Brno’s review of practices: Smart waste management

An introductory review of SMART measures and best practices in waste collection and utilization of municipal solid waste

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Abbreviations

BUT	Brno University of Technology
CEP	Circular Economy Package
CSO	Czech Statistical Office
EIA	Environmental Impact Assessment
ICT	Information and Communication Technologies
ISOH	Waste Management Information System of the Czech Republic
MBT	Mechanical Biological Treatment (plant)
MW	Municipal Waste
MMW	Mixed Municipal Waste
PAYT	Pay As You Throw (waste collection system)
SL	Sorting line
UPI	Institute of Process Engineering (*www.upi.fme.vutbr.cz*)
WM	Waste Management
WMP	Waste Management Plan
WtE	Waste-to-Energy (plant)

1 Executive summary

The main aim of the study is to find and describe the best SMART technologies for the city of Brno, with a focus on the Spitalka district.

RUGGEDISED is a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three lighthouse cities: **Rotterdam**, **Glasgow** and **Umeå** and three follower cities: **Brno**, **Gdansk** and **Parma** to test, implement and accelerate the smart city model across Europe.

The research team (**BUT UPI**) has prepared an introductory review study that describes the key areas related to SMART measures and technologies in waste management. The study starts with a brief project introduction and review of legislation in the field.

Section 4 is devoted to trends in waste management in Europe. **ZERO waste concept**, **Pay-as-you-throw** (PAYT) system and SMART **waste collection** systems are highlighted.

- The main purpose of the PAYT system is to **minimize the residual mixed municipal waste** (MMW) tax for responsible residents and to **maximize the separation rate** of recyclable components from municipal waste. There are several approaches to PAYT. The PAYT system is relatively easy to install in family houses districts combined with a door-to-door collection system. The implementation of PAYT system is more challenging in dense urban areas.
- The waste collection system is anonymous (more households per container) and reusable waste separation may not be so efficient. Therefore, it is necessary to introduce advanced containers identification system to make **PAYT functional**. These containers are **monitored** during collection (**weighted and identified**) and the information is stored in a cloud storage for further processing, which is another important step.
- Design and subsequent implementation of **SMART waste collection** system represent a compromise, where three main "pillars" of sustainability should be taken into account:
    - **Economical feasibility**.
    - **Environmental benefits** - represented by national legislation and EU WM goals.
    - **Social regards** - friendly and comfortable system for the citizens.
- Several collection systems are described. It is stated that waste collection is a very expensive process, it is a key issue of the whole chain of waste management. **Dry recyclables** system was mentioned as an alternative to existing collection scheme with several fractions.
- Special attention was devoted to "SMART" waste collections technologies, which are expanding in the international market. Namely, they were:
    - **Underground clever containers**. Very interesting in section 4.4 is the **case study from the city of Stavanger**, based on the earlier cooperation of BUT with this Norwegian city.
    - **Underground vacuum collection systems**. This modern and sophisticated waste collection system is being implemented in newly built districts in Europe and Asia. It allows the waste to be collected less frequently, it is possible to transport fractions more efficiently when waste is compacted, there is no need to secure the appropriate routes for large garbage trucks. The

obvious disadvantage is high investment costs for the system implementation into the current districts

- Underground clever containers also open possibility for **dynamic collection** (collection on request) – it is a collection of filled containers which reports a certain degree of their filling.
- **Technical sorting** is also proposed as an alternative to the current collection scheme. It recovers recyclables directly from residual waste. **Mechanical-biological treatment plant** (MBT) is necessary. The main advantage of MBT is the treatment cost. The main disadvantage is the low quality of output materials (e.g. secondary raw materials, various types of fuel or compost) which affects the market interest in these products.

- Regarding residual waste utilisation, environmental benefits (expressed by avoided CO_2 emissions) of thermal treatment of waste in incinerators are calculated for Czech energy mix. Such an analysis is especially important in the situation, where **waste-to-energy** is sometimes seen as a redundant technology in the light of the circular economy. For CZECH Conditions and current Energy mix for **heat** and **power production**, WtE plants with high heat delivery to district **heating systems** (which is a case of **SAKO Brno** WtE plant) significantly contribute to avoiding CO_2. **Waste-to-biofuel technology**, which is shortly mentioned in section 7, represents an interesting alternative producing high-value products, especially for cases, where positive effect of cogeneration in WtE cannot be utilised due to missing demand on the heat.
- Finding a compromise among economic, environmental and social criteria is a complex task. It is proposed to take advantage of sophisticated complex computational tools and evaluate thoroughly the cost-benefit analysis of conceptual changes and individual measures implementation. Examples of such tools developed at **BUT UPI** are introduced in Appendix 1 and Appendix 2.

The key section is section 5, where a **questionnaire** has been created and circulated among project partners. The questionnaire covered five areas of questions, namely:

- Basic information about **waste management** in your city (12 questions).
- Basic information about the **collection of municipal waste** in your city (9 questions).
- Basic information about **facilities** in your city (region) (11 questions).
- Basic information about **collection vehicles** in your city (7 questions).
- Basic information about the **collection system** and its **organization** (12 questions).

The survey was organized as a two-step procedure. In the **first round**, simple **YES/NO** questionnaire. The questionnaires have been received from cities **Gdansk, Glasgow, Parma** and **Rotterdam**. Answers are attached to this document as Appendix 3. The feedback was not received from the city of Umeå. After that, more detailed questions have been raised aiming at the interesting answer from all five parts in the second round – Appendix 4. Here cities representatives were emailed individually. The goal was to explain waste management in the city in more details. Unfortunately, feedback was only received from **Parma** but not in a complete way.

Answers were processes to get condensed information about current and planning SMART measures in the lighthouse cities.

Furthermore, the research team deals with current trends in the context of waste management in section 7. The key technologies or systems are:

- **Waste-to-Biofuel**.
- **Biotechnology** for converting waste oil into plastics.
- **Dry recyclables**.
- Collection with the **automatic side loader**.
- **Industry 4.0** and **SMART City** concepts.

Description of best cases for the Brno city can be seen in section 8. There have been created waste production forecasts with ***JUSTINE tool*** for five types of waste (Mixed Municipal waste, Paper, Plastics, Glass, Biodegradable waste). With reference to section 4 selected concepts are briefly evaluated by SWOT analysis in Brno WM context.

The main **recommendation of the additional steps** can be found in section 10:

- **Specify the area of Spitalka** in terms of expected population, housing structure and overall organization of the district. This will be the result of an urban study. This step also provides better insight into the expected waste production in the district.
- Narrow the list of **solutions and technologies**, which could be applicable in the Spitalka District. Interconnection with the existing system and future spreading into other districts should be addressed).
- Take advantage of up-to-date simulation tools to evaluate the positive and negative effects of implementing of each of the concepts. Here three pillars of sustainability are highlighted: **environment – economics – social acceptance**. It is also mentioned that **SMART concepts**, which are very often appealing to stakeholders, could significantly contribute to the future cost of the service. The simulation contributes to defining a concept as a trade-off of afore-mentioned pillars.

2 Introduction

RUGGEDISED is a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three **lighthouse cities**: **Rotterdam**, **Glasgow** and **Umeå** and three **follower cities**: **Brno**, **Gdansk** and **Parma** to test, implement and accelerate the smart city model across Europe.

The RUGGEDISED project is a part of the Horizon 2020 program, which was adopted by the European Union. For five years, cities Rotterdam, Glasgow, Umeå, Gdaňsk, Parma and Brno will work together and **share their experience in smart solutions implementing** in the areas of mobility, energy, Information and Communication Technologies (ICT), and social, economic and environmental issues. The goal is to improve the quality of life in a city.

Working in partnership with businesses and research centres these six cities will demonstrate how to combine **ICT, e-mobility** and **energy solutions** to design smart, resilient cities for all. This means improving the quality of life of citizens, reducing the environmental impact of activities and creating a stimulating environment for sustainable economic development.

This study aims at Brno city waste management. The Brno City Council has approved the selection of a part of **Teplárny Brno area** and **Spitalka area** as a site for investment plan development. In the future, there should be a modern, low-energy **district corresponding to the Smart city parameters** in the locality.

An effective and user-friendly waste management system is an integral part of the modern city district. This study presents initial analyzes, which describe the limits and possibilities of using this territory from the point of view of waste management.

The research team (**BUT UPI**) has long been engaged in solving the problems of waste management from several perspectives:

- **Analysing** the current state of waste management.
- **Prediction** of the future state of waste management.
- **Case studies** and **Feasibility studies** of waste management.
- **Design** of new technological solutions.
- **Integration** of new facilities into the proper functionality of the city.

3 Up-to-date state of Czech waste management and its legislation basis

The legislative framework generally describes the status of investment plans and projects within the current legislative environment. The following documents were taken into account for the study:

- **Waste Management Plan** (WMP) of the Czech Republic for the period 2015 to 2024.
- European Directive **2006/12/ES** on Waste and Related Directive **2008/98/EC** on Waste.
- Czech Law **185/2001** Coll. on Waste.
- The **proposal of new Waste Law**[1].
- European Directive **1999/31/ES** on the Landfill of Waste.
- European Directive **2000/76/ES** on the Incineration of Waste. The Directive sets out conditions to be met for waste incineration and co-incineration and also sets emission limits for waste incineration and co-incineration. Czech Directive **415/2012** implements this European Directive into the Czech legal environment.
- European Directive **2008/1/ES** on Integrated Pollution Prevention and Control (IPPC).
- Czech Law **100/2001** Coll. and its novel no. **39/2015** determines among other things the intentions subject to special assessment procedures under this Act. Under this procedure, also known as EIA (Environmental Impact Assessment), a professional assessment of the effects on all of the environmental components is performed.
- "**Circular Economy Package**" as a part of Circular Economy Action Plan[2] as a part of **ZERO Waste concept**, see section 4.

The European Waste Framework Directive 2006/12/EC and the subsequent Directive 2008/98/EC on Waste are primary regulation acts governing the management of waste throughout the European Union. These legislative acts are reflected in the legislation of the individual EU states. In the Czech Republic a law 185/2001 Coll. on Waste is valid, however, new waste law and its implementing regulations are being prepared. The new legislation should clearly state what waste cannot be landfilled from 2024 onwards. It is awaited, **that it will not be possible to landfill MW with a calorific value of dry matter higher than 6.5 MJ/kg**, which corresponds to the valid limit due to decree 387/2016 Coll. The calorific value of incinerable residual MMW waste in the Czech Republic currently exceeds this value and is not expected to change around 2024.

Due to the expected ban on landfilling of unusable waste in 2024, the focus is mainly on the reduction of landfilling of biodegradable waste, which is based on the Czech Republic's WM commitments as defined by Directive 1999/31/EC on Landfill of Waste. As the most important landfilled material flow has been identified as residual mixed municipal waste (MMW). It may consist of up to **about 50% of biodegradable materials**, the rate depends on a specific location (e.g. local building types, socio-economic factors or WM infrastructure). Despite the efforts of the biodegradables separation directly from its producers (inhabitants), the problem of biological MW landfilling is still relevant, because this separation has its limits.

[1] The proposal of new Waste Law. Available online: www.caoh.cz/odborne-clanky-a-aktuality/navrhy-obou-novych-odpadovych-zakonu-k-pripominkam.html

[2] Circular economy strategy – Environment – European Commission. Available online: http://ec.europa.eu/environment/circular-economy/index_en.htm

The obligation to avoid the landfilling of biodegradables to 35% compared to the 1995 landfilled amount is stated for Czech WM according to Directive 1999/31/EC on Landfill of Waste. The Czech WMP sets an even stricter target, namely a drop to only 24% of the weight of the landfilled biodegradables in 1995 by 2020. In 1995, 1,530 kt/a was deposited in the Czech landfills according to the Czech Ministry of Environment, that means a maximum of 360 kt/a landfilled biodegradables in 2020 according to the current WMP. It is expected that in the processing capacity of Czech waste-to-energy plants would be at most 1,100 kt/a.

According to analyzes and predictions of the biodegradable content of Czech residual MMW, it becomes obvious that waste-to-energy plants would be insufficient to reach the required level of biodegradables recovery in 2020. Biodegradables production reducing, enhanced infrastructure implementing, and other solutions are expected in this context. In the case of non-compliance with the objectives of the EU Directive, a penalty of € 1,750,000 + € 10,000 per day is a threat, which can be cascaded to the municipalities and their budgets. According to WMP of the Czech Republic, the objective for residual MMW treatment is: **„Mixed communal waste (after separation of material recoverable fractions, hazardous components and biodegradable municipal waste) should be mainly energy recovered in facilities designated for this purpose in accordance with valid legislation "**. The proposed measures leading to this objective are, among others, the following:

- **The fee for landfilling** of recoverable MW will be continuously modified in a way it would disadvantage the landfill of those types of waste that will be banned from 2024 onwards according to waste treatment hierarchy (see section 4.1).
- Residual MMW should be classified as a **waste group** that is expected to be banned from 2024.
- Adequate recovery of MMW in waste-to-energy plants without its pretreatment.
- The building of the **appropriate and efficient infrastructure** will be encouraged to support waste energy recovery (especially the residual MMW).

4 Trends in Europe

The incentives across Europe and European Union are related mainly on reduced waste production (ZERO waste concept, circular economy vision), sustainable waste treatment (waste treatment hierarchy) and an effective collection and production of secondary raw materials. In this context it, the following trends in WM have been selected for this report:

- ZERO Waste concept.
- SMART waste collection.
- SMART secondary materials production.
- SMART residues handling.

It is emphasised that only mature technologies and measures with high-practical impact and at least one commercial applications have been included. In other words, theoretical concepts and not-proven technologies have been excluded.

4.1 Zero waste concept

Waste industry is one of the most developed areas in the EU. Directive **2008/98/EC** defines basic procedures for waste handling known as "**Waste treatment hierarchy**". Its scheme is depicted in Figure 1. It places the waste production prevention in the first place and reuses for the same or another purpose. When this is not reachable the maximal recycling should be targeted. Consequently, energy utilization is preferred for disposal (e.g. landfilling).

Figure 1 Waste treatment hierarchy[3]

A more advanced approach not only to waste management is a **Circular Economy strategy**. It aims at raw material consumption minimizing through more effective waste prevention, reuse and recycling, as illustrated in Figure 2. In January 2018 the European Commission adopted a new set of measures called "**Circular Economy Package**" as a part of Circular Economy Action Plan[4].

