CZK 60 million per year.

Terms of realization (costs of achieving): Exploitation of energy savings economic potential would require expend funds in the amount matching to CZK 1 to 5 thousand / GJ of annual final energy savings, or of about CZK 150 to 800 million in total.

Similarly, it is possible to consider the use of technical potential savings in buildings of Prague in care of City Districts. In these of about 540 buildings in the city district administration the economic potential is estimated at approximately 390 thou GJ / year.

4.1.1 | Constructing new or reconstructing selected existing buildings (owned by the City) to near-zero energy standard(intelligent buildings)

Brief description: At the core of the measure - while respecting the motto above – it is to demonstrate an exemplary city role in the construction of new, eventually substantial modernization of existing buildings owned by the City. The aim is to achieve at constructions so little energy intensity that it can be referred to as the objects with near-zero energy consumption. It would require high-tech reduction of the building envelope heat losses, introduction of controlled ventilation with heat recovery and utilization of renewable resources to cover part of the remaining energy needs.

By taking into account the other aspects during the construction (e.g. friendly water use, materials of construction, advanced BMS, etc.) the buildings should be able to aspire to the designation of "intelligent building". Thus, for example, it is considered for object "Emmauzy" in Vyšehradská Street, the poor condition of it forces a major reconstruction. It is also the best opportunity to apply the principles of considerate architecture by that high visible and historically valuable building (more on this see in Appendix).

Projected effects: When this concept of reconstruction of existing buildings or during new construction before 2020 could be achieved by reduction of heat consumption for heating by 50 to 60% (before these mandatory standards will become effective). To the model total floor area of 50,000 square meters it could mean annual supplied energy savings in the final consumption of 20 to 30 thou GJ / year with corresponding primary energy savings of between 25 to 40 thou GJ / year.

With an average CO_2 emission factor of 75 kg per 1 GJ of primary energy re-calculated this corresponds to an annual contribution to reducing emissions of this greenhouse gas in the amount of **2-3 thousand tons / year**. Reducing energy consumption will also bring savings in operating costs; the total amount corresponding to this amount is of 7.5 to 12 million CZK per year (by price of 1 GJ of primary energy of 300 CZK).

Terms of realization (costs of achieving): The using of this energy savings potential would require to spend for standard buildings (with a greater proportion of non-transparent structures in the building envelope) funds in the average amount about of **4 to 5 thousand CZK per m^2** of energy reference floor area corresponding to the required investment of **CZK 200-250 million**.

For buildings which façade is fully glazed (case of object Emauzy), but investment demand can be several times higher. For this reason, we recommend to use for this concept of modernization the support of future Operational Programme “Prague - Czech Republic pole of growth”.

4.2 | Advanced energy management in City‘s buildings

Brief description: Consistent monitoring and energy management can contribute to further energy savings or reduction of CO_2 and other pollutants emissions. For the future, therefore, we propose to introduce advanced energy management in the city buildings, which will be in accordance with the standards ISO 15001 or even 16001 and which also will allow automatic data collection of energy consumptions (at least at the main points of supply). Waveforms consumption of electricity and other network energy (gas, heat or even water) will be transferred to the joint information center, where data will be stored, analyzed, and in the case of irregularities it will be immediately notified of the serious deviations.

Projected effects: Successful energy management can reduce energy consumption according to the practice of other 1-5% above frame of technical measures. If the energy management at the same time was introduced into the objects being referred to the economic potential of savings, it could yield annual savings of up to an additional 10-30 thousand GJ / year of primary energy.

With an average CO_2 emission factor of 75 kg per GJ primary energy it corresponds to an annual contribution to emission reduction of the greenhouse gas in the amount greater than **1 thousand tonnes / year**. Reducing energy consumption will also bring savings in operating costs; the total amount corresponding to this amount is of CZK 3 to 9 million per year (the valuation 1 GJ of primary energy by price of 300 CZK).

Terms of realization (costs of achieving): Assumption for realization is the identification of all supply points and the installation of metering devices capable of the remote data reading and the data transferring to a central place for an archiving, analysing and final reporting. Typical costs of a metering unit may be of thousands CZK. If it were in selected city buildings installed 300 thus advanced meters, the total costs can be estimated at 4-5 million CZK (including license purchase or development of suitable software).

5 | Cost optimization

The above measures have real potential to contribute to reducing CO_2 emissions. Individual measures differ in degree of reduction of CO_2, thus making and the associated level of investment.

Economic benefits are mostly lower energy costs, but also may have a non-monetary form (for example, through the insulation can increase the utility value of the property).

Some measures will help to reduce CO_2 emissions and are recoverable; thoes should be implemented with priority.

However, there are measures that would be economically feasible only with some form of non-repayable aid covering part of the initial or even operating costs. It is highlighted in the table below, which measures concerned to it. So in this case it is valid, that they reduce CO_2 emissions and in the range outlined their implementation they can be regarded as prudent and bringing more positives, which cannot be immediately quantified in monetary terms. They will by the other way, such as user comfort, extended life, better outlook and so on.

Table 1: List of measures proposed for low-carbon development strategy of Prague for the period 2013-2033

	Title of action	Estimated benefits in savings in CO_2 emissions [thou tons / year]		The estimated initial cost of achieving [CZK million]	
		from	to	from	to
	The low-carbon measures in the production and supply of energy				
	Fuel				
*	*Eliminating the use of solid fossil fuels in unsuitable sources of heat by substitution for a low-carbon alternatives*	15	18	500	750
	Making more efficient use of natural gas development in Prague condensing technology	10	10	500	1500
	Thermal energy and cogeneration				
	Increasing the supply of heat from a source of high-efficiency cogeneration EMĚ I	30	50	500	1000
*	*The use of heat from a source high-efficiency cogeneration EK I (by construction of thermal power supply Kladno-Prague)*	30	50	2000	2500
*	*Transformation district heating systems in Prague into heating station mode*	20	20	1000	1000
	Electricity				
	Recovery of transformers in the distribution network for new and fulfilling future requirements for so-called "eco-design" (less losses)	0,5	1	21	24
*	*Limitations of technical and non-technical losses in the distribution system and aimless use of electricity for end customers by creating smart distribution network*	30	60	3000	4500

	Title of action	Estimated benefits in savings in CO_2 emissions [thou tons / year]		The estimated initial cost of achieving [CZK million]	
		from	to	from	to
	Renewable and secondary energy sources (alternative energy sources)				
*	*Increased energy recovery of waste heat (or even electricity)*	20	30	500	2000
*	*Energy utilization of biowaste to produce biofuels for vehicles (collecting or processing municipal waste) to CNG*	1,4	1,4	100	150
	Streamlining sewage pipes CWTPP for possible heat supply to external customers	3	5	80	250
*	*Use of surplus biogas CWTPP to produce biofuels for vehicles to CNG*	1,2	1,6	40	60
*	*Expanding high-efficiency heat pump applications*	1	3	400	1200
*	*Support the development of photovoltaic power installations on buildings*	40	85	5000	10000
	The low-carbon measures in the final energy consumption				
	Transport				
	Enhance the usability of recovered energy in the metro	17	17	650	650
*	*Heating new metro line D with the help of heat pumps*	0,2	0,3	30	40
*	*The introduction of automatic monitoring consumption in selected facilities Prague Public Transport Company*	1	3	3	4
*	*Support the introduction of vehicles with environmentally friendly drive ***				
*	*Electromobility within the Town Public Transport in Prague ****				
*	*Measures increasing the efficiency of transport technical infrastructure ****				
*	*Preference freight intrusively ****				
	Population and non-production sphere				
	High-tech renovation of residential buildings by 2020	90	105	13000	16000
*	High-tech renovation of residential buildings after 2020	220	250	33000	36000
*	High-tech energy-efficient new construction	12,5	13,5	2500	3000
*	Support the installation of renewable sources in the residential area under the programm the Clean Energy Prague	10	1	1000	1500
*	Increasing motivation to apply modern methods in reducing the energy efficiency of non-manufacturing sector entities	10	10	5	15
	Industry				
*	*Enhancing motivation to apply modern techniques to increase energy efficiency in the industrial entities*	5	5	2,5	7,5