[3] Waste Treatment hierarchy. Available online: www.andrewtmarlow.wordpress.com/2012/05/15/waste-hierarchy/

[4] Circular economy strategy – Environment – European Commission. Available online: http://ec.europa.eu/environment/circular-economy/index_en.htm

Figure 2 Circular economy scheme[5]

The **ZERO Waste Business Principles** and **ZERO Waste Community Principles** included the concept of ZERO Waste or Darn Close. Those principles recognized that nothing can be perfect and that a mature industrial economy could not reach literal ZERO Waste. Those principles said that businesses and communities that divert 90% of all their discarded materials from landfills, incinerators and the environment would be considered ZERO Waste businesses and communities.[6]

4.2 PAYT

Regarding the set WM goals for municipal waste separation, it is often necessary to motivate the population to meet these objectives. This means especially to create a **functional infrastructure** for the possibility of separate collection of paper, plastics, glass, metals and biowaste. It is appropriate to expect the design of new collection routes as well as adjusting the frequencies of a collection of different municipal waste (MW) fractions in this context. **The PAYT**[7] **system** is very popular in the world (Germany, Denmark, Ireland, Spain and others) and it is part of motivation programs to achieve higher and better quality of MW fractions separation by producers (citizens). It is a trend that can ensure the maximization of sorted components while minimizing residual MMW production. This achieves a higher degree of compliance with the waste management hierarchy. The main purpose of the PAYT system is **to minimize the residual MMW tax** for responsible residents and **to maximize the separation rate** of recyclable components from municipal waste. PAYT is also one of the recommended measures as stated by the Roadmap for the Czech

[5] Green growth and circular economy - Envirnment – European Commision. Available online: http://ec.europa.eu/environment/green-growth/index_en.htm

[6] ZERO waste international alliance working towards a world without waste. Available online: www.zwia.org

[7] Pay as you throw (PAYT)

Republic, a document by EC[8].

There are several approaches to PAYT. The PAYT system is relatively easy to install in family houses districts combined with a door-to-door collection system. Here, it can be realized with a low effort by a proportional waste fee to container volume. Individual production values are tracked for each PAYT participant in the context of the cost related to container handling and further treatment. The MW production is not anonymous and there is more responsibility in waste pretreatment by its producers in this case. The implementation of PAYT system is more demanding in dense urban areas. The waste collection system is anonymous (more households per container) and reusable waste separation may not be so efficient.

PAYT systems can work efficiently even in densely populated areas, if:

- there is an effective and comfortable system of the separate collection available.
- people know a quality control system of the material exists and could lead to the identification of misuse (e.g. transparent plastic bags for kerbside collection of lightweight packaging).

Therefore, it is necessary to introduce advanced containers identification system for selected MW streams to make PAYT functional. These **containers are monitored during collection** (weighted and identified by selected parameters) and the information is stored in a cloud storage for further processing. Based on the information, overall MW productions trends are evaluated in relation to a waste container or a house number. Further, it is possible to set appropriate WM costs and taxes for MW producers.

It is obvious from the already operating systems that when the PAYT system is introduced, there is an **increase in the overall cost of waste collection**. However, the production of **residual MMW per inhabitant is lower** and there is a **significant increase in sorted MW production**. An inappropriate operation of PAYT system may support a creation of illegal black dumps. The performance of PAYT systems could be “high tech” by weighing each container (bag) when collecting the waste. The amounts of the material collected might be augmented considerably if offering more service to the citizens, i.e. option of switching to kerbside collection for paper and (lightweight) packaging materials

4.3 Smart waste collection

Separate collection schemes in the capital cities of the EU-28 states were assessed in a **report** for the European Commission[9]. The assessment focuses on the priority waste streams: metal, plastic, glass, paper and biowaste. It includes an assessment of the legal framework and the practical implementation of separate collection systems in **28 European countries**, together with an in depth-analysis of systems applied in European capital cities.

[8] Roadmap for Czech Republic, Extend and enforce PAYT scheme. Available online: http://ec.europa.eu/environment/waste/framework/pdf/CZ_Roadmap_FINAL.pdf

[9] Directorate-General for Environment (European Commission): Assessment of separate collection schemes in the 28 capitals of the EU. Final report – Study. Published: 2015-12-10. Available online: https://publications.europa.eu/en/publication-detail/-/publication/2c93de42-a2fa-11e5-b528-01aa75ed71a1/language-en

Design and subsequent implementation of smart waste collection system is a **challenging task**. The goal of the SMART solution design is to find a balanced system that will have to be a compromise. Three main "pillars" should be taken into account:

- **Economical feasibility**.
- **Environmental benefits** – represented by national legislation and EU WM goals.
- **Social regards** – friendly and comfortable system for the citizens.

Finding a compromise among economic, environmental and social criteria is a complex task. Due to the technological development and modern computational possibilities, a use of sophisticated tools is appropriate for complex tasks evaluation. **Sophisticated complex computational tools** are especially suitable for:

- Conceptual changes planning and for **system preparation or adjustment**:
    - Comprehensive evaluation of **future cost**.
    - **Scenarios** and **simulations modelling** (more solutions are to be simulated and an optimal system is selected).
- Operational optimization:
    - A proper organization of services in cities.
    - In the WM context, this is a requirement for a comprehensive tool that can analyze the waste collection system (from the point of view of selected criteria) and propose economically or environmentally optimal solution for a city or region. Czech company which is interested in the collection system is a **RAltra** with a sophisticated monitoring online system – **Protank Dynamics**.

From the **research point of view**, the smart waste collection represents vehicle fleet and collection routes proposal to ensure optimized waste collection in the selected city or selected area. The main objective is to **optimize, i.e. minimize the selected parameter**, which can be e.g. **economy** (collection price), **environmental impact**, **collection mileage** or **time**. At the same time, it is assumed that the objectives set in the WM will be attained, above all the higher degree of separation of usable components of MW is assumed.

4.3.1 Typical MW collection systems

Typical waste collection systems are very similar both in Europe and in the world. From the collection company's point of view, the collection systems can be divided into three categories:

- Container collection.
- Collection centres.
- Modern "SMART" solution collection system.

New trends in MW collection are very rare and are more about continuous enhancing of existing systems, e.g. modernization of collection systems to **minimize operating time** and **cost**. Environmental impact, i.e. reduction of pollutants released during the collection becomes also important. This can be achieved through the use of alternative fuels such as LPG, CNG, hybrid or pure electric-driven vehicles. It can be stated that **waste collection is a very expensive process**, it is a key issue of the whole chain of waste management.

Container collection (detail description of bins and containers see in section 6) is realised by garbage trucks with the various compacting cylinder. Above all, it is a vehicle with a linear or rotary press system. In terms of greater usability of vehicles, it is desirable that the vehicle also has the possibility of a hydraulic arm movable in all directions for the handling of separation container or underground containers.

Collection centres (Collection yards) are designed for the district waste production. This solution is used especially for bulky waste, and almost any MW can be collected.

The solutions to **"SMART" waste collection** are expanding. These are mainly sophisticated and modern **vacuum piping systems** that centralize waste from the selected collection points into large-volume and/or pressing containers. Realization of such a project is **very capital cost demanding when implemented** in existing infrastructure (engineering networks transferring, etc.). On the basis of the Helsinki case study[10], the costs related to the collection of 1 t of waste is estimated at EUR 350. The standard door-to-door collection system is estimated at around 40 EUR/t.

However, this modern system can be incorporated into the construction plans of **new city districts with higher population density or modern SMART city projects**. More information is provided in section 2.3.4.

The possibilities for collecting individual MW commodities (e.g. **paper, plastics, glass** or **residual waste**) must take into account if PAYT system, returnable packaging system or appropriate infrastructure is available in the region. The option of the separate waste collection also influencing the production and parameters of residual MMW. In general, the adjustment of collection systems can be divided into the following two groups:

- Individual collection of selected MW groups, separate container for each commodity.
- Dry recyclables collection together in one container.

Recyclable outputs of both alternatives are necessary to be processed on the sorting lines and consequently transmit as a secondary raw material to the recycling facilities or sell to the world market. Previously the majority of plastics were sold to China. Due to **considerable import restrictions on China's market** (2018), a European plastic secondary raw markets have some difficulties. Only very pure high-quality secondary raw material without further additives can be sold to China. A market interest is still about the transparent PET.

The **standard separate collection scheme** consists in the separation of the following commodities from MW:

- Plastics
- Paper

[10] Pneumatic vs. door-to-door waste collection systems in existing urban areas: a comparison of economic performance. Available online: www.sciencedirect.com/science/article/pii/S0956053X1200236X

- Glass (colour, white)
- Metal
- Organic (biowaste)

One can also see the following options:

- E-waste
- Bulbs
- Batteries

In the case of **Dry recyclables system**, the situation may be affected by the potential returnable packaging system in the region. Backed packages are a positive motivation for consumers (MW producers respectively) for MW separation increasing, especially **beverage packages waste production may be minimized**. Dry recyclables system may be also gainfully for distributors and dealers (supermarkets) when a part of backed packages is produced (the deposit is paid) but the packaging material is not returned into the system. Dry recyclables are an exciting solution for many European cities and it can save on the cost of the collection task. In the case of Dry recyclables, municipalities provide the collection of:

- Residual waste.
- Organic waste.
- DRY recyclables waste which is necessary to sort in next step.

4.3.2 Waste collection optimization and periodic/dynamic planning

The use of optimization tools should be able to design adequate collection routes, to propose changes in up-to-date systems, to identify inappropriately used containers and their capacities, and to assess and compare different collection systems. The key task is to predict and draw attention to the uncertainties of some input parameters. For the optimization applications in the field of WM, we can expect an analysis of the **current WM state** and further an **estimation of a future situation** that is in accordance with the stated **WM objectives** based on CEP[2]. Thanks to world trends (e.g. container identification or container filling reports) it is necessary to look at the potential of waste collection optimizing tasks from two views. These are the so-called periodic or dynamic planning. Both variants have their advantages and limitations:

- **Periodic collection** – these collection plans are predetermined under the collection contract, e.g. a collection of residual MMW is done two times a week. The collection company realizes an identical system every week, seasonality exceptions may be addressed, e.g. in the case of bio-waste. The main disadvantage of the periodical collection type is that the collection vehicles are not used to 100% of their potential and they also serve partly-filled containers.
- **Dynamic collection (collection on request)** – it is a collection of filled containers which reports a certain degree of their filling. A dynamic collection is mainly used for large-volume or underground containers in different European cities.

An advantage of container monitoring is a possibility of retrospective evaluation of waste production. In particular, it is an information how much waste is produced for example by an apartment house, a shopping mall or several family houses, within the reference period. This

knowledge on production opens a way towards balanced **PAYT system**. It is also possible to analyze trends in the production of the selected MW groups. These modern tools are an excellent option, but they are associated with other necessary investments and operating costs.

Another way to use optimization in the context of WM is balanced models for facilities. This is mainly about a use and interconnection of **techno-economic models** of sorting line facilities, composting plant, WtE plant and also models of waste collection and transport. The research team (**BUT UPI**) can evaluate selected tasks using own created tools that can work with real infrastructure models, analyze existing plants, and predict developments based on goals or legislative regulations from the point of view of WM.

4.4 Case study Stavanger

The Norwegian city of Stavanger is presented as an example of the optimized waste collection, where a dynamic system with underground containers with sensors is largely used. Stavanger is the fourth largest **Norwegian city with 133,000 inhabitants**. The sensors monitor waste level in containers using ultrasonic waves and they send the information about container fullness to the interactive database where they are then evaluated by the dispatching centre. In Stavanger, **underground containers are used for paper, plastic, biowaste, glass, textiles and residual MMW collection**. For illustration, Figure 3 shows the deployment of underground containers for paper collection in the city.

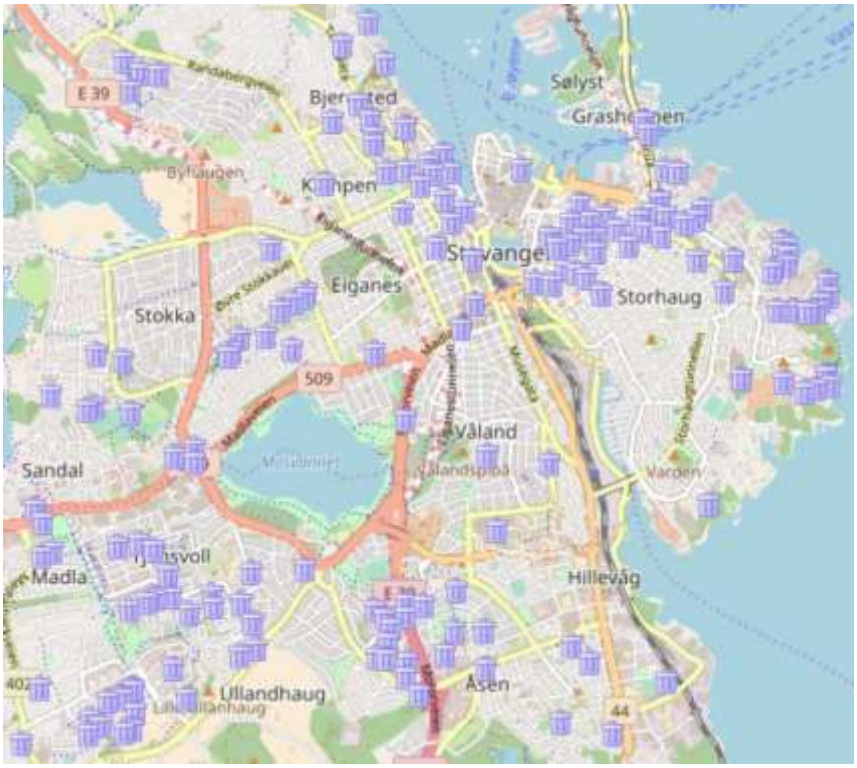

Figure 3 Location of underground containers for paper, Stavanger, Norway (Source: BUT based on data provided by Stavanger council)

The emptying of these underground containers is realized on the **dynamic planning** principle when a group of containers is identified to be depleted based on an acceptable rate of fullness which is set at 75%. Every garbage truck driver has a **tablet with a software application** that helps him with dynamic planning. The driver chooses which container he plans to export and the application generates the fastest way. Other drivers and their **traces are visible within the application**, and in the case of duplicity (i.e. two drivers decide to empty the same container) alerts are displayed. It should also be noted that the **fastest route does not need to be the shortest way**, the application can take into account the **current traffic situation**, **accidents**, **actual constraints** and **other factors**.

4.5 Underground clever containers

Another option for SMART solutions in cities is so-called **SMART bins**. These are specially and modernly designed containers for MMW or material recoverable waste. They are provided with **solar panels** that produce energy for the **press ram or internet communication**. Using the press **the waste is compacted** and the volume of the container is up to five times more usable, as shown in Figure 4. In addition, the fill level sensor is located in these containers. The fill level determines whether or not to empty the container. **Containers communicate with cloud storage** to where they send actual information about waste level. The connection is wireless and the cloud storage predicts the future trend in container waste level and on the basis of historical data it is able to **compile an optimised plan of the collection**. Due to the solar panels, it is not necessary to connect the containers to the electricity network.

Figure 4 Modern solar-powered trash compactor bin and with the press compactor (Source: Martin Sekanina, Soňa Jurčáková)

Simultaneously with the use of **SMART clever containers**, it is necessary to use the software application for monitoring, filling level and information about the emptying containers. The screen in Figure 5 is an illustration from company Verb GROUP[11] which is active in the development of waste monitoring solutions.

[11] Verb GROUP. Available online: www.verb.cz/bigbelly-cz

Figure 5 SW application of container monitoring from company Verb GROUP (Source: Verb GROUP)

4.6 Underground vacuum collection systems

Collection of municipal waste is an indispensable activity of each municipality. Waste collection and transport costs represent up to 25% of total WM spending from the point of view of the city (municipality). These **costs often have an increasing tendency**, because mainly the production of separated MW increase every year in countries with developing WM. This trend brings with it higher demands on hygiene, equipment and the overall infrastructure of the system. **Appropriate selection of the waste collection method is a key factor for effective municipal WM** since collection and transport of MW usually consist of 50-75% of all waste management costs, i.e. the overall costs of handling MW. Responsible municipalities are therefore looking for new and, above all, efficient ways of waste collecting to minimize costs and improve the overall efficiency of the system. One of the potential alternatives to the traditional way of collecting waste is the **pneumatic piping system**.

There are several manufacturers and suppliers in this field (Envac[12], ST Engineering[13]). For the main principle introduction, **MetroTaifun** system was chosen as an example – see Figure 6. MetroTaifun[14] is the world's most modern automatic waste collection system, which conveys waste & recyclables through underground and/or above-ground pipelines that can extend **up to 4 km from the waste collection point**. MetroTaifun has developed modern solutions for all applications; large and small, including hospitals, residential areas, industrial areas and shopping centres, sports complexes, hybrid and mobile systems. This modern and sophisticated waste collection system is being **implemented in newly built districts** in Europe and Asia. The pneumatic underground system is used in locations where traditional garbage collection by garbage trucks is inefficient or

[12] Envac company. Available online: www.envacgroup.com

[13] ST Enginering. Available online: www.stengg.com

[14] MetroTaifun. Available online: www.metrotaifun.com

undesirable (apartment buildings and neighbourhoods with high comfort and high level of service).

The main principle of Metro Taifun you can inspect on official video presentation:

- MetroTaifun Waste Collection Solutions for large areas.[15]
- MetroTaifun hospital solution. [16]
- MetroTaifun, the Automatic Waste Collection System (AWCS) for sustainable cities. [17]

When **comparing this modern collection method and up-to-date procedures** using the door-to-door system, it can be stated that the modern system allows the waste to be collected less frequently, it is possible to transport fractions more efficiently when waste is compacted, there is no need to secure the appropriate routes for large garbage trucks. The obvious disadvantage is high investment costs for the system implementation into the current districts. The standard door-to-door system is not so investment demanding as an automatic solid waste collection system.

Figure 6 MetroTaifun automatic solid waste collection system (Source: MetroTaifun)

4.7 Separate collection and technical sorting possibilities

Secondary raw materials could be produced from MW in different ways. The material recoverable content may be collected separately or it may be mechanically sorted from residual MMW. When treating the plastics together with the residual MMW and their extraction from the mixture, the sorting is done on a simple sorting line or it is treated in the more enhanced way in **mechanical-**

[15] MetroTaifun Waste Collection Solutions for large areas. Available online: www.youtube.com/watch?v=LUkzqtaLXQU&t=1s

[16] MetroTaifun hospital solution. Available online: www.youtube.com/watch?v=4lLf98YRVNI

[17] MetroTaifun, the Automatic Waste Collection System (AWCS) for sustainable cities. Available online: www.youtube.com/watch?v=gHmt1GTVlnM

biological treatment (MBT) plant. However, MBT operation is based on further waste streams recovery or disposal. The recoverable products from MBT treatment (e.g. plastics or paper) and from the separate collection have to undergo further treatment in sorting plants in order to meet the product specifications for recycling. **MBT is not a final treatment** for MW streams and operating units are focusing mainly on stabilization of MW biological content. Refuse-derived fuel producing and further energy recovery of MW is also an option of MBT operation, however, the material recovery rate is comparable with WtE plant operation in this case.

The problematic of different MW streams options are also discussed in professional journals[18] and thorough evaluation of preferred collection scheme assumes advanced computational modelling. The responsible municipal waste management approach depends on various factors, e.g. on available infrastructure, logistic options, expected socio-economical development, legislation rules and commitments or valid waste management aims.

The main **advantage of MBT is the treatment cost**. The main **disadvantage is the low quality of output materials** (e.g. secondary raw materials, various types of fuel or compost) which affects the market interest in these products – see in Figure 7.

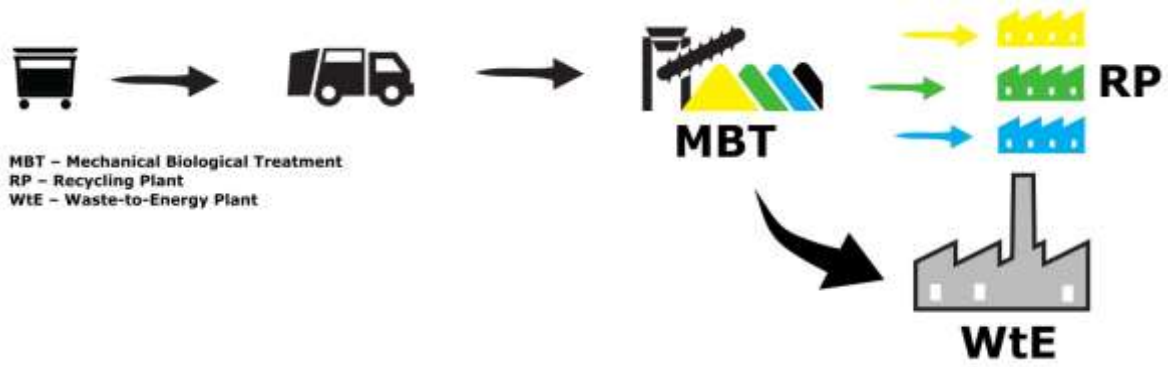

Figure 7 MBT technology and collecting system (Source: BUT UPI)

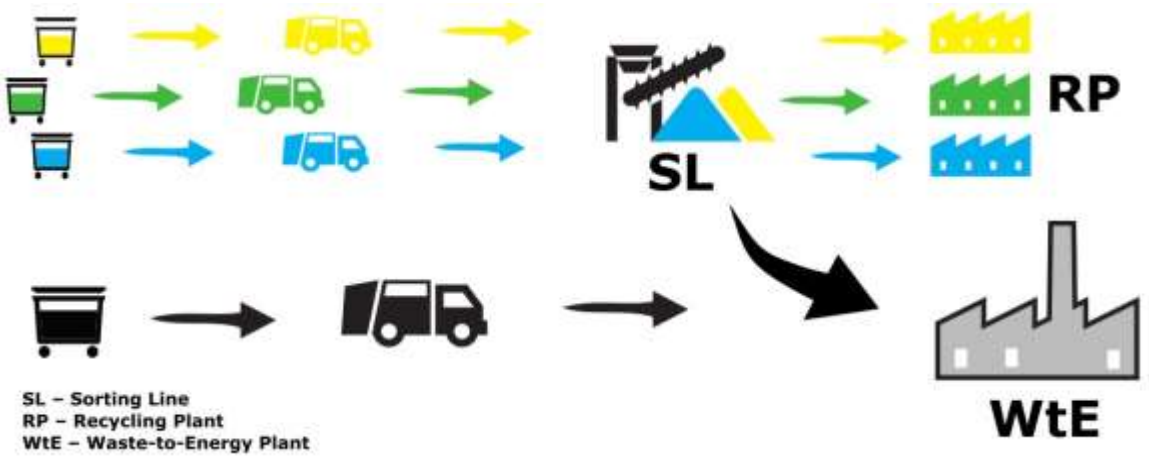

Figure 8 Sorting line and collecting system (Source: BUT UPI)

[18] Feil et al. 2016 Separate collection of plastic waste, better than technical sorting from municipal waste?. Waste Management & Research. 35(2), 172-180.

Figure 8 describes a typical collection system for the Czech Republic. The main difference from Figure 7 is the separate collection and then the commodities are **individually sorting on the sorting line**. In the Czech Republic, paper, plastic and tetra-pack are sorted by default. The other commodities like glass and metal are transported into recycling centres (metallurgy, glassworks). The sorting line can serve as a temporary warehouse for glass and metal. The MMW is transported directly to the WtE plant, respectively to the landfill.

In the case of MBT (Figure 7), all **MW is collected by one container** and MBT is divided into the required commodities. Commodities are further sold in the market.

4.8 Smart treatment of material unrecoverable municipal waste

Landfilling is the least preferred option according to waste treatment hierarchy (section 4.1). The more responsible approach may be a stabilization or fuel production in MBT plant, but landfilling amounts are still significant and MW potential is not sufficiently covered. WtE technologies are the usual solution to achieve higher levels of hierarchy when material unrecoverable MW is treated. The profits of WtE operation are significant, especially in large agglomerations.

The main advantages are MMW volume reducing (into 10 % of inlet MMW volume), waste stabilization and neutralization and energy recovery of low-calorific compounds (e.g. biowaste) together with high-calorific part of MMW mixture (e.g. unsortable or unsaleable plastics). Energy outputs may reduce primary energy sources through electricity production or by heat supplies if the central district heating network is available.

WtE is sometimes seen as a redundant technology in the light of the circular economy. As an example, ZERO Waste Europe raised 9 reasons[19] why we better move away from waste-to-energy. One of the claimed reason is, that burning waste contributes to climate changes. However, the overall CO_2 balance (considering CO_2eq as an indicator of climate change) is tightly bound to heat delivery and local conditions, as demonstrated in Figure 9.

For CZECH Conditions and current Energy mix for heat and power production, WtE plants with high heat delivery to district heating systems significantly contribute to avoiding CO_2 emissions.

[19] Available online: https://zerowasteeurope.eu/2018/02/9-reasons-why-we-better-move-away-from-waste-to-energy-and-embrace-zero-waste-instead/

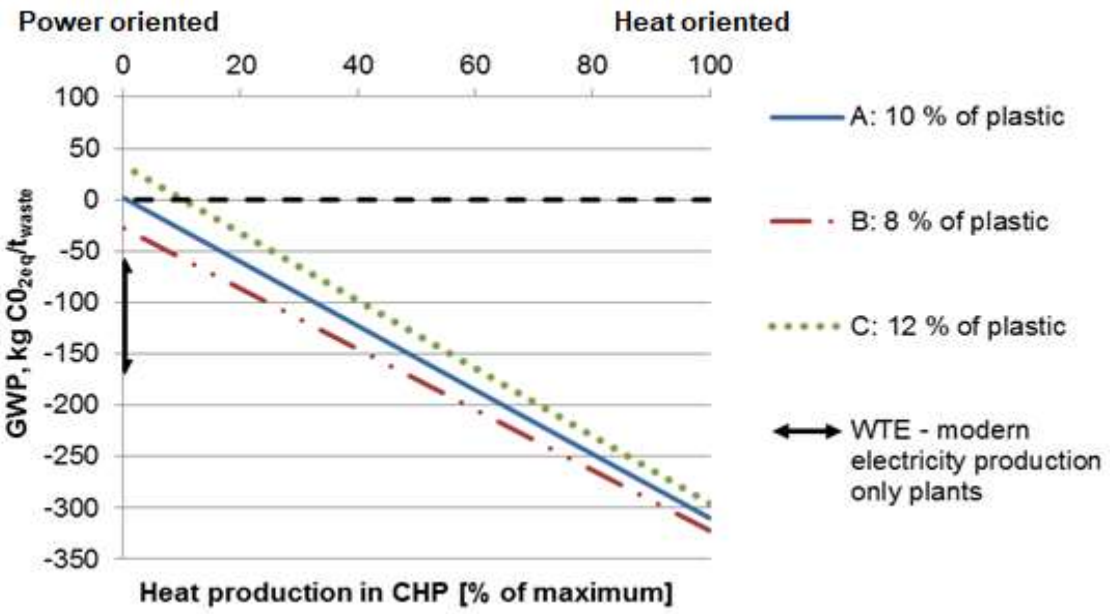

Figure 9 Global warming potential savings through heat or power oriented up-to-date waste-to-energy process (CHP – combined heat and power production, cogeneration; WTE – waste-to-energy, GWP – global warming potential)[20] (Source: BUT UPI)

The afore-mentioned facts cannot be generalized. Local energy mix plays a crucial role. On the other hand, missing the opportunity to deliver heat causes a reduced contribution to CO_2 savings.

[20] Ferdan T., Pavlas M., Nevrlý V., Šomplák R., Greenhouse Gas Emissions from Thermal Treatment of Non-Recyclable Municipal Waste, Frontiers of Chemical Science and Engineering (FCSE), doi.org/10.1007/s11705-018-1761-4, ISSN 2095-0179

5 RUGGEDISED lighthouse cities and smart solutions

RUGGEDISED is a smart city project funded by the European Union. It brings together three lighthouse cities: **Rotterdam**, **Glasgow** and **Umeå** and three follower cities: **Brno**, **Gdansk** and **Parma** to test, implement and accelerate the smart city model across Europe. Working in partnership with businesses and research centres these six cities will demonstrate how to combine **ICT**, **e-mobility** and **energy solutions** to design SMART, resilient cities for all. This means improving the quality of life of citizens, reducing the environmental impact of activities and creating a stimulating environment for sustainable economic development.

To review current waste management practices and especially **SMART solutions** applied in lighthouse cities was the first objective of this study. Based on this, the authors decided to prepare questionnaires. The survey was organized as a two-step procedure. In the **first round**, simple **YES/NO** questionnaire was circulated.