Title of action		Estimated benefits in savings in CO_2 emissions [thou tons / year]		The estimated initial cost of achieving [CZK million]	
		from	to	from	to
*	*Economic potential savings for all objects owned by Capital City of Prague*	12	12	150	800
*	*Construction of new eventually reconstruction of selected existing buildings owned by the City on a building with almost zero energy (intelligent buildings)*	2	3	200	650
*	*Advanced energy management in buildings of City of Prague*	1	1	4	5
TOTAL		**576**	**883**	**77123**	**99683**

Remarks

**) The measures are economically beneficial for the investor under the condition the obtaining any form of investment or operating aid (same or similar as to the present)*

***) The effect of the reduction of CO_2 emissions is already assigned to those proposing the production of biofuels "bioCNG"*

****) Effects and costs of these measures cannot be quantified at this time (it is necessary to develop ideas in more detail)*

6 | Examples of potential specific projects of low-carbon strategy implementation

6.1 | Example No 1 Streamlining Sewage sludge processing facility at CWTPP for possible heat supply to external customers

Introduction

Sludge facility of Central Waste-water Treatment Plant at "Císařský ostrov" in Prague is at the same time a major producer and consumer of energy.

Controlled decomposition of the collected sludge in the wastewater treatment process in anaerobic conditions helps to exploit the energy potential of organic matter in the sludge biogas (a mixture of gases containing 60-65% methane and the remaining 30-35% carbon dioxide, and then a small amount of further water, hydrogen sulphide , nitrogen, oxygen and others trace elements).

More than 50% of the theoretically available energy of sludge dry matter (in terms of its calorific value) are doing to transform into biogas, which in recent years means in absolute terms from 18 to 19 million Nm^3 of biogas per year with a total energy content of **100 to 120 GWh / year**.

The vast majority (85-90%) of the total biogas production is then fired in cogeneration engine units for the production of electricity and heat. At present, in the Central Waste-water Treatment Plant there is 5 units with a total power output of 5.4 MW of biogas annually producing more than **35 GWh of electricity and theoretically the equivalent amount of heat (actually slightly less due to non-utilization of the total available heat output of machines).**

About 4% from produced electricity are spent by technological self cogeneration engine consumption and at least a further 10% cover the energy needs of sewage sludge processing facility. The rest of the produced electricity (28-30 GWh / year) is used to cover the energy needs of water lines, and to these extent, that the biogas cogenerations cover more than 75% of electricity consumption of water waste treatment today.

Sludge is required before the inlet into the digester preheat from average of 15 ° C to the desired 50-55° C. With the respect to, that the daily production of rough mixed sludge is around 2000 m^3/day, for heating is needed - by taking into account the efficiency of heat transfer in heat exchangers - 85-90 MWh of heat per day or more than 30 thousand MWh / year. The preheating the sludge consumes a significant portion of the total heat coming from engine and stack gases cooling. Heat passage in the fermentation tanks leads to further losses of heat. As a result of gradual renovation but it represents an average about 10-15% of total consumption of heat. In practice, the exhaust temperature of the drain away sludge after a delay of about 20 days from the second stage tanks is still above 50°C.

From this temperature the sludge is gradually cooled in the working tank below 20°C, in the mechanical presses dewatered and then shuttled to the final disposal off-site treatment plant.

The proposed measures

The outlet temperature of the digested sludge is so high that it seems to be economically viable and technically feasible to consider the preheating input implementation of (non-digested) sludge with the heat extracted from digested sludge through heat exchanger equipped by integrated working area with a suitable heat transfer medium such as water or antifreeze.

The introduction of recovery would have managed to reduce heat consumption for the whole sludge facility by up 55-60 MWh / day, which corresponds to an annual savings of more than 20,000 MWh / year. To illustrate, it is more than 50% of the heat needed to heat tanks now.

The heat produced by cogeneration engines would be possible to use at this level for other purposes. Very prospective customer can become the Prague district heating company due to the proximity of its central source of heat "heat plant Juliska", which is from the wastewater treatment plant by beeline less than a kilometre away. The volume of supplied heat to the central source can achieve annual total of 17-18 GWh of heat or 60 up to 65 thousand GJ / year (in the future maybe even more). Source operator would save operating costs associated with the purchase of natural gas for the preparation of this heat supply amount.

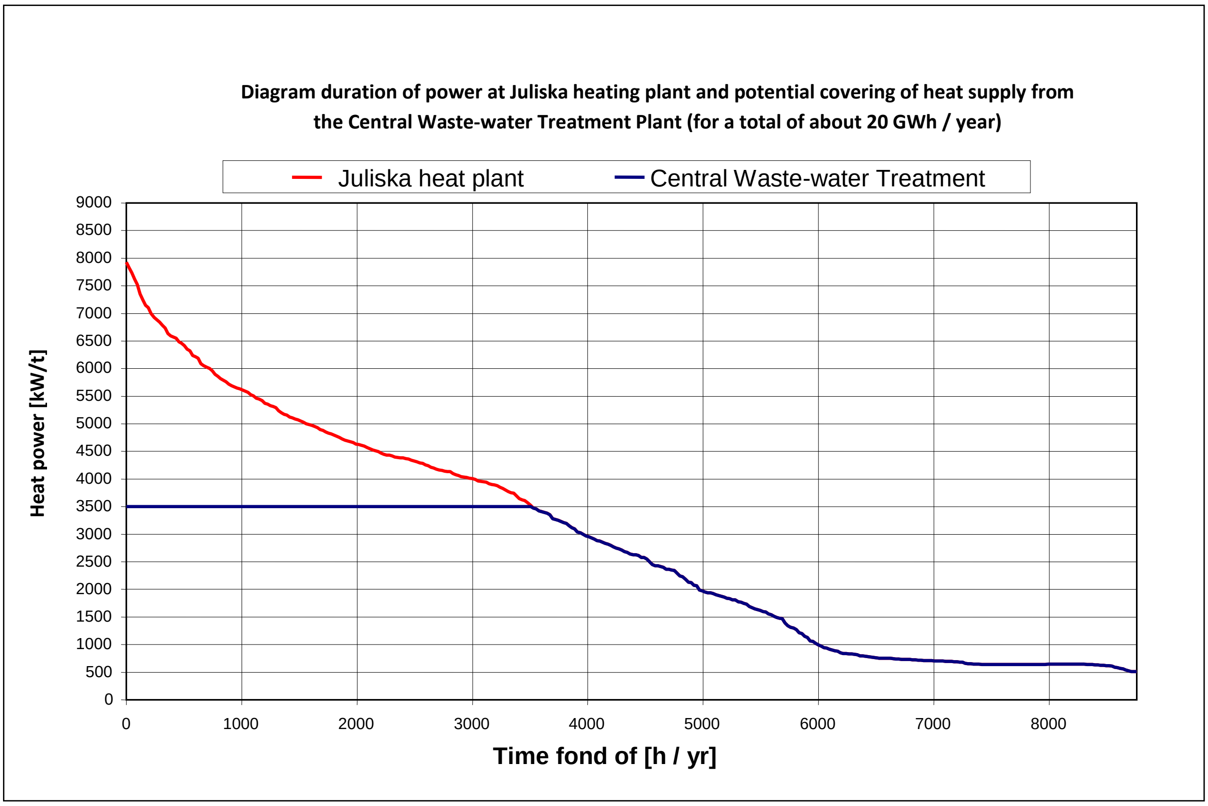
Other possible large customers, however, can be on the right bank side of the city (such as Prague Zoo or the Botanical Gardens). Both urban facilities for today's heat needs utilize so natural gas or even electricity, thus expensive energetic media.

The investment costs of the recovery introduction is to be estimate - according to the indicative bids - at 20-25 million CZK. To the exchanger(s) the investment costs would coincide 15-20 million CZK (higher if required preheating to temperatures close to 40° C and if more units were installed). The remaining costs would be associated with linking them to the route of sludge and with location either inside the existing buildings or in a newly built building in a convenient open location close to the reservoirs. Certain costs will then probably require modification of algorithms for filling and discharge including a re-set up of control system.

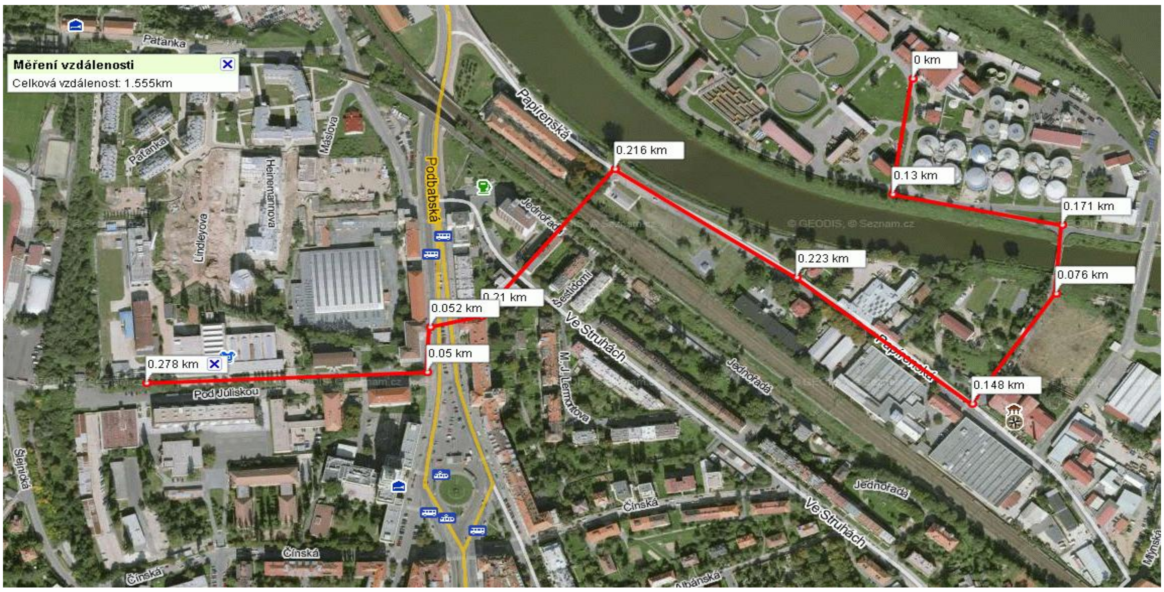
The construction of hot pipes connecting to the selected location would require approximately several tens of millions. In the event, that it would be Výtopna Juliska (Juliska heating plant source) with an estimated path length of about 2 km, the investment could be roughly estimated to about 60 million CZK; at the Prague Zoo and Botanical Gardens could be similar, if the heat was distributed to the all pavilions.

With selling price of heat, which would be advantageous to heat consumers so far (under today's variable costs), the measures for the above mentioned sale of heat seem to be repayable within 5 to 10 years, the operation life of the devices, however, will be longer than 15-20 years.

Graph 1: Diagram duration of power at Juliska heating plant source in hot water and potential covering of heat supply from the Central Waste-water Treatment Plant (with a maximum of 3.5 MW, i.e. for a total of about 20 GWh / year)



Picture 1: A possible route of hot pipes from building space of Central Waste-water Treatment to heating plant Juliska and its length (precision guidance would need to be verified)



Conclusions

By the installation of heat recovery only a part of the total heat potential of digested sludge can be utilised. Another option is to cool down the sludge by installing a heat pump, which at its output enables reheating of the sludge for a further 5 to 10 ° C (i.e. total of 40 to 50 ° C).

When identical amounts of the supply and return sludge in tanks it brings additional 10 to 25 MWh / day, which corresponds to annual sum of 4-8 thousand MWh. This would represent additional 10-25% of current consumption.

Ultimately, it would be sufficient to cover the needs of thermal sludge management sewage only in 20-30% of current performance, and perhaps even less.

The enormous energy potential is hidden in the temperature of the treated water discharged back into the river. With an average outflow recorded in the last year of about 3.65 m3 / sec a possible cooling of sewage water of at least 5 K, i.e. from an average of about 17 ° C to 12 ° C, it gives a 75 MW thermal potential. It could be utilized by heat pumps to increase the temperature of the medium coming from the heat exchanger, when cooling the output sludge, at 55 optionally up to 70°C. Waste or treated water is now used according to procedure described e. g. in Oslo, Helsinki, Bern (see Appendix 8).

If they could achieve high efficiency of heat pump operation (heating element to be at least 3.5-4, if equipped with a working circuit driven by an electric compressor, or 1.5-1.7 if based on absorption cooling machines), it could be economically advantageous to cover the residual heat needs of sludge management by a generated heat and to offer for other using all the heat produced today by the biogas cogeneration units.

It follows that the CWTPP could supply in the future its surroundings more than 30 GWh or otherwise over 100 (!) thousand GJ (at the temperature level to 85-90 ° C). If there was an interest on delivery, then even much larger amount of heat at a lower temperature level.

We therefore recommend performing a functional test of reliability of heat recovery from sludge and, if positive, precising the estimations of investment requirements and possible heat supply, and if positive, initiating the project preparation.

6.2 | Example No 2

Energy savings in the central heating and cooling system in Capital City's of Prague building complex in Mariánské Square

Introduction

The Capital City's of Prague building complex near Old Town Square and Mariánské square, which includes five separate buildings (New City Hall, Prague Municipal Library, east wing of which is City gallery in, New office building, so-called City Hall blocks and the Old Town Hall), share a common source of heat for heating and service hot water. This is the boiler room located in the basement (-1st floor) of the New Town Hall. In the past it covered also the needs of building, where the former company Terplan was settled, now disconnected and sold to a private investor currently considering a way of its use.

In 2012, it was provided a detailed assessment of the boiler room operation and subsequent heat distribution system, with a focus on those areas appeared to be cost-effective for energy savings.

Proposed measures

The task was divided into six sub-tasks (fulfilments), each successively analyzed of the current situation, then identified the appropriate measures to increase energy efficiency and subsequently quantified the potential economic benefits and the estimated costs of implementation including the final recommendations.