The questionnaire can be divided into five parts:

- Basic Information About **Waste Management** In Your City (12 questions).
- Basic Information About **Collection Of Municipal Waste** In Your City (9 questions).
- Basic Information About **Facilities** In Your City (Region) (11 questions).
- Basic Information About **Collection Vehicles** In Your City (7 questions).
- Basic Information About **Collection System** And Its **Organization** (12 questions).

The questionnaires have been received from cities Gdansk, Glasgow, Parma and Rotterdam. Answers are attached to this document as Appendix 3. The feedback was not received from the city of Umeå.

Basic Information About Waste Management In Ruggedised City

Based on a questionnaire survey, it was found that the cities that sent back the completed questionnaires had prepared WM strategic plans. It was confirmed that they have evidence of waste production, but the waste production information is not publicly available. In the city of Glasgow, smart clever bins are planned in the future. GPS monitoring of collection is used in Gdansk, Glasgow and Rotterdam, Parma is going to use GPS monitoring in the next year (2019). Gdansk and Rotterdam use underground containers in the city. Fill level of containers is monitored in Glasgow and Rotterdam. The analysis and composition of the waste are carried out in Parma, two times per year in Rotterdam. Glasgow has only historical data from an analysis in 2014.

Basic Information About Collection Of Municipal Waste In Your City

All cities claimed that they have an established correct infrastructure for collecting MW. In the city of Glasgow, there are Dry recyclables collected. It means, they collected paper, plastic and aluminium to one bin – materials with recycling potential. In Parma, the collection is carried out in a similar way, dry recyclables mean metal, plastic and tetrapack. In all cities, glass and biowaste are separately collected.

Basic Information About Facilities In Your City (Region)
Gdansk, Glasgow and Parma operate sorting line(s) in the city, Rotterdam sells separately collected waste to the third party (to the market). Gdansk and Parma are operating the composting plant. The transfer station is used in cities like Glasgow, Parma and Rotterdam due to transport for the longest distances. Recycling facilities are situated close to all cities. Waste to energy plant is being currently operated in Gdansk, Glasgow and Parma.

Basic Information About Collection Vehicles In Your City
No city uses alternative fuel for waste collection vehicles, LPG vehicles are used only in Parma. The city of Gdańsk uses a special monitoring system for vehicles which is based on fuel consumption and current speed.

Basic Information About Collection System And Its Organization
All cities collect waste according to prepared plans. The optimization of collecting routes is used in Gdansk, Glasgow and Rotterdam. All cars are weighed during the unloading. Emissions production is not taken into account in collecting plans and the reduced environmental impact was not a subject of any study.

After that, more detailed questions have been raised aiming at the interesting answer from all five parts in the second round – Appendix 4. Here cities representatives were emailed individually. The goal was to explain waste management in the city in more details. Unfortunately, feedback was only received from Parma but not in a complete way.

Generally, the cities involved in the Ruggedised project are very similar in the area of waste management. Typical facilities are used:

- Transfer stations.
- Sorting lines.
- Water treatment plant.
- Recycling plants.
- Others.

At the same time, the underground containers are used very often. The underground containers are very useful for city centre or for places where is not enough space for standard containers. All the cities involved in the project have in common to connect the advanced vehicle monitoring to planning potential. Concurrently, the planning could be dynamic with the reaction to the current traffic situation. There is also a great effort to use advanced "smart" technologies in containers e.g. fill level sensors, using interactive communication dispatching centre.

6 The potential WM tools in Brno smart city context

Fee for waste disposal at the landfill - The proposed changes are both material and procedural in nature (the feepayer will be the owner of the landfill fee, which is obliged to include the fee for the deposit for the waste in the landfill, the newly divided individual fees, the fee administration will be performed by the State Environmental Fund and the customs office as the paying agent, with the fee administration, is fully governed by the Tax Code).

Municipal waste fee - this issue will only be revised in the local fees law (the amendment to this law elaborated in conjunction with the Ministry of Finance is attached to the proposal), the municipality may choose either a fee for a municipal waste management system based on a similar principle as a canceled fee under section 10b of the local tax law, or a fee for the disposal of municipal waste from a real estate, which is based on the actual amount of waste generated that has been deposited in the collecting containers or at designated places, or the capacity of the collectors ordered at fee period.

The operation of the waste facility - waste collection facilities will have to equip the premises of the equipment with the CCTV system and keep the record for a specified period of time.

Permitting the operation of waste management facilities - in particular with regard to the need to ensure a regular review of the permit to operate the facility, sets the maximum period for which the permit can be issued (5 years); for the operation of a mobile device for the treatment or recovery of waste throughout the territory of the Czech Republic, it will be sufficient for the operator to obtain permission to operate the facility from the regional authority in whose territory the registered office is situated. Unlike the existing legal regulation, to clearly distinguish the total quantity and distribution of individual types of the facility in the territory of the Czech Republic.

Collection of waste - the collection of waste by mobile devices is prohibited on the grounds that it is not possible to check whether or not the mobile operator has legally handed over the waste received or illegally disposed of, the mobile collection is not canceled without replacement (mobile collection function the proposed legislation replaces, albeit not to the full extent, by establishing the possibility for the facility operator to take waste to its facility already at the place of loading and by introducing waste and waste management institutes).

Basic provisions - a more detailed definition of the four procedures to determine that waste will cease to be waste.

Addressing the issue of illegally concentrated waste (so-called black landfills) - the proposal is based on a constitutionally established principle of ownership (Article 11 (3) of the Charter of Fundamental Rights and Freedoms) and establishes a procedure for identifying a person responsible for illegally concentrated waste and for ensuring that waste is disposed of and transferred to a facility for waste management at the same time the petitioner foresees the solution of the so-called black landfills by means of non-legislative tools (this issue can be solved within the framework of the MŽP Program through specific calls of the national environmental program managed by the State Environmental Fund).

Waste trafficking - will be subject to a separate permit, with the possibility that this activity will be carried out not only by operators who are operators of waste management facilities.

At the same time, the draft law takes over a number of institutes from the valid legislation that has proved in practice (e.g. financial reserve for reinsurance and subsequent landfill care, waste management plans), either unchanged or only in a slightly revised form.

From the point of view of the Czech Republic, several waste collection systems can be distinguished, the main ones are:

- "Door-to-door" system - this is a waste disposal system, the garbage truck stops at each house individually, and the bins or bags are relevant to the house.
- Delivery system - the inhabitants carry the produced waste to the points for collection, where one collection point is intended for more houses.
- Collecting points (collection centres) - high-volume waste or waste (e.g. electric waste, building rubbish, soil), which is not collected in a classical way, the citizen exports waste to collection points as collection yards.

The collection method refers to waste separated, bulky, hazardous, biowaste, etc. It can be considered a subcategory of the delivery method and is realized on the basis of collection yards. It is mainly used for MW components, where the above types of collection are significantly uneconomical or inefficient.

The selection of the type of collection in a given location is determined by a number of factors, especially the economic aspect, the amount of waste produced at the selected site or the disposal solution for the location of the containers. The delivery system has lower investment costs but is less available to citizens, less yield and quality of MW components than Door-to-Door. The door-to-door method is most convenient for the citizens, but economically, from the point of view of the collection company, it is very expensive. The amount of financial demanding depends on the number of containers in the collection nest or address point. For example, family houses that have multiple collection containers (mixed municipal waste, biodegradable waste and separated components) at their address point. In this case, all containers cannot be served during one collection, but the address point needs to arrive multiple times based on the number of containers. This fact raises the overall economy of the collection and it is necessary to correctly evaluate how many containers and what type of collection will be economically efficient.

Types of waste containers

Many types of waste containers are currently used. Containers can be divided into:

- spill (with top and bottom spouts)
- exchangeable - usually bulk containers.

Spill containers with top spillage

For mixed MW and separated waste, especially plastics and paper, the following containers are usually used (Table 1), currently dominating plastic and metal containers are gradually exchanged.

Containers with a capacity of 120 and 240 litres also exist in a special brown version with ventilation holes designed for the collection of biowaste. Currently, these can be seen in many municipalities.

Table 1 Standardly used bins and containers in the Czech Republic (Source: BUT UPI)

Container/bin type	Container material	Container volume	MMW collection	Separated MW collection	Wheels on container
bin	plastic	60 l	yes	-	yes, 2
bin	plastic/metal	80 l	yes	-	yes, 2
bin	metal	110 l	yes	-	no
bin	plastic/metal	120 l	-	yes	yes, 2
bin	plastic	140 l	yes	-	yes, 2
bin	plastic/metal	240 l	yes	yes	yes, 2
bin	plastic	660 l	yes	yes	yes, 4
bin	plastic	760 l	yes	yes	yes, 4
container	plastic/metal	1100 l	yes	yes	yes, 4

Spill containers with bottom spillage

Spill containers with lower discharge are used for separated waste components, mainly so-called separation bells or underground containers. Separation bells are plastic, fiberglass or metal containers, typically in variants 1,300, 1,500, 2,000 and 2,500 liters - a sample (Figure 10). The dumping of the bells is carried out by means of a hydraulic loader container. The container is manipulated with the metal eye and the dump is realized by means of the second eye, thanks to which the lower part of the container is opened. There are two bottom opening mechanisms: either side or centre.

Figure 10 Bell containers (Source: 3PM[21])

[21] 3PM s.r.o. Online available: www.3pm.cz

At present, the use of containers with lower spillage in the form of containers underground, so-called underground containers into which waste is shredded from small wastebaskets, so-called casting shafts (Figure 11), is on the rise. They are mainly located in historic city centres to ensure a sufficient volume and containers do not disturb the character of historical buildings. Underground containers are also opening up and spilling, using a hydraulic-powered vehicle. Investments for the construction of underground containers are approximately 700 thousand CZK. In case of installation in historical parts, it is necessary to calculate also the potential transfer of utility networks, which can increase the costs of the installation of underground containers. The research team has a techno-economic model for the calculation of underground containers, which will be further exploited.

Figure 11 Underground containers for separate waste (Source: Prague 9 – official website[22])

Changeable containers and High volume containers

In the category of changeable high volume, we include containers, which are used for example in collection yards or occasional collection of biowaste (campaigns). Containers are usually unsuitable for collecting mixed waste, with the exception of impact collections of larger or high volume MW. Instead, they are commonly used to transport separately sorted waste components. The most used type of containers is stretch containers (Figure 12, right), respectively. Mulden (Figure 12, left). High volume containers are manufactured from 5 m^3 to 30 m^3.

[22] Prague 9 – official website. Available online: www.praha9.cz/urad-a-samosprava/zivotni-prostredi/odpady/podzemni-kontejnery-na-trideny-odpad

Figure 12 High volume containers used in the Czech Republic (Source: MEVA-TEC s.r.o.[23])

For proper system setup and container selection, a feasibility study is required with the help of an optimization task for selected collection systems and containers. The research team has a number of developed optimization and computational tools for dealing with waste management, including:

- ***NERUDA Tool***[24] – optimization tool.
- ***JUSTINE Tool***[25] – a tool for prognosis of waste production, comparison current situation and future trends.
- ***Techno-economic model*** for selected technological solution.

[23] MEVA-TEC s.r.o. Available online www.mevatec.cz

[24] More information about tool in Appendix 1

[25] More information about tool in Appendix 2

7 Trends in a worldwide context

There is a large number of innovative trends in the world. The trends include, above all, **monitoring** and **comprehensive data** collection from all sectors of human activity. These data are then evaluated, subsequently, time, cost and other savings are realized to improve the efficiency of any sector.

In the context of waste management, the **key element is plastic waste** treatment and recovery. China has restricted the import of plastics, they require only high-quality and clean plastics, and therefore a large quantity of sorted, separately collected plastics remain in cities or huge warehouses in Europe. From this point of view, it is necessary to focus mainly on the development of the plastics market and related treatment infrastructure, to identify which plastic waste can be considered as a tradable commodity, how it can be processed, and evaluate the overall **complex plastics treatment system proposal**. The treatment system begins with the **collection** and **transport** of waste. In large cities, the so-called **vacuum pipe systems** for waste collection (e.g. MetroTaifun) (see section 4.6) or a sophisticated self-serve waste collection technique (automatic side loader). Also, recycling centres should not be forgotten.

From the point of view of new technologies in secondary raw materials production, it is obvious that based on Industry 4.0 approach, the **digitization and automation** in the industry are introduced, which is expected mainly in automated sorting lines.

As a trending technique in residual MMW final processing, a modern waste-to-energy plant, waste-to-biofuel can be included.

In this section short descriptions of chosen technologies and systems will be provided:

- Waste-to-Biofuel.
- Biotechnology for converting waste oil into plastics.
- Dry recyclables collection.
- Collection with the automatic side loader.
- Industry 4.0 and Smart City concepts.

Waste-to-Biofuel (Edmonton, Emerkem)[26]

Enerkem Alberta Biofuels located in Edmonton, Canada, is the world's first major collaboration between a large city and an innovative waste-to-biofuels producer. The project addresses the non-recyclable and non-compostable waste disposal challenge by diverting household waste destined to landfills. Using a thermochemical process, Enerkem converts household waste into clean biofuels and green chemicals, such as ethanol and methanol.

Biorefinery process enables the use of municipal solid waste and other waste residues as unconventional and low-cost feedstocks for the production of biofuels and renewable chemicals. Enerkem's technology is deployed through a process that converts non-recyclable waste into a

[26] Official webpage. Available online: www.enerkem.com

pure synthesis gas (or syngas). This syngas is then converted into biofuels and other widely used chemicals using catalysts. In less than 5 minutes, waste destined to landfill becomes clean transportation fuels or renewable chemicals, which can then be used to form other value-added products. It is claimed, that the Enerkem technology is, therefore, feedstock flexible and multiproduct.

Since 2000, Enerkem has tested and validated a number of different feedstocks – from solid waste coming from several municipalities to dozens of other types of residues. In Enerkem's system, these feedstocks are converted into methanol, ethanol or other renewable chemicals. In turn, methanol is a chemical building block for the production of secondary chemicals, such as olefins, acrylic acid, n-Propanol, and n-Butanol, which can then be used to form thousands of everyday products.

Enerkem's exclusive process is environmentally sound. It requires relatively low temperatures and pressures, which reduces energy requirements and costs. Enerkem's proprietary technology was rigorously scaled up from pilot to demonstration to commercial stage during an unprecedented period of 10 years of disciplined efforts.