It is concluded that it would be possible to reduce the current annual consumption of natural gas (at 5.5 to 6.5 GWh / year in gross calorific value) of more than 20%, which corresponds to financial savings at the amount of 1 to 1.5 million CZK / year. Following modifications of energy system are the necessary assumptions for it:

- Close down the central source of sanitary hot water (SHW) and the delivery decentralized as close as possible to consumption points (using the electric flow or compact storage water heaters). Consumption of SHW is small and especially in summer may decrease the effectiveness of preparation of it to less than 20%. It is caused partly by keeping the entire primary circuit running and partially SHW circulation through piping in buildings. Net economic benefit can reach the amount of 300 000 CZK / year. Developed implementing modernization project of entire system envisages the decentralization; it will be possible for a longer period in the summer shut down the boiler room. This results in significant savings, while substantially increasing the efficiency of water heating.
- The optimization measures in the heat distribution system (change of transfer stations linkage to prevent heating water return overflow into the back pipes of the primary circuit, exchange of circulation pumps by new ones with a smooth circular regulation, exchange components of measurement and control, and tie-in control system plus optimization of

power and control algorithms, the separation of boilers from the system by a hydraulic balancer and hydraulic balancing of system). Those measures contribute to temperature lowering of the heat and return water, elimination of excess heat supply, reducing of pumping work (electricity) and thereby streamlining of the entire system operation. Total savings are estimated at a few percent of current consumption of natural gas and several tens of MWh of electricity equalling to the total financial savings of several hundred (estimate 300-500) thousand CZK a year.

- Installation of a new condensing gas heat source with a rated heat output of 1.2 MW, which will be able to cover more than 85% of heat supply in the year with year-round high average efficiency, lessening the annual gas consumption (at constant heat consumption) by 8-10% or of 500 to 700 thousand CZK / year.

Aggregate investment costs of these measures were estimated at 5-7 million CZK, while the simple payback period to 5 years. If their implementation was conceived by EPC, the expected savings were by selected implementer guaranteed.

Conclusions

In considering the potential savings other possible measures were analyzed. **To centralize the cold source for all these objects as is the case today with the heat has been identified as promising**.

Due to the fact that all objects are now connected by an underground collector, it appears as simply technically solvable, that in appropriate technical room in the New Town Hall (easiest in the boiler room on the site of one of the boilers) there was installed cold source of type chiller, i.e. water cooler able to reverse operation as a heat pump. Then it could prospectively meet the cooling needs of the New Town Hall, the City Library and possibly even other objects.

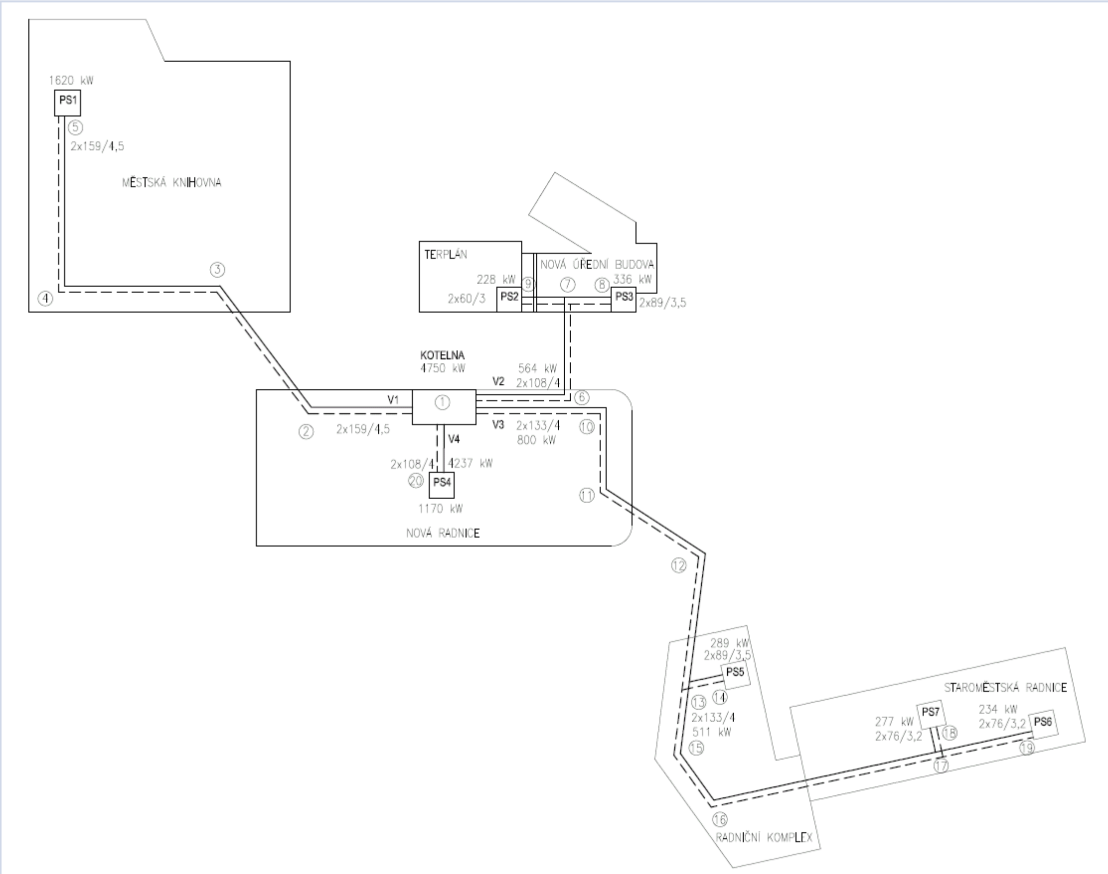
Centralization could improve the operation economy by including the construction of a hot-water loop and heat exchanger, which was put into the ventilation tunnel of the Old Town underground station. Heat generated by the chiller was thwarted in the air discharged from the Metro during cooling needs. On the contrary, at the beginning or end of the heating season, when the operation of the subway station main ventilation fans, the heat from the ventilation air would be from the underground by chiller (as the heat pump) collected and used in the New Town Hall heating system .

Although the intention from the perspective of operational savings versus costs of implementation was not worthwhile in the term of equipment functional life, it can bring many other benefits that are now difficult to quantify financially (e.g. the possibility of removing refrigeration equipment from the roof of New Hall, a disposal of the engine room of cooling in the Municipal Library and its use for other purposes such as housing, simplifying of maintenance and supervision, and resource cooling capacity for other possible deliveries). Just this list suggests that the proposal may eliminate future investment and bring positive economic effects, which largely evaluate the initial investment.

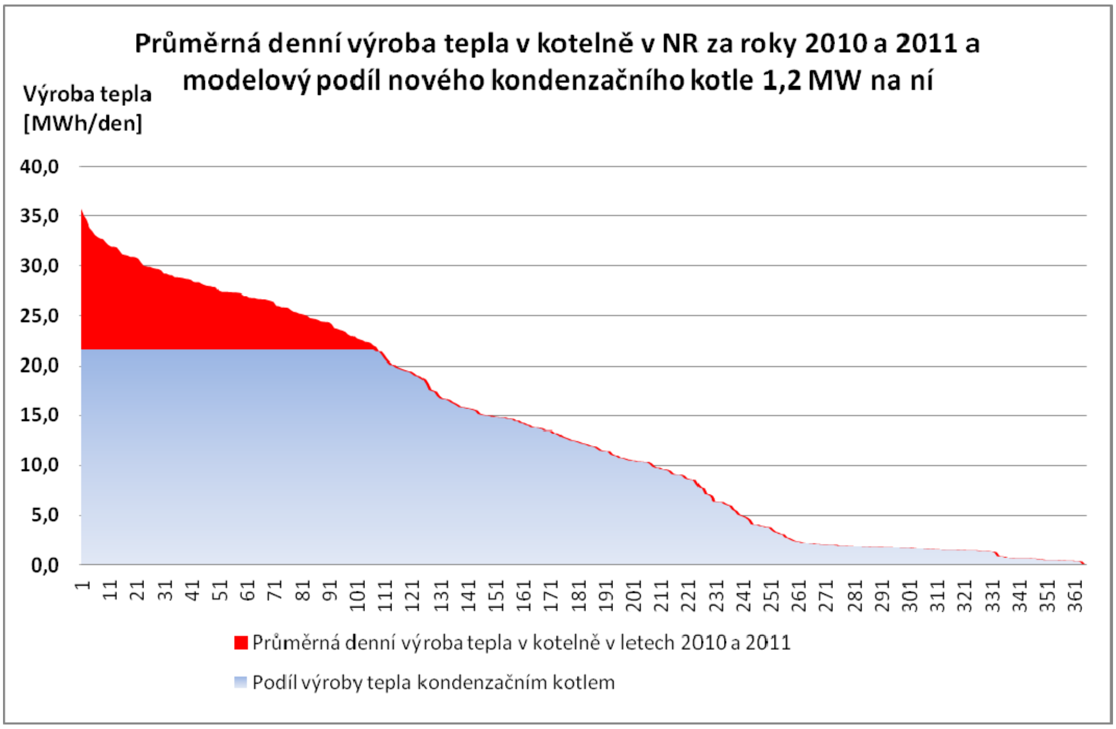
In light of these facts, it makes sense to seriously consider the possibility of such applications using the de facto alternative source of energy (heat respectively cold of an exhaust air from the subway) in more detail.

Possible measures for the improvement of thermal-technical properties of enclosing structures of buildings or other saving measures were not the objects of assessment (e.g. refurbishment of ventilation control systems); they could bring further indispensable energy savings.

Picture 2: Diagram of buildings connected to the central boiler room at the New City Hall



Graph 2: The average daily production of heat in the boiler room at the New Town Hall in 2010 and 2011 and a model share of a new condensing boiler of 1.2 MW on it



6.3 | Example No 3
Reconstruction of the Capital City's of Prague object "Emauzy" in Vyšehradská Street into a model building (with near-zero energy consumption - an intelligent building)

Introduction

The building property owned by the Capital City of Prague standing next to monastery Na Slovanech (Vysehradska 2077/57, Praha 2, and also nick-named "Emauzy") is the administrative structure built in the turn of sixties and seventies of the 19th century under the spirit of the technological modernity. Former it was used by the Design Institute of the City of Prague, today it houses the Institute for Planning and Development of City of Prague.

Object de facto consists of three buildings (referred to as A, B and C) perched on a common "neck" of the ground floor, which serves as the entrance to each of the objects having other than office spaces (e.g. exhibition halls).

The facades of houses are of lightweight cladding Boletice panel system. Heating or cooling go from a central source located on the -1st floor of Building C. Heating or cooling water is through the piping system distributed from the boiler room, respective from cooling generator, to heating or cooling consumers, which are fan-coil-under-sill-window units. In the same time they supply of fresh air directly from facade while heating or cooling the air to a desired temperature with the help of the heat-exchanger through which the intake outdoor air is after treatment subsequent distributed. Fan-coil units are always common for the three offices on the same floor.

Technical condition of buildings is very poor. Claddings still have serious structural defects, poor thermal-technical properties of the used materials and obsolete level of technical building equipment (especially system controlled ventilation, heating and cooling) lead to high energy consumption.

In the summer, the power of existing source of cold is not sufficient and therefore the split units are gradually installed at the offices. In the winter, the situation is reversed - people complain about the inability to achieve reasonable thermal comfort. In addition, temperature control sensor is now common for three offices, what is a reason for further discontent.

The building is an architectural point of view, however, recognized as a valuable building and is situated in a location with good access. It seems therefore desirable to hold its necessary reconstruction in the near future as exemplary. Not just in terms of low energy requirements, but also other monitored aspects, so that it can be considered an "intelligent building" (e.g., in terms of the way of workspace design, used construction materials, alternative energy sources, advanced building management system etc.).

The proposed measures

The essence of this revitalization concept is to propose a solution that, on the one hand, preserve the architectural value of the building, but at the same time allows to integrate various measures anticipating more so-called "criteria of sustainability".

The basic assumption to achieve this goal is mainly to conceive the modernization of envelope of the building, and facility technology in such a way that after completion the building will meet the prescribed limits of specific energy consumption to be classified as a building of the energy class "A" (or otherwise make it to the building "with almost zero energy consumption"[1]).

In practice, this will require the building envelope reached lower above standard heat transfer average coefficient (typically around 0.7 times the present reference value for refurbished buildings). In addition the building should be equipped with central forced ventilation system with high performance heat recovery and also some form of renewable energy would be used in such an extent to achieve low values of the amount of non-renewable primary energy consumed by the building. Using a heat pump capable recovered the heat or cold from the large underground spaces that are under the facility seems perspective too; photovoltaic on the roof of the building respectively integrated into the opaque parts of the vertical structures would be so advantageous.

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[1]) Building with almost zero energy consumption is defined by Czech legislation (Act 406/2000Sb., On energy management and Decree 78/2013 Coll., Energy performance of buildings) as building with very low energy consumption, that is significantly covered by renewable sources.

If the object simultaneously performed other exemplary function (sustainability criteria), it is desirable also to remember the kind of materials used (with regard to the energy contents). Further to integrate the green into the building, to ensure re-use of gray water and rainwater, to create an exemplary concept of workspace and to support the friendly transport modes (such as allocating space for bicycle storage room for cyclists, install charging stations for electric vehicles, etc.) for staff.

All these broader aspects of "sustainability of buildings" are more detail evaluated by building certification systems (e.g. SB Tool CZ, LEED, BREEAM ad.). It is advantageous to use them as an optimization tool by the building's design.

Conclusions

According to the expert estimates, it should be possible to achieve the specific heat consumption for heating to 25 kWh / m^2 / yr, the total energy supplied incl. electricity consumption for lighting and other appliances around 100 kWh / m^2 / yr and non-renewable primary energy approximately 200 kWh / m^2 / yr.

The current situation is compared to around 400 kWh of delivered energy per m2 of floor area per year (according to the current PENB object has a floor area of about 7,500 square meters), of which about 260 kWh in the form of natural gas and 130 kWh of electricity. This corresponds to the primary energy consumption of over 700 kWh/m^2.yr or in financial terms, the annual energy costs more than 700 CZK/m2.yr.

At the same time also there can be significantly reduced the amount of water consumed (in real terms as much as 50% of the current value) and be created working conditions for employees that match the buildings of the 21st century.

The building should achieve by these parameters when processing Certificate Energy Performance of Building pursuant to Decree 78/2013 Coll., On the energy performance of buildings, energy class A. It should also aspire to obtain the highest possible rating by one of the certification systems (see, eg, SB Tool CZ).