Enerkem's four steps of the thermochemical process are:

- Feedstock preparation.
- Gasification.
- Cleaning and conditioning of syngas.
- Catalytic synthesis.

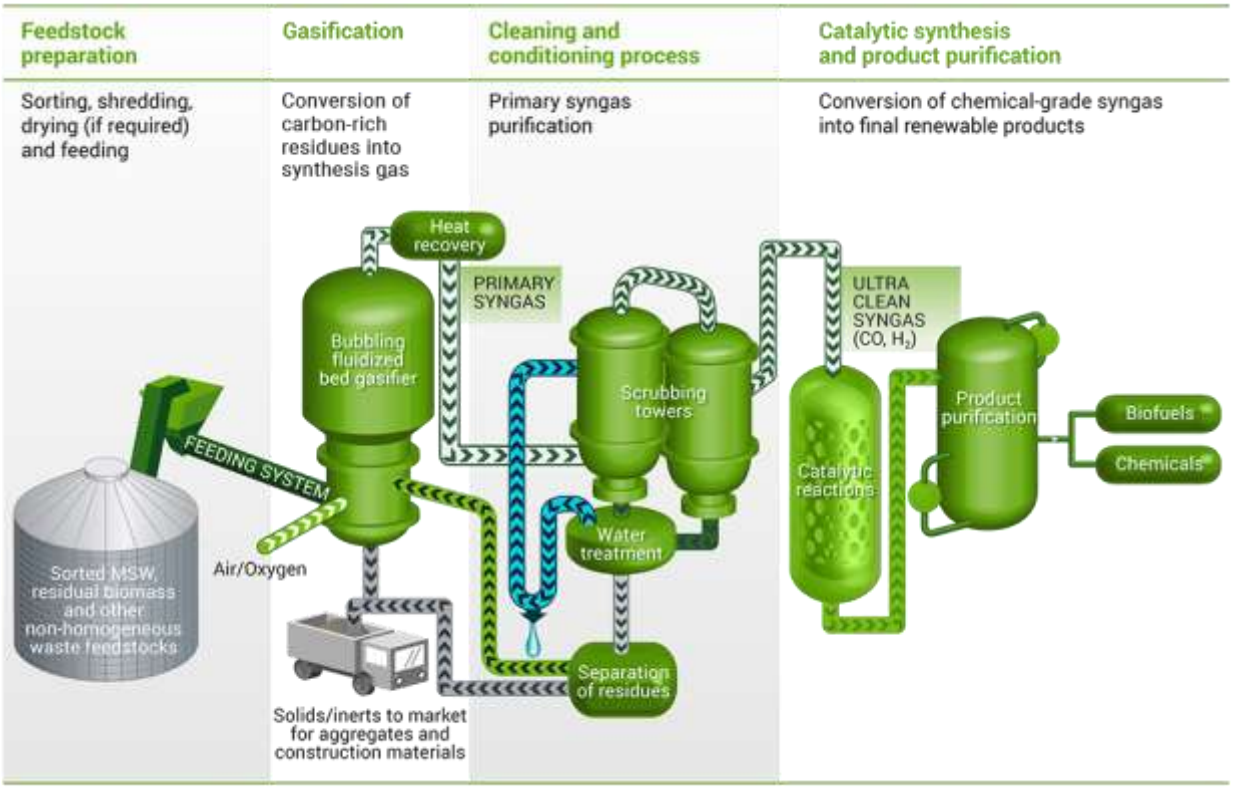

Figure 13 Basic scheme for technology Waste-to-Biofuel (Source: Enerkem [27])

The waste-to-biofuel technology is to be developed also in Europe, specifically in Rotterdam. More information about the current situation in Rotterdam is on the website[28].

Biotechnology for converting waste oil into plastics

Hydal[29] is biotechnology developed by Nafigate Corporation to produce a biopolymer from waste oil (e.g. used cooking oil) on an industrial scale. The technology is not consuming food chain sources like competitors that process e.g. sugar, starch or corn. The other advantage is very good biodegradability of produced plastic material. Currently, biotechnology Hydal is a unique technology for the mass production which can convert waste into bioplastics.

Dry recyclables

Co-mingled collection of dry recyclable material may be an effective way for disposing of clean, uncontaminated recyclable materials. However, the separated MW stream still has to undergo further treatment in sorting plants in order to meet the product specifications for recycling. The advantages may be container space reduction (in the densely built-up area) or more efficient production of secondary raw materials. On the other side, logistics may be more demanding on traffic routes and collection technologies using. The potential benefits of dry recyclables collection benefits have to be evaluated through case studies using complex computational tools.

[27] Technology – Enerkem. Available online: www.enerkem.com/about-us/technology

[28] Enerkem to Lead Consortium to Develop Waste to Chemical Project in Rotterdam. Available online: www.waste-management-world.com/a/enerkem-to-lead-consortium-to-develop-waste-to-chemical-project-in-rotterdam

[29] Biotechnology Hydal. Available online: https://www.hydalbiotech.com

Collection with the automatic side loader

At present, the Sidewinder XTR ™[30] system is emerging primarily in the US. This type of garbage vehicle is one operator efficiency which needed any operators – only drivers. The car arrives in front of the container and serves a specific container by the long hydraulic arm. This system is a modern solution for collecting and can save high wage costs. The main disadvantage is that the container must be located at a predetermined location (in front of a house and close the road).

Figure 14 Automatic side loader (Source: New Way® Trucks: Refuse Trucks & Garbage Trucks [31])

Industry 4.0 and Smart City concepts

This is a trend of monitoring, digitization and automation in industry. The aim is to redirect the simple activities that people have taken to fully automated control using computers and robots.

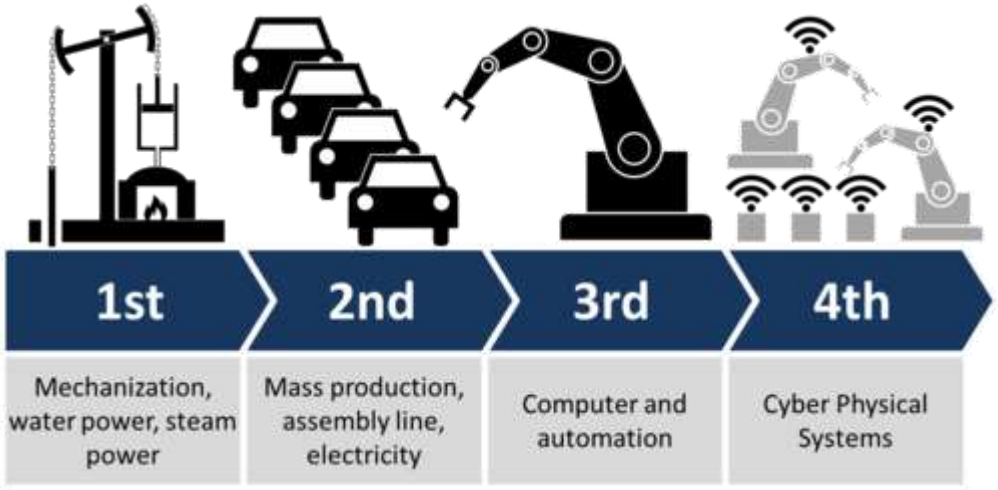

Figure 15 Basic description of industry development (Source: Cliexa[32])

Industry 4.0 is a very important part of the Smart City concept that uses digital, information and communication technology to improve the quality of life in cities. It focuses on efficient use of existing and finding new resources, reducing energy consumption, eliminating environmental

[30] Automatic side loader. Available online: www.refusetrucks.scrantonmfg.com

[31] New Way Sidewinder XTR Automated Side Loader. Available online: www.standardequipment.com/product/new-way-sidewinder-xtr-automated-side-loader

[32] Available online: www.cliexa.com/2017/03/physicianentrepreneurs

burdens, optimizing traffic and sharing data for public purposes.

- The Smart City concept can be divided into several areas:
  - Smart economy.
  - Smart transportation.
  - Smart environment.
  - Smart people.
  - Smart living.
  - Smart government.

In the context of waste management and potential interconnection with Industry 4.0, will be included:

- Using automated sorting line.
- Using underground containers to provide larger volumes with the comparison as in the standard containers (3 m^3 or more).
- The Metrotaifun system is a sophisticated pneumatic system for transporting waste to a central point.
- Clever trash bin with built-in sensors of the fill level.
- Software which can optimization collection routes with different systems:
  - periodical planning,
  - dynamic planning,
  - other planning (combination).
- Autonomous management of WM from a complex solution point of view.

8 Best cases for the Brno city (The Spitalka district)

Proposed solutions reflect respected pillars of sustainability:

- Cost.
- Environmental impact.
- Social aspects.

With respect to set EU goals for WM, which can be considered as ones corresponding to environmentally-sound solutions, the recycling rate of re-usable materials should be at 55% in 2025, 60% in 2030 and 65% in 2035 according to CEP[2]. These targets are set relatively challenging, taking into account the current level of recycling, which requires:

- Creating infrastructure to sort commodities such as paper, plastic, glass, metal and bio-waste, which is the largest fraction of municipal waste in recycling context.
- Establish a functional system in individual municipalities and district across the agglomeration and prepare complete new plans to manage the new containers and to adjust the frequency of exports.
- Motivate the residents to cooperate with the new system. On the other hand, this has to be done in a user-friendly way under acceptable cost.

8.1 Wm overview in Brno city – current situation

The overview represents a short summary of key-figures from WMP of City Brno. Currently, a complex, adequate and efficient collection system is realized and further developed in Brno City. An expected future trend is to establish and maintain a comprehensive, adequate and efficient network of waste management facilities as close as possible to their location.

8.1.1 Basic socio-economic parameters

As already mentioned, the WMP of the Statutory City of Brno is based on the WMP of the South Moravian Region and then on the Czech WMP for the 2015 – 2024 period. All WMPs are processed on the basis of the Czech Waste Act 185/2001 Coll.

There are 377,028 inhabitants in the city of Brno (December 2015, according to the Czech Statistical Office). This is approximately 32% of all inhabitants living in the South Moravian Region. The population structure in Brno is obvious from Table 2.

Table 2 Statistical sociological data – population structure (Source: CSO)

The municipality with extended powers	Population 2015-12-31	Gender		Age		
		Male	Female	0 to 14	15 to 64	Above 65
Brno	377,028	181,890	195,138	55,325	246,583	75,120

Demographical data are stated in Table 2.

Table 3 Statistical demographical data (Source: CSO)

The municipality with extended powers	Total area (ha)	Buildings and yards (ha)	Population density (pop/ha)	Built-up area population density (pop/ha)
Brno	23,018	2,090	16.4	180.4

Population divided by type of housing see in Table 4.

Table 4 Permanently occupied houses (Source: CSO)

The municipality with extended powers	Population divided by type of housing		
	Detached family house	Terraced family house	Blocks of flats/apartments
Brno	88,721	95,851	192,456

8.1.2 Current MW generation rates in Brno

Brno MW productions are recommended to be compared with production in other Lighthouse cities. This idea was included in the questionnaires (see section 2.6). Unfortunately, the information was not delivered. For this reason, comparisons based on production and on-going technological solutions were not possible.

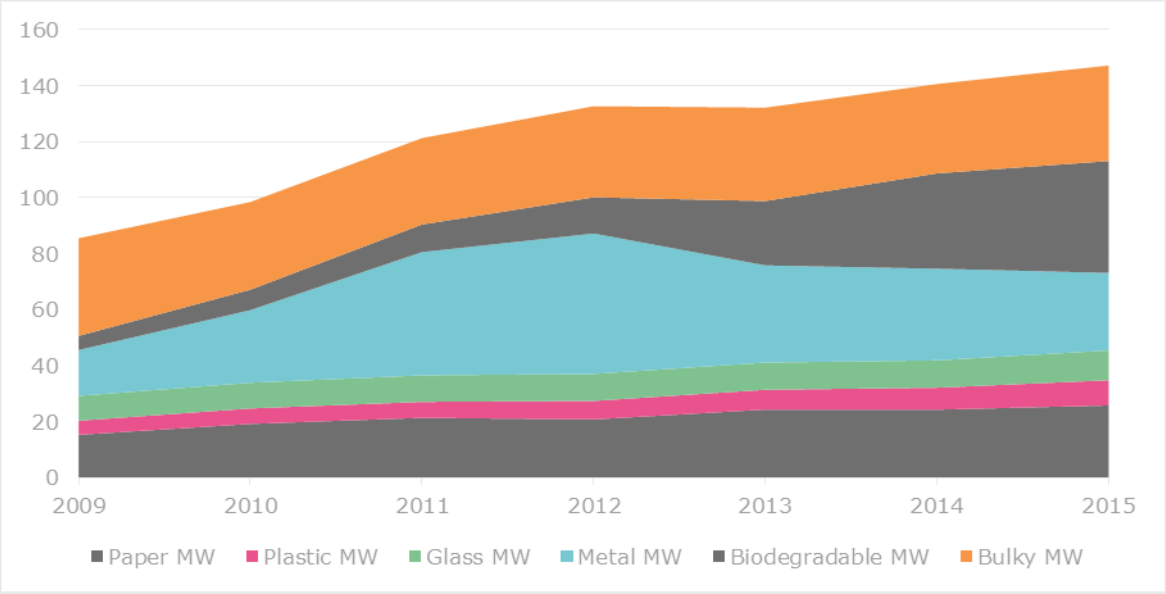

Figure 16 MW production in South-Moravian region, kg/inhabitants/year (Source: ISOH)