Investment costs can be according to date processed analysis and preparatory modernization projects estimated at several hundred million CZK (the actual amount will depend mainly on the materials and technical equipment and other enforcement actions that will require upgrading facades with improved thermo-technical parameters in terms of strengthening statics of object). The annual operating cost savings for energy could conversely be 3 to 3.5 million CZK.

6.4 | Example No 4

Pilot project proposed for introducing electromobility in bus transportation in Prague (in the area operated by the Prague Public Transport Company)

Introduction

City bus public transportation is generally regarded as one of the most promising areas, there might be promoting emission-free electro-driven vehicles in the near future.

In the world, a series of pilot and demonstration projects test the various versions, both in terms of the vehicles (e.g. hybrid electro-driven with at the same time assisting / rechargeable diesel-driven buses, electro-driven buses with the power of batteries only, or from the so-called super capacitors or fuel cells) and of charging infrastructure (the so-called slow and fast contact charging with the help of universal or special-purpose interface, pantograph or even contactless magnetic induction).

So Prague Public Transport Company (hereinafter PPTC) monitors that development and according to the possibilities tests of the specific vehicle types and of different charging ways at real Prague's traffic.

The existing results of these tests but still remain below expectations and more help for formulating, what the electricity-powered buses and a charging infrastructure in Prague will look like and what functions they have to fulfil. It can be summarized in a few basic propositions.

PPTC as a public carrier - governed by the principles of reliability and economic availability of offered services - logically can accept only a design that can withstand real-world conditions. In Prague's public transport it means to be capable to keep the timetable reliably even by the recharging needs on the various rugged routes.

Another premise is that the chosen electromobility solution could be expandable to a sufficient number of vehicles, ensuring cheaper and easier maintenance.

The third necessary assumption is, of course, the fact that the costs of acquisition and subsequent operations should be the same sum or (preferably) less compared to today's diesel-driven buses.

The last condition implicate to introduce the electric vehicles on such routes, where the environmental benefits of zero-emission drive can be economically the highest (i.e. in very rugged terrain, where diesel-driven buses consume significantly more fuel).

Possible intersection of these factors could be, based on the experience gained by PPTC and on the current state of technology and prices, the following concept.

Pilot project proposal

Prague's public transport buses range on common lines more than 200 km daily. Still, the electro-driven bus manufacturers are not able to offer a model that would be able to meet this range by the one-time charging battery. It is primary due to the small capacity of currently available battery types (compared their weight to the diesel weight in the tank, which would guarantee the same range). Their price is high; when trying to reach the range over 150 km, it increases the cost of the electro-driven bus up to twice of the price of a standard bus with a conventional (internal combustion) engine. In practice, insufficient range requires to ensure short recharge of the electric bus somewhere on the route, what further increases the overall costs. Bulky extra batteries reduce the payload capacity of the vehicle and number of transported passengers. The combination of these negatives makes essentially impossible to achieve the transport costs comparable to now regular diesel-driven buses.

Most lines in Prague, however, are one-way distance of 10-15 km; at the final stop of the route the buses always remain at least several minutes (in some cases, several dozen minutes).

For perspective thus it seems rather use of vehicles, which do not have batteries of such a strong capacity (we estimate for the car at 12 m length 50 kWh as sufficient), but they are capable of very rapid recharging. The vehicle should also be equipped with a system for continuous rapid charging at the final stations and also in the depots. Charging method should rather be based on open standards then on proprietary design covered of patent protection of one manufacturer. These conditions could meet the design preferably in the form of a pantograph installed on the roof of the vehicle, what would be upright only when charging. This would result in a lower price of the vehicle, ideally approaching the price of a common diesel-driven bus.

Similarly, the charging stations would be designed effectively. It appears to be economically disadvantageous to invest in the stations connected to the public electricity distribution network as a single supply points. With the building of stations considerable investments would connect; operation would further burden of the high permanent cost, what could increase the end-price of electricity to several times compared to current price for tramways.

Using of the existing substation infrastructure for tramways would be definitely better, if legally permissible. Design may be different; apparently the most cheaply by leading out of power and neutral lines on the brackets near trolley wires. Substations are designed for performance-limiting current of up to several thousand amperes, which is sufficient for fast battery charging. And what is also important, the price of electricity would be the same as for tramways (i.e., at about 2 CZK / kWh excluding depreciation of investment costs in setting up of charging stations).

Another reason, why the charging infrastructure of electro-driven buses to design primarily in tram network substations, is the ability to acquire buses for charging by power generated and given back by the braking trams to the power lines. It is often used by just moving vehicles, but it is thwarted often. Temporary storage of this energy can be provided by stationary reservoirs formed by well-connected super capacitors that are connected to the trolley or cable lines 600 V at a suitable place.

As far as in the new programming period 2014-2020Operational Programme "Prague - Pole of growth of Czech Republic" anticipates supporting of saving measures in the town public transport, between which explicitly states the use of electric energy from the rail vehicles for other purposes, it is recommended - in the case of approval of this proposal by the European Commission- to originate of a comprehensive project involving the installation of stationary electricity storage device at the appropriate location (e.g. one or more selected substations) to use the recovered energy just to recharge the battery of the electro-driven buses.

Thus conceived design has a real chance to become truly economically advantageous. But it requires synergy between PPTC, city representatives and suppliers who are able and willing to participate in the development of electromobility concept for public bus transport in Prague.

Potentially suitable for testing it appears using of the charging points in the terminal at the metro station Želivského, where buses depart towards Jižní Město, Podolí and Újezd nad lesy from. On the route to South City there is the Vršovice bus garage yet, what can provide facilities for testing, as well as charging (in the grounds there is a tram substation). The hilly terrain could be suitable for testing of practical solutions and for replacement of diesel buses, which are reported in uphill above-average fuel consumption and so negligible emissions.

For starters, on this route one car can be tested, and if successful, it is possible to gradually increase their number. Other suitable routes can be identified in the direction of Vysočany - Prosek and Dejvice - Suchdol. In the final stage several hundred vehicles **operated by several dozen charging stations** could be gradually "electrified"**.**

Possible ecological benefits

According to preliminary estimates, so conceived electro-driven bus could have less than half of the average power consumption (meaning at the level of "tank-to-wheel") than they show now the diesel-driven buses (1-1.5 kWh of electricity per car length of 12 m for driving at a distance of 1 km). At the current prices of electricity and oil, it would be possible for the electro-driven bus in comparison with the diesel-driven one to achieve savings of about 5 CZK / 1 km drive. By the current annual range 50-60 thousand kilometres it matches to the savings of "fuel" costs of about 250-300 thousand CZK / year / vehicle.

The initial additional costs of purchasing a new vehicle with the parameters above compared to the diesel version may be several hundred thousand up to 1 million CZK. Construction of at least two charging stations at the depot Vršovice and in above mentioned the recharge point near the metro station Želivského may require in its simplest form (the construction of several columns with brackets and power conducts) a few hundred thousand CZK. Installation of a stationary tank of electricity using recovered power from the tramways could represent then costs of several million CZK. The costs connected with recharging infrastructure would be gradually repaid from lower operating costs expected for electro-driven buses. Their payback could accelerate by the gradual expansion of the electro-driven bus fleet of PPTC (if the operation proved it).

Conclusions

With the regard to these facts, we recommend this pilot project in the frame of the Energy plan of Prague for implementation and outline possible next steps:

1. Formation of the research team for the development of vehicle and so charging system technical design.
2. Budgeting of pilot project and quantification of potential operation savings
3. According to the results a work out the submission for supporting the whole project or a part of it from the available grant programs (e.g., the aforementioned Operation program "Prague - Pole of growth of Czech Republic").