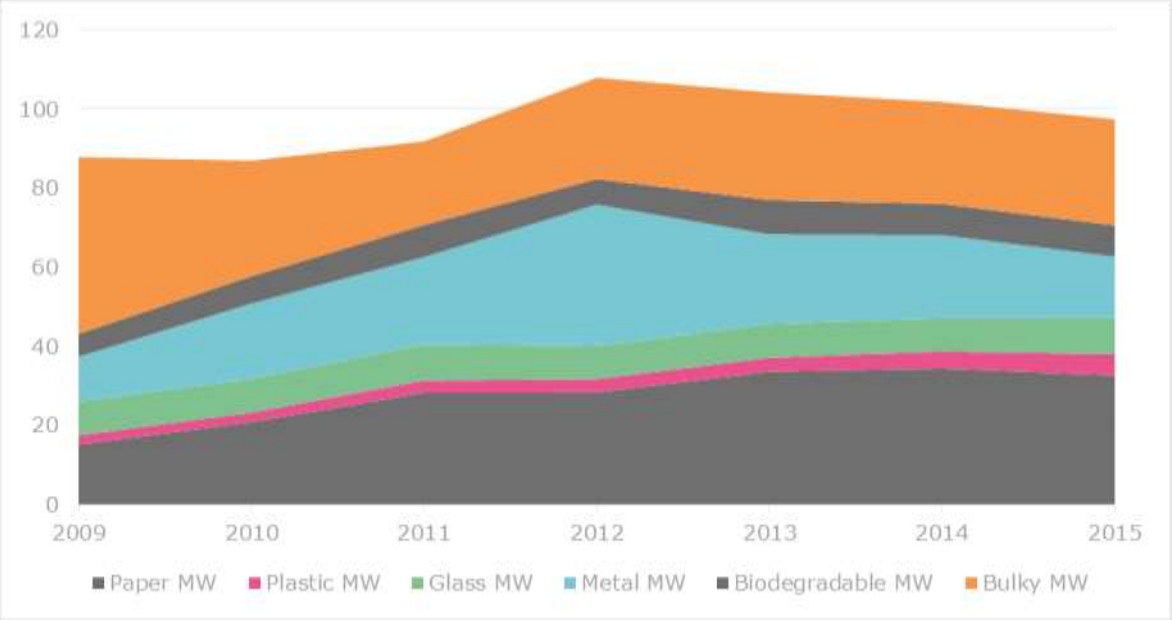

Figure 17 MW production in Brno municipality, kg/inhabitants/year (Source: ISOH)

To present the production in Figure 17 the following datasets were regarded:

- Data on waste generation within the municipal system at the regional level from 2009-2015 (206 regions for the Czech Republic), disposal codes A00, BN30, AN60.
- For the purposes of this study, the following waste codes of material-useable MW components were monitored:
- MMM – residual mixed municipal waste (cat. n. 20 03 01).
- MW paper and cardboard (cat. n. 20 01 01 and 15 01 01).
- MW plastics (cat. n. 20 01 39 and 15 01 02).
- MW glass (cat. n. 20 01 02 and 15 01 07).
- MW biodegradable waste (cat. n. 20 01 02).

MW metals production shows totally random values without correlation with values of remaining metal fraction in residual MMW. In the case of bulky waste, it was assumed that its character did not have a significant effect on the production of residual MMW. The other factions are negligible in terms of the quantity produced.

Table 5 shows the percentage of MW production in 2015. The year 2024 have been evaluated by the **JUSTINE tool** [33] based on an analysis of historical data for the period 2009 to 2015 in the city of Brno.

[33] More information about tool in Appendix 2

Table 5 Estimation of residual MMW composition in Brno municipality with extended powers (Source BUT UPI)

(% wg.)	2015	2024
Metal	2.55 %	2.69 %
Glass	7.15 %	6.62 %
Paper, cardboard and carton	9.42 %	8.56 %
Plastic	12.22 %	9.59 %
Electronic waste	0.42 %	0.44 %
Textile	6.77 %	7.15 %
Combustible residue	13.56 %	14.32 %
Organic compounds	28.42 %	30.03 %
Hazardous compounds	0.65 %	0.69 %
Mineral compounds	2.52 %	2.66 %
Fraction below 40 mm	16.33 %	17.25 %

2015 Separation rates according to ***JUSTINE***[34] **tool:**

- **Paper**: Brno municipality with extended powers 65.6 %, South-Moravian region 66.3 %, Czech Republic 65.4 %.
- **Plastics**: Brno municipality with extended powers 19.7 %, South-Moravian region 32.3 %, Czech Republic 37.7 %.
- **Glass**: Brno municipality with extended powers 41.5 %, South-Moravian region 54.2 %, Czech Republic 53.2 %.

The efficiency of MW sorting can be quantified as a separation rate, this means separated particular component (plastic, paper, glass) production related to overall component production in MW (including the portion in residual MMW). The separation rate then indicates how many per cent of the total potential (output) of the particular MW component has been separated for further treatment. The separation rate describes more about separation efficiency than only MW production and includes information about possible improvements in the MW sorting system. Serious discussion of target values of future separation and prediction of residual MMW parameters (e.g. calorific value for energy recovery) may be based only on the basis of updated data on the composition of residual MMW and separated MW. It is recommended to analyze the current composition of this MW groups and to carry out these analyzes at regular intervals.

[34] More information about tool in Appendix 2

8.1.3 Current waste treatment in Brno City

This section presents the current status of WM in Brno city. The system is described from a comprehensive point of view based on the technological integration of the existing and / planned on the territory of Brno. Currently, operating facilities in Brno include:

- Waste collection centres.
- Sorting lines.
- Biogas stations.
- Composting plant.
- Waste-to-Energy plant.
- Landfills.

For a future MW separation improving, it is also important to describe the current state of disposal of the biodegradable component in residual MMW. These biodegradables are energy recovered in **SAKO Brno, a.s.** waste-to-energy plant. A complex computational assessment is necessary for a comprehensive discussion of increased MW separation consequences.

Waste collection centres

One of the most important parts of WM infrastructure is collection centres. Currently, 37 centres are operating in the Brno city. These are fenced, secure areas equipped with waste collection containers. It serves the citizens of the city of Brno to drop off of separated components of MW, hazardous waste, bulky waste and also electrical equipment. At present, they play a key role in separating of biodegradables. Waste disposal is free of charge for inhabitants. Only tire collection and some building waste are charged, which can be disposed of only in selected centres. The centres are tailored to all types of municipal waste produced and therefore ensure the fulfilment of a wide range of objectives set in the WMP.

Material recoverable waste treatment plant – Sorting lines

The sorting line for the treatment of separated MW from Brno agglomeration is the facility in the SAKO Brno a.s. waste-to-energy ground and the sorting operation has an annual throughput of 10 kt. Currently, the line is used for plastic and paper. The line is located in unsuitable spaces, and therefore, a project of building a modern sorting capacity will be presented in section 8.4.

Biodegradable waste treatment plant – Biogas stations

Two types of equipment can be used to use separately collected biodegradable MW. An anaerobic system for the production of biogas (biogas stations) and anaerobic composting plant. There are these plants operating in Brno City area:

- Biogas station ID CZB00786 “Ústav využití plynu Brno, s.r.o.”, IČ 41605691, capacity 770 t/a.
- Composting plant ID CZB00790 “Centrální kompostárna Brno, a.s.” IČ 26937794, capacity 70 kt/a.
- Composting plant ID CZB00247 “DUFONEV R.C., a.s.” IČ 25538748.
- Composting plant ID CZB00103 “SETRA, s.r.o.” IČ 220159, capacity 10 kt/a.

In addition to these devices, aerobic systems of community and domestic composting can be considered, although in these systems waste does not enter the waste statistics. The capacities of the current composting plants are more than sufficient for the needs of the city, even in the case of an eventual increase in the separation of biodegradables.

8.1.4 Current MW collection system

A properly set separation system is a key indicator for achieving WM goals. The city of Brno provides a separate collection of plastic, paper, beverage cartons, glass, metals and it using container collection and collecting yards. The containers are operated by standard garbage trucks or other specific loading technology.

The number of containers for paper, plastic and glass in the city of Brno is presented below, as well as information on the number of empty. Altogether, 1,387 paper containers (Table 6), 1,351 plastic containers (Table 7), and 1,910 containers for glass (Table 8) are in currently operated in Brno city.

Table 6 Waste collection frequency – paper (Source: Brno WMP)

Separated MW	Waste collection frequency	Container volume (litre)				Total
		240	1,100	2,500	3,000	
Paper	1 times a week	68	338	-	-	406
	2 times a week	71	819	-	-	890
	2 times a week (underground container)	-	-	-	12	12
	3 times a week	-	62	-	-	62
	3 times a week (underground container)	-	-	-	1	1
	Request	-	16	-	-	16
Paper total		139	1,235	0	13	1,387

Table 7 Waste collection frequency – plastic (Source: Brno WMP)

Separated MW	Waste collection frequency	Container volume (litre)					Total
		240	1,100	2,500	3,000	5,000	
Plastic	1 times a week	60	210	10	60	17	357
	2 times a week	78	728	14	41	20	881
	2 times a week (underground container)	-	-	-	12	-	12
	3 times a week	-	79	-	3	2	84
	3 times a week (underground container)	-	-	-	1	-	1
	Request	-	16	-	-	-	16
Plastic total		138	1,033	24	117	39	1,387

Table 8 Waste collection frequency – glass (Source: Brno WMP)

Separated MW	Waste collection frequency	Container volume (litre)						Total
		240	900	1,300	1,500	2,500	3,000	
Glass	1 times a 14 days (underground container)	-	-	-	-	-	1	1
	1 times a 14 days (coloured glass)	380	-	-	2	1	-	383
	1 times a 14 days (white glass)	379	-	-	2	1	-	382
	1 times a 2 months	-		-	6	-	-	6
	1 time a month (coloured glass)	-		1	3	19	-	23
	1 time a month (white glass)	-	-	1	4	19	-	24
	1 time a month (coloured glass)	1	4	172	287	23	-	487
	1 time a month (white glass)	1	3	176	289	23	-	492
	2 times a week (underground container)	-	-			-	13	13
	Request (colored glass)	-	-	3	-	-	-	3
	Request (white glass)	-	-	5	-	-	-	5
	Request (coloured glass)	3	42	-	8	-	-	53
	Request (white glass)	3	28	-	7	-	-	38
Glass total		767	77	358	608	86	14	1 910

The tables show that they are used to collect both classical containers, separation bells and underground containers. Underground containers are used primarily in the city centre to provide sufficient capacity.

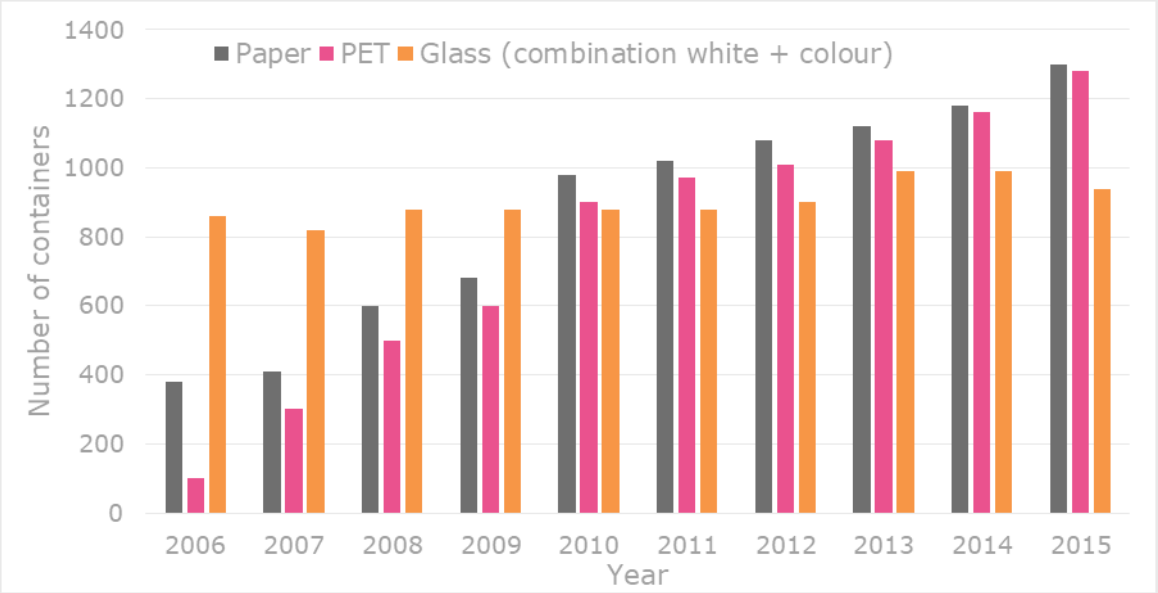

Figure 18 The number of containers in Brno (Source: Brno WMP)

An important aspect in WM is the residual MMW collection. This is a residual waste, which is preceded by the sorting of material recoverable, bio-waste, hazardous or high-volume waste. The information of containers in Brno is presented in Table 9.

Table 9 Waste collection frequency MMW (Source: Brno WMP)

MMW	Waste collection frequency	Container volume (litre)						Total
		60	110	120	140	240	1,100	
MMW (residual)	1 times a week	2,364	19,208	7,165	2,618	9,897	1,161	42,413
	2 times a week	2	1,666	833	71	7,119	2,957	12,648
	3 times a week	-	-	-	-	66	430	496
MMW total		2,366	20,874	7,998	2,689	17,082	4,548	55,557

8.2 Thermal treatment in SAKO Brno, key installation for effective utilisation of residual waste

The waste to energy facility ensures inertisation of biodegradable waste and it is also an important source of energy as it operates as a heating plant and power station. However, unlike these sources, it does not utilise primary non-renewable materials and energies to produce steam and electricity. The generated steam covers part of heat demand in Brno.

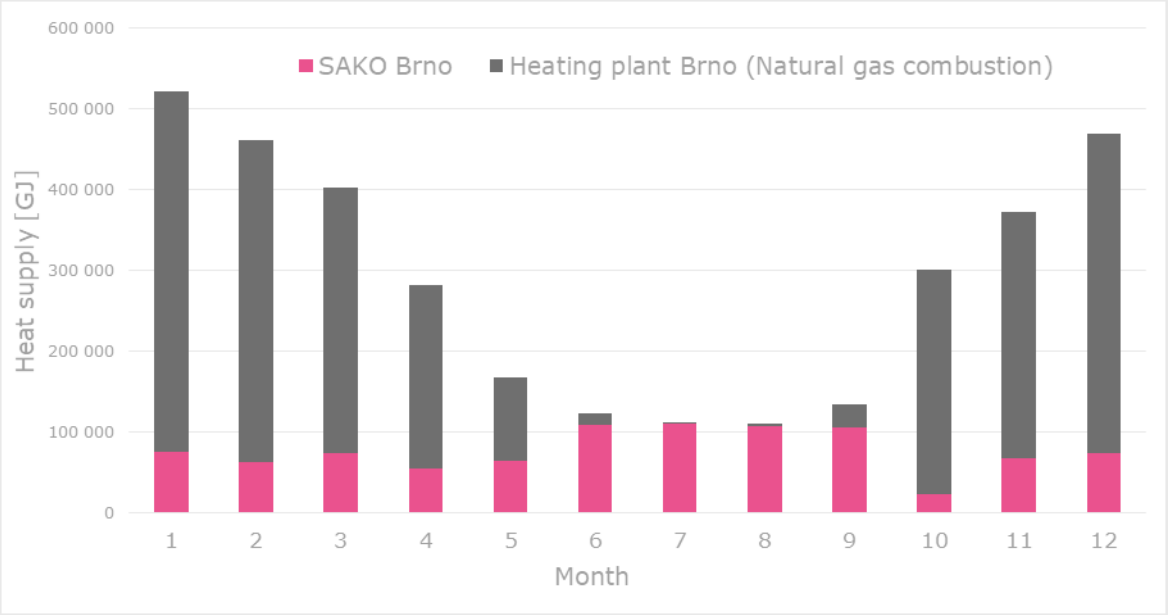

Figure 19 Heat supply – Heating plant Brno and Waste-to-Energy plant SAKO Brno (Source: Brno WMP)

Technological process of SAKO Brno WtE facility:

Weighing system – The weighing system is the inlet point for trucks of all suppliers and consumers of waste and raw materials. Weighing is automatic and the data is processed by a special software programme. On arriving at the incineration plant, the trucks bringing in waste pass through a detection system that can detect ionisation radiation. The weighing system keeps records of inputs and outputs to/from the waste to energy facility. This is where the waste path is divided into the path for waste intended for energy recovery and path of separately collected waste intended for final sorting at the post-sorting line.

Waste bunker – Once weighed, the truck with combustible waste heads towards one of eight feeding gates. The operator checks the declared waste and permits its emptying into the bunker. The crane operator uses a polyp grab to remove the fed-in waste from the inlet chutes of the waste bunker and crushing system chutes and moves the waste further into the bunker where the waste is homogenised and feeds the waste into the hoppers of the individual boilers.

Boilers with accessories – The boiler room is fitted with two five-pass boilers with reverse grates type MARTIN, whose technical parameters and air mode ensure optimal operating conditions of the waste incineration process. Waste neither fed to the boiler burns by itself and does not need any additional fuel. Waste passes through the heating, drying, gasifying, burning and final burning stages on the grate. The temperature in the boiler incineration chamber is above 1000°C. The waste incineration product – slag – falls into a wet extractor. This is where the slag is extinguished and cooled and then transported through a vibration sorting system via a belt conveyor to the slag bunker.

Turbine – Superheated steam passes through a bleeder condensing steam turbine with high

pressure and low-pressure sections. High-pressure superheated steam expands in the turbine and thermal energy and pressure energy are transformed into mechanical energy resulting in mechanical action through a bladed rotor drive. The rotor is connected to a gearbox and el. power generator transforming mechanical action into el. energy. Regulated as well as unregulated turbine takeoff ensures electricity generation as well as steam supply for the central distribution system of the city of Brno as well as for technological purposes.

Chemical water treatment – Chemical water treatment ensures sufficient supplies of feeding water with the defined parameters for the entire boiler boiling system. The feeding water consists largely of return condensate coming from the CZT network, clean condensate from the air-cooled condenser and water from chemical water treatment which mainly utilises drinking water for the treatment. Given the relatively high salt content in raw water, if untreated, the boiler boiling system would get clogged with mineral sediments and the turbine could be damaged and oxygen dissolved in water would strongly contribute to the boiler boiling system corrosion.

Flue gas treatment – An integral part of the waste incineration technological process is the five-stage flue gas treatment system.

- First flue gas treatment stage is installed directly in the boiler incineration chamber. Chemical reactions ensure a significant reduction in the volume of nitrogen oxides in the flue gases.
- Second flue gas treatment stage is adsorption of heavy metals and persistent organic pollutants type PCDD/F, PCB and PAU.
- Third flue gas treatment stage consists in the spraying of finely disperse aqueous limy suspension in flue gas stream. Gaseous flue gases from the boilers are fed through flue ducts into absorbers where the flue gases are cleaned.
- Fourth flue gas treatment stage is installed in the flue duct between absorbers and textile filters and it is based on the dry lime method consisting in the addition of dry slack lime into the flue gases stream. This treatment starts automatically if the concentration of acid components in flue gases increases.
- Fifth flue gas treatment stage is textile filters used to separate all mechanical pollutants and solid reaction products from the flue gases. The end product of flue gas treatment consists of limy salts, fly ash, activated carbon and reagent excess. The entire flue gas treatment process is controlled automatically by a control system so as the output of the flue gas treatment system contains a residual content of monitored pollutants at a level below the permissible emission limits. The flue gas treatment efficiency with respect to the pollutants is at 99 %. Before entering the duct, the flue gases are continuously monitored and evaluated.

Slag management – Slag management is the end-of-pipe technological system treating slag - the waste inert product of the incineration process. The technology is used to handle and separate slag, it consists of a slag bunker, traveller crane, conveyor system and separation line. After passing the combustion chamber, slag passes through a wet slag extractor and via belt conveyors it is transported to a concrete bunker. Sorted iron and aluminium are transported off-site for further reuse as secondary raw materials. Slag is used to secure landfill sites. The company's objective is to ensure such quality parameters of the slag to enable its use as building material (backfill, underfill) and thus minimise waste production.

8.3 Current WM objectives in Brno city

The current WM objectives can be divided to:

- Project "**Second Life**".
- Project "**RE-NAB**".
- Project "**RETRO-USE**".
- Project "**RE-TEX**".
- Domestic waste composting.
- MW treatment facility.

Project "Second Life"

The City of Brno will be continued in the activity **"**POINT USE**"**, which is described in the analytical part of the Brno waste management plan. In the next phase of the project, it is planned to increase the number of RE-USED POINTS and to introduce reusable boxes (cartons, reusable boxes for collection of products for reuse), and then the boxes can be collected at all waste collection centres in Brno.

Project "RE-NAB"

The RE-NAB project has been launched in the city in April 2016 to support the use of old furniture, "furniture bank". The RE-NAB functional furniture project is an example of coordinated collaboration between the Department of the Environment and the Department of Social Welfare of the city of Brno. Residents of Brno can donate unnecessary furniture to people with social problems.

Can be devoted:

- wooden, metal or plastic tables, tables, chairs, cabinets, chests of drawers, beds, and shelves,
- all other usable furniture,
- garden furniture.

Due to hygienic reasons, upholstered furniture is not donated. In the city of Brno, there are four waste collection centres (SS Veveří, Jan Svoboda, Okružní and Hapalova) where large containers, for old furniture, are located. Then the old furniture is transported to SAKO Brno, a.s. Here is a prepared list of currently available furniture with real photos. Subsequently, the Social Welfare Department offers the old furniture inhabitants of the city of Brno with the social problem. These inhabitants haven't funded for new equipment of the flat or family house.

Project "RETRO-USE"

The Statutory City of Brno project "RETRO-USE" is a unique activity for the prevention of waste from culture and social areas. Since August 2016, RETRO-USE has been supporting everything that is no longer needed in households, made before 1989, and also interesting for cultural institutions. From a historical point of view can be devoted interesting items such as:

- books, magazines,
- household equipment or technical equipment,
- personal papers,
- old photographs,
- films,
- toys,
- and sporting goods.

Some of them are cleaned or repaired and storage in museums or using for theatres activities. RETRO-USE is also a social project, including the establishment of a sheltered workshop, some of the old items can also serve for students. Project RETRO-USE will help to lengthen the lifecycle of old items. The Statutory City of Brno cooperates with the American Fund, o.p.s. and other cultural institutions such as the Moravian Gallery, the Brno Technical Museum, the Military Historical Institute.

Project "RE-TEX"

The RE-TEX project is based on the use of older clothing and textiles. All waste collection centres in the city of Brno will be involved in the project. At the same time, a wide network of containers on the streets of the city of Brno is created. These containers should reduce the walking distance and contribute to higher utilization of the containers. Textil from containers will be taken to the warehouse hall for re-sorting, hygienisation and storage. The re-use of sorted and hygienised textiles is mainly planned through the social services.

Domestic waste composting

The city will continue to distribute domestic waste composters among inhabitants to family houses and block of flats. This step depends on the interest of the inhabitants and there is the correct step how to reduce biodegradable waste in mixed municipal waste. According to this activity, there is a potential take subsidy from the Environmental Operational Program and cooperate with the company SAKO Brno, a.s.

MW treatment facility

The "Brno Recycling Center" project is being prepared by SAKO Brno, a.s. because of the outdated sorting line in the waste-to-energy plant area. The centre will produce secondary raw materials and potentially further material recovery. The project will support the collecting network and infrastructure within the city of Brno and it consists mainly in construction and modernization of municipal waste collection, sorting and treatment facilities (collection and separation technique, collection yards construction, overground and underground containers and related infrastructure) and increase in production of secondary raw materials. The project is described in more details in section 8.4.

8.4 Current "advanced" SMART solutions in Brno City

Current trends in SMART solutions in Brno are very few. As a key SMART solution can be considered the integration of the heating plant and the waste-to-energy plant in the heat supply for the city. From the point of view of WM, modernization of the waste treatment centre in SAKO Brno, a.s. and consequent infrastructure and motivation programs are projected for a purpose of secondary raw material production. Currently, the project is registered in the EIA[35] information system. Other solutions that are acceptable the Brno city are described by SWOT analyzes in section 9.2.

Recycling centre project

The project is divided into three main parts:

- **Glass separation:** The city of Brno will have a unified system of glass collection and its transport and preparation for further processing. It will be necessary to increase the number of containers, optimizing their volume and allocation, to invest in collecting vehicles and ensuring a regular collection. Separated glass will be collected from the entire Brno agglomeration. The glass waste will be stored in a collection centre and then after removal of undesirable admixtures sell to the authorized person for further processing.
- **Collection centre:** The new large collection yard will serve not only for citizens from the adjacent agglomeration but also for local companies to ensure collection of more MW types by a single system. Areas for concentration and subsequent sorting will be built on the site and large capacity storerooms and handling vehicles will be acquired. Subsequently, the commodities will be distributed for further recovery (both material and energy). The project also includes a connection to the railway.
- **Sorting line:** Due to the increase in the quantity and separated waste in the agglomeration area, it will be necessary to build a new sorting line which will have sufficient capacity. The technology will be also applicable to more MW types and sorting procedures.

[35] www.portal.cenia.cz/eiasea/detail/EIA_JHM1435

9 The Spitalka district – basic description of the territory

The Brno City Council has approved the selection of a part of Teplárny Brno (heating plant) area and Spitalka area as a locality for investment plan development. In the future, there should be a modern, low-energy **district corresponding to the SMART city parameters** in the locality. The district can become an inspirational pattern for further city development, which will provide not only housing but also a potential for business opportunities to avoid unnecessary mobility. The aim is to create a modern district, using state-of-the-art techniques and trends, where it can demonstrate the current opportunities in the construction of an energy self-sufficient and sustainable districts which will respond to the actual needs of citizens with regard to the self-sufficiency and sustainability of this place.

An initial analysis is prepared, which will describe the limits and possibilities of the use of this territory, and an urban-architectural competition will be prepared which will include a wider area projection and it will be pre-announced during the year 2019. It is also necessary to prepare changes in the valid land use plan and, together with the academic sector, to suggest which advanced techniques would be used for the district construction. Concurrently, construction finance modules will be assessed. After the project documentation preparation and all necessary permits obtaining, construction could begin sometime in 2022.

The Spitalka and heating plant area are located in the Brno-střed (Brno-centre) district in the area between Vlhká and Cejl Street. This area has the considerable territorial potential for urban development. Along the eastern and southern parts of the heating plant, the existing production facilities at Plynárenská, Spitalka and Radlas are actually being rebuilt. In this locality, it is also prepared the project of revitalization of the Ponec river along the Plynárenská Street in connection with the entrance to the heating plant. The area locality is obvious in the Brno agglomeration map in Figure 20, a more detailed view of the area of interest is in Figure 21.

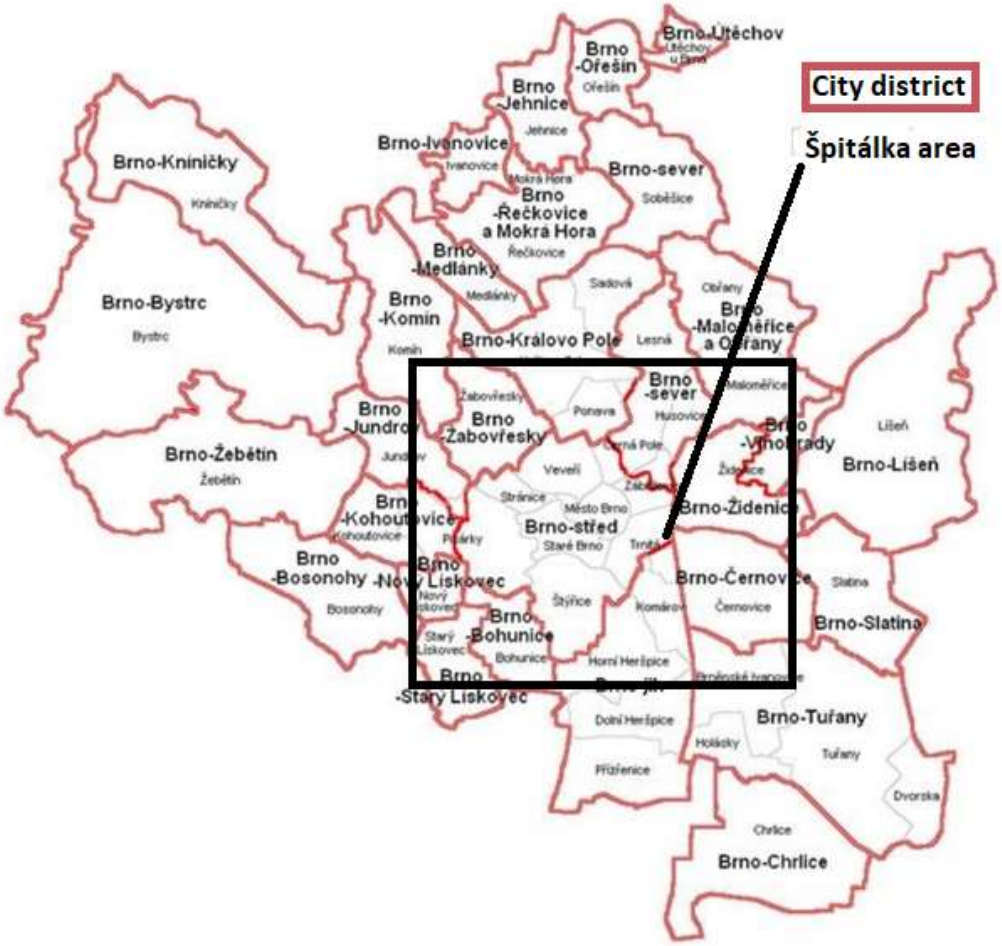

Figure 20 Brno agglomeration – 29 city districts, more details are obvious in the figure below