6.5 | Example No 5

Identifying possible specific measures for utilizing more economical and ecological forms of cargo transportation

Introduction

There is a system of conditional entry of heavy trucks and buses to the city center and in selected districts in the surrounding area in the city of Prague. It is obligatory to submit for the entrance permission at the City Hall Traffic Agenda Department. To obtain the permission is not a legal right (i.e. the submit can be rejected) and applications are assessed individually; the issued approvals have limited validity duration (either short for single entry with a maximum of eight days or long term up to one year).

Currently two zones of limited entry are defined. The first zone controls the entrance to the historic centre of nearly the entire territory of Prague 1 and a part of the territory of Prague 2 (between the streets Resslova, Žitná, Sokolská, Wilsonova), for trucks over 3.5 tonnes and buses. For a positive result, the vehicle must comply with the emission standard EURO IV (beginning January 1, 2013). Entry is limited in time from Monday through Friday from 8 to 18 hours.

The second zone covers a broader area of Prague 4, 6 and 7 (see map below) and allows the entry of vehicles above 6 tons provided of prior consent to entry.

In the context of this regulatory action it is perspective to complement it by an environmentally friendly way to transport cargo in a such defined area of the city.

Identification of specific measures

As electro-driven rail vehicles are several times more efficient than combustion-driven vehicles, it is useful to consider greater use of rail transport network in Prague for freight transport in the center.

Specific plan fulfilling this strategy is intention to build a railway siding to ZEVO Malešice. In future the significant part of the waste collected at ZEVO from distant parts of Prague or surroundings (estimated at more than 100,000 tons / year) could haul by rail rather than road traffic. It could be carried the slag back from the plant (representing about 25% of the original weight of waste, i.e. currently about 75,000 tons / year), ash (6-7 thousand tons / year) and ferrous metals from the graded slag (units of tons per year). In contrast, the equipment would be supplied by this way the necessary operating materials (Sorbalit, urea, ammonia water and so). For increasing capacity ZEVO Malešice, either by reconstruction of existing lines or adding extra fifth line, this type of transport would be more desirable.

Theoretically was considered possibility to transport of municipal waste collected on the left bank side of the city, starting at Suchdol and ending at Chuchle by rail in the future .

This region annually produces about 100,000 tons of mixed municipal waste. This is transported to ZEVO by the mass trucks trailers (capable of transporting two ISO containers with a volume of 30 m3 each, i.e. 20 tons), after re-loading from "kuka cars" (collection trucks) at the current transhipment center Jinonice equipped for this purpose by semi-mobile press. The traffic routes of these trucks could be eliminated in the future. The length of existing transport link between transhipment Jinonice and ZEVO Malešice is about 20 kilometers on the South Junction, two-way distance is about 40 kilometers. Per year it could be restricted around 5,000 transport routes, 200,000 vehicle-kilometers respectively 4 million tonne-kilometres. With an average consumption of about 40 liters of diesel per 100 km, when driving the truck on the current route, the savings can be estimated to 80,000 litres of diesel per year.

For reloading to rail it would be needed to build the appropriate transshipment on a suitable railway station. It seems appropriate to set up it in Řepy, near the railway station Praha - Zličín. If the Railway Infrastructure Administration (SŽDC) agreed, the used press from Jinonice could be moved into this place. It would need also to modify the construction of the platform so that the waste containers would be placed on the wagons. A possible deployment of cars series Slps of the loading weight of about 50 tons (actually limited by the specific gravity of the cargo) was pre-negotiated with the company Czech Railways Cargo (ČD Cargo). They are equipped with three rotating carriers of swap bodies ACTS; one car could transport of three containers, each with a tonnage of compressed municipal waste of around 10 tons, i.e. total of 30 tons / truck.

With the average daily waste production of about 270 tons (100000/365) it would be sufficient to dispatch one train per day with a total of 9 cars. The total length of the set, with regard to the length of one car (about 20.5 meters), would be - including the locomotive - about 200 meters. All three siding rails with ZEVO have over 300 meters, from that the straight ones have just over 200 meters (siding rail 3). The estimated number of such large sets would correspond to the number of the days of the year (365); it is also feasible from hygienic reasons.

Location of transshipment to the railway station Praha - Zlicín is interesting so from the perspective of future tram transport possibility. But it would be needed to verify in cooperation with the PPTC the possibility of using trams; to identify a suitable route and ferry times and then the method of loading and unloading containers near ZEVO. For the usual size of the tram sets consisting of two vehicles, however, the transport capacity per set were significantly smaller. Obviously it would be necessary for the distance remaining between the final tram stop and ZEVO to use cars again, if there was not another solution.

The investment costs for the construction of siding to ZEVO are tentatively estimated at 500 million CZK. As for the future adaptation of the left bank transshipment, investment demand is not known. It could / should, however, be significantly smaller (perhaps up to tens of millions CZK). Additional costs can be expected by the operation, because the prices of rail transport are approximately twice higher than those now used in transportation.

The transport of sewage sludge from the CWTPP is the second purpose fulfilling this strategy. Sewage sludge processing facility of the plant produces over 60,000 tons of decayed dewatered sludge per year. That is transported by the cargo containers outside of Prague territory. Nowadays there is needed for the transport about 9 fully loaded trucks (with load capacity of 20 tons) per day or more than 7,000 one-way transported routes per year at the waste dump in Benátky nad Jizerou. Every truck runs 30 to 40 km in both directions across the territory of Prague; per year that is 200 to 300 thousand vehicle-km or 10-15 thousand tonne-km. This type of waste could be transferred to the rail in future by changing its disposal concept.

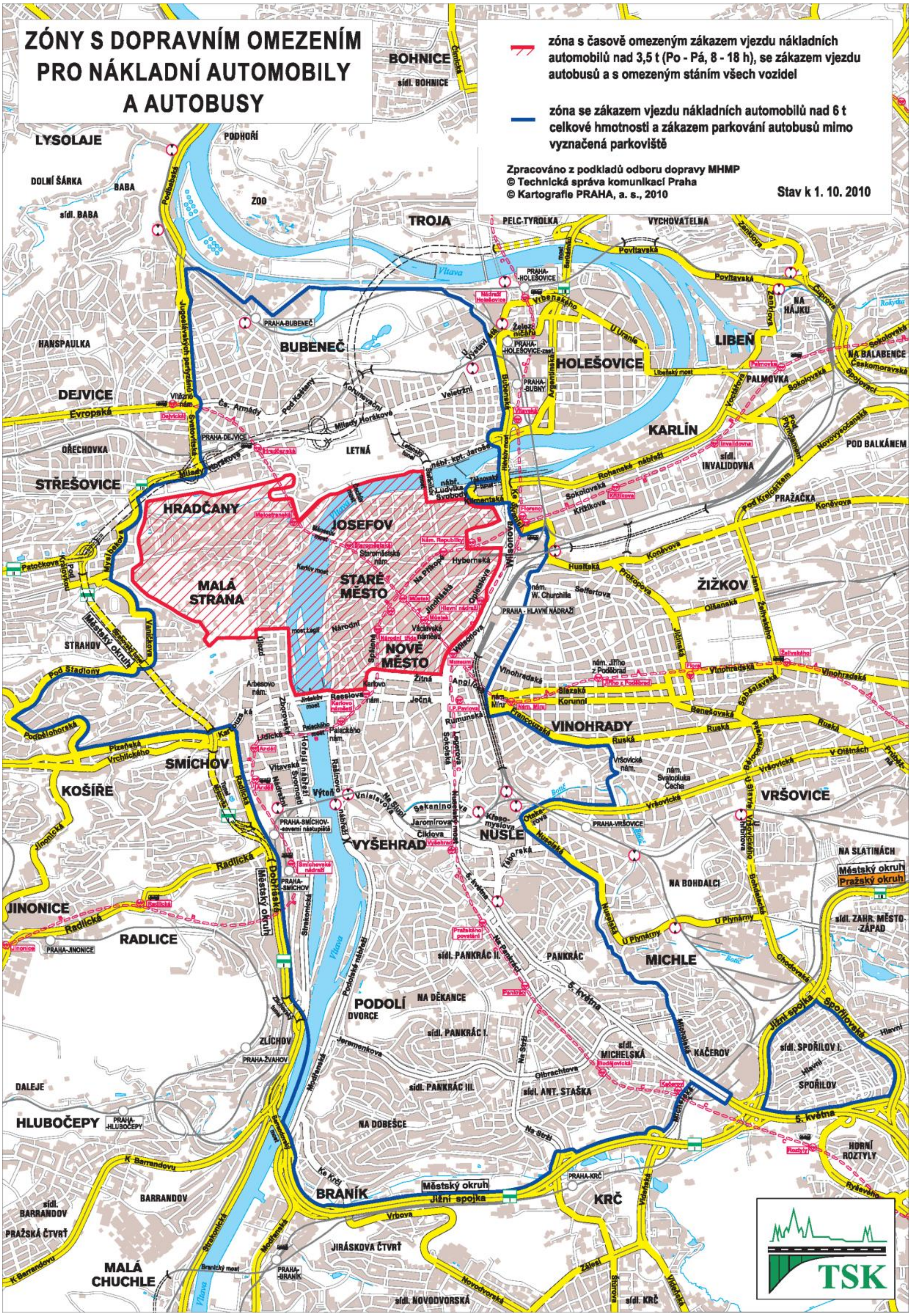
Deployment of the rail transport could be feasible for the transportation of construction materials to and construction debris removals from larger building sites in the city. It concerns to planned new extensive construction sites Bubny or Smíchov with direct access to the railroad, or possible construction of metro line D in future. In this context, the construction of tunnel Blanka missed the opportunity to use rail transport.

Some cities abroad integrate to the strategy of friendly freight transport also urban tram network. The City Transport companies own special tram cars capable of transport of selected item categories. For example, it is used for the bulky waste collection or for transport of large quantities of goods from one place to another (e.g., from a logistics center at the outskirts of the city to the factory in the center). Transportation is provided by tram cars with special superstructures and shipment is realized in such a time not conflicted with the rush hours (in weekends, at night, etc.). Also conditions in Prague suit to this type of friendly transport. At least the two locations in Prague was identified by the PPTC leadership as an areas for suitable docks - at the railway station Prague Malešice on the Černokostelecká street and then at the final tram stop Sídliště Řepy near the railway station Prague-Zličín.

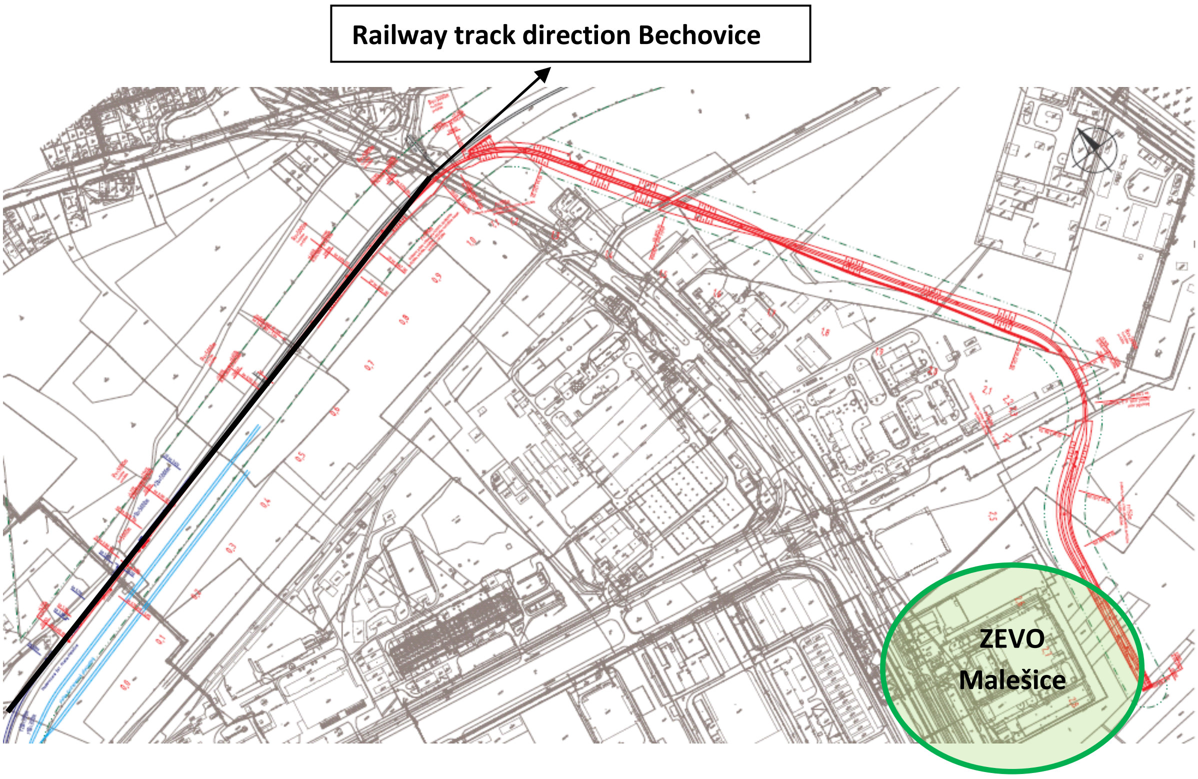
Logistical or better Urban consolidation centers (UCC) are tools, how to limit the number of transport routes trucks in densely populated areas further. With their help, the shipments are collected for different types of customers in one location and then processed together with the help of the fleet of environmentally friendly vehicles (eg vehicles to CNG, electric, etc.). Their formation and operation must generally be subsidized from public sources. However, if the entrance to the regulatory restrictions on just only environmentally friendly modes of transport, they can be economically self-sufficient.

However, this issue already exceeds task defined by the EPP. Consultants recommend consequently to these topics to begin detailed discussion of the applicability of mentioned or other measures to promote environmentally friendly means of transport in Prague. From the perspective of the city, transportation by railway or tram cars or low-emission trucks can be desirable alternative at least for those kinds of loads, the amount of which varies annually in the tens thousands of tons, the needs of their transport are planned and repetitive, and the place of dispatch and of destination are stable.

Picture 3: The map section defining a restricted entrance zone for trucks and buses in Prague



Picture 4: A segment of the cadastral map Malešice / Štěrboholy showing the railway line Prague - Bechovice (black) and the plotting of the proposed railway siding to ZEVO Malešice (red)



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List of abbreviations

EPP	Energy Plan of the capital city of Prague
REZZO	Register of emissions and sources of air pollutants
CNG	Compressed Natural Gas
CWTPP	Central Waste Water-Treatment Plant in Prague