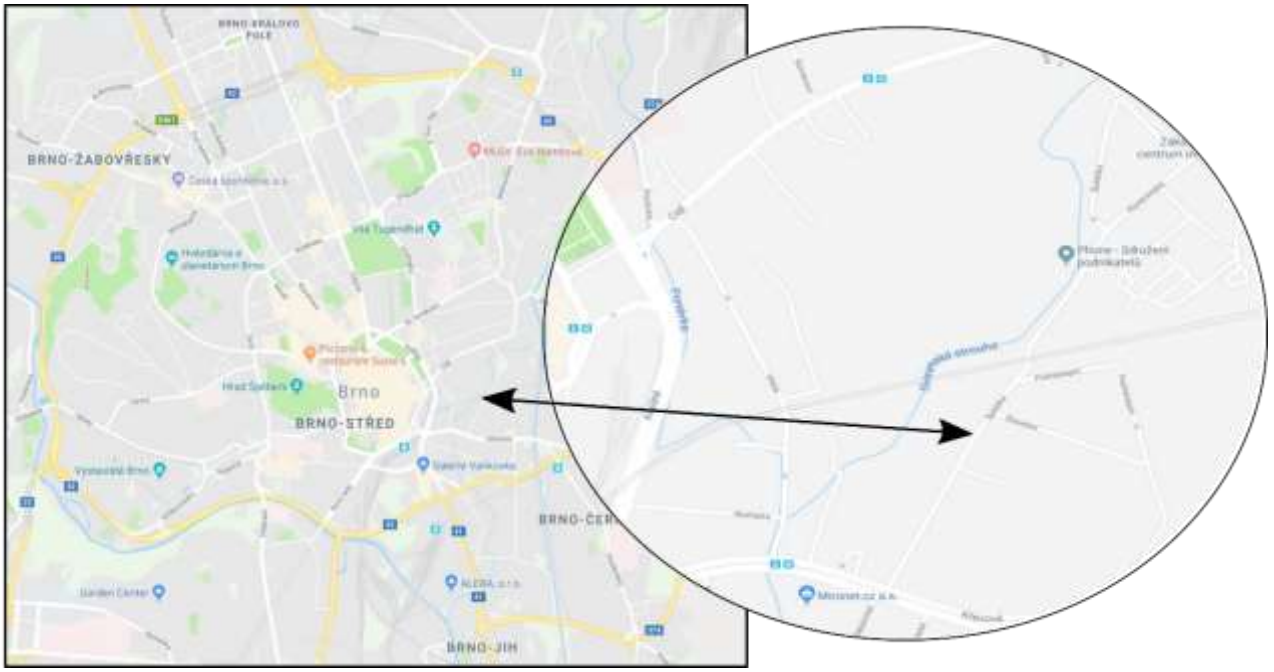

Figure 21 Location of Spitalka district

9.1 Waste production prognosis for subject area

The forecasting procedure uses trend analysis as a basic tool that shows the basic trend in the development of the production of a particular catalogue number or a group of categorical numbers. Afterwards, the result of the forecast is corrected using the data from every municipality in the Czech Republic. The correction is made by balancing the data with the ***JUSTINE* tool**[36,37] with respect to the forecast trend in the higher territorial unit (it must be true that the sum of the forecasts generated at the level of all the municipalities is in line with the forecast at the level of the region or the whole territory).

In the case of the MSW, which falls under the municipal collection system in the municipality Brno, a long-term decreasing trend can be seen. Based on the forecast, production is expected to be around 64.5 kt in 2024 see in Figure 22.

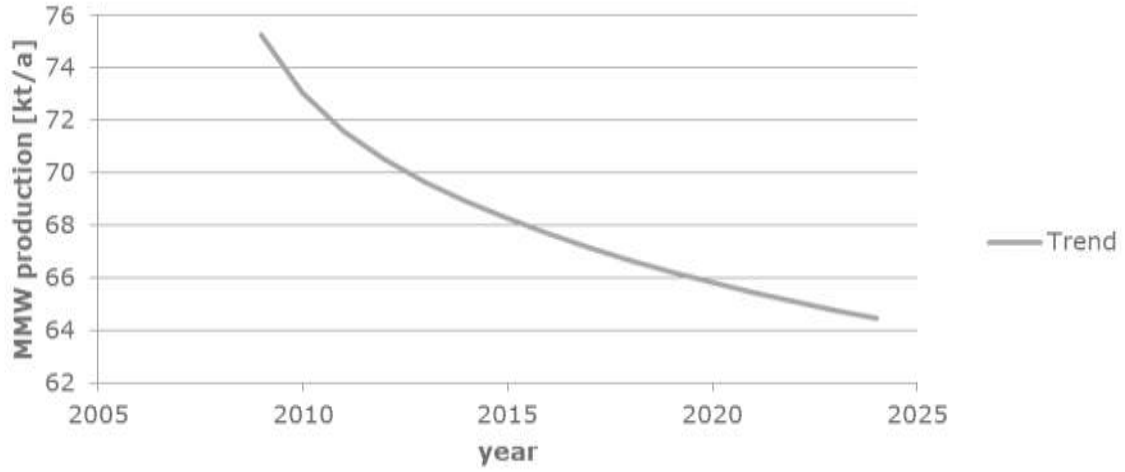

Figure 22 Mixed Municipal Waste production in Brno (Source: BUT UPI)

Total production of MSW, which is produced within the system of municipalities and firms, recorded the most significant decline in 2010. From this period it shows a slightly decreasing trend. In 2024, production is estimated to be approximately 103.3 kt (

[36] Jiří Kropáč, Radovan Šomplák, Martin Pavlas: Hazardous Waste Treatment Infrastructure Planning – A Multi-Commodity Mathematical Modelling Approach

[37] More information about tool in Appendix 2

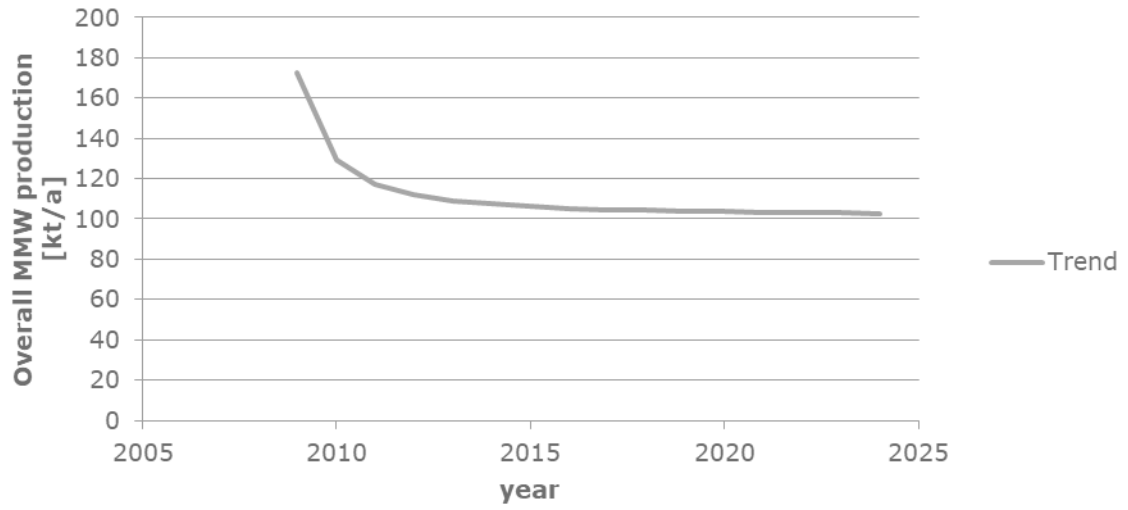

Figure 23).

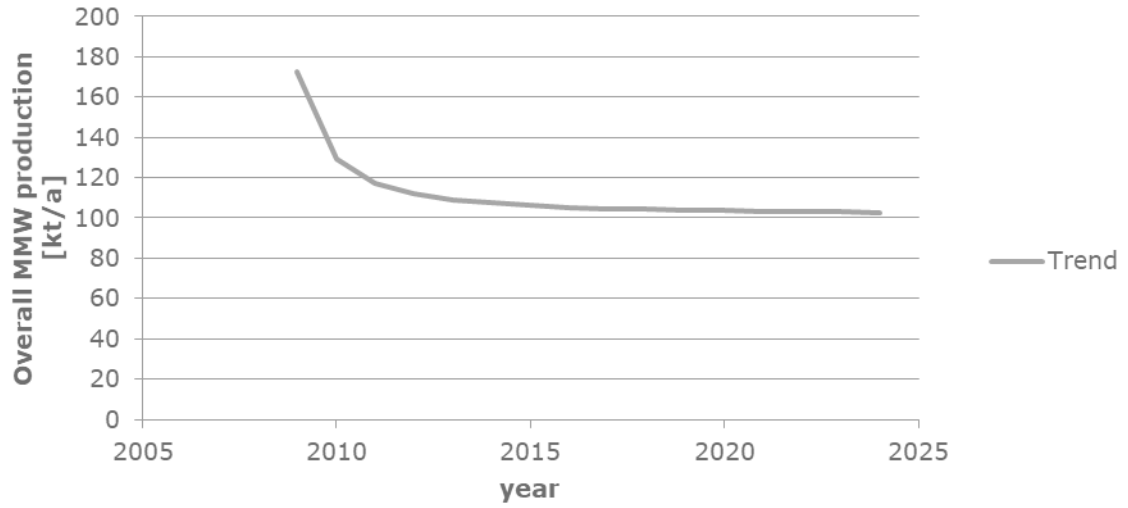

Figure 23 **Overall Mixed Municipal Waste production in Brno (Source: BUT UPI)**

Separated MW paper production prognosis for 2024

Separate paper production has a marked upward trend over the period under review. The resulting prediction, which was created by the balancing by *JUSTINE*[38] tool, diverges from the original trend to lower values. This is due to the character of forecasts within the territorial division of the all considered areas. For the year 2024, paper production was forecast at 13.2 kt (Figure 24).

[38] More information about tool in Appendix 2

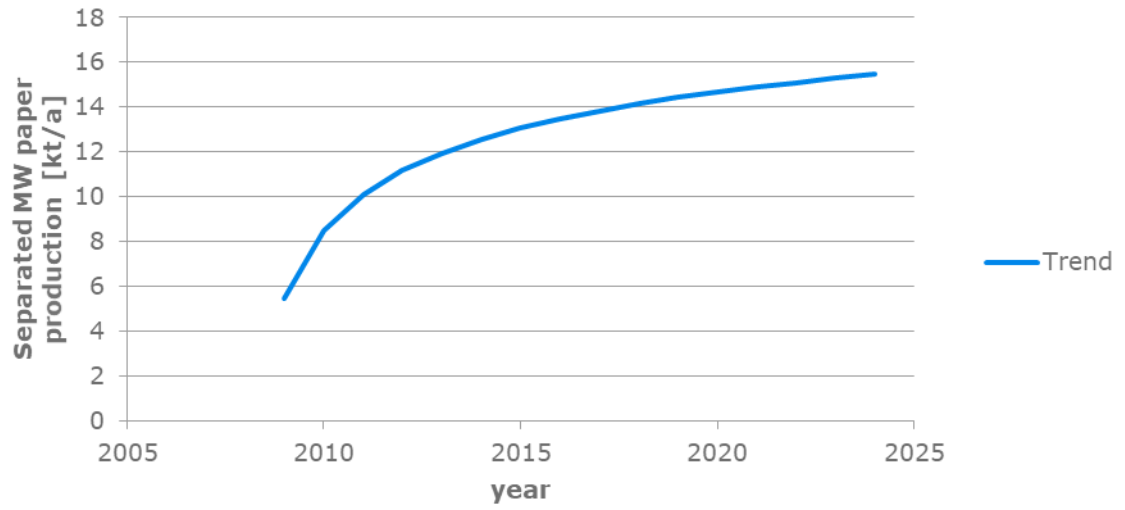

Figure 24 Separated Municipal Waste – paper production in Brno (Source: BUT UPI)

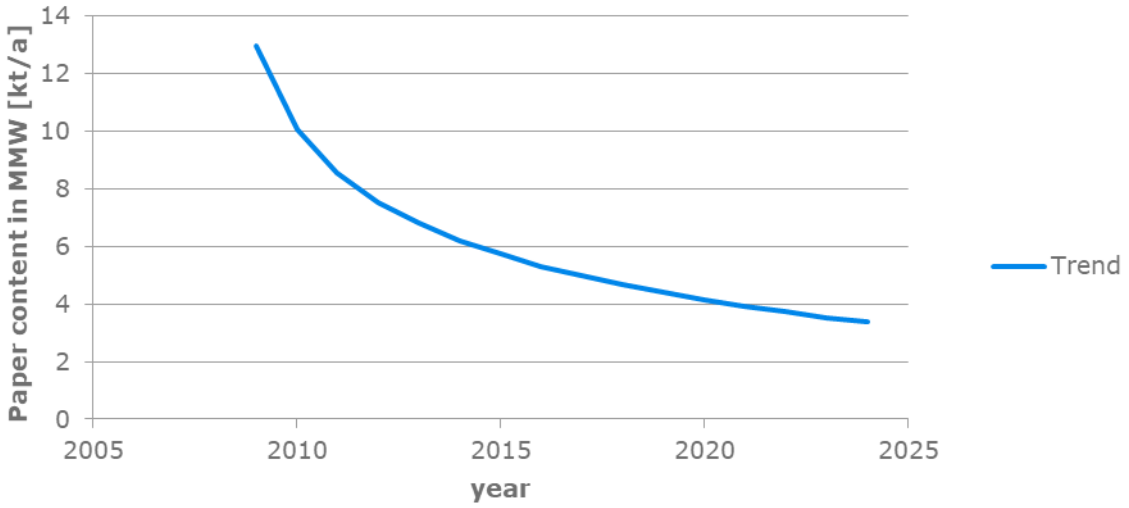

Figure 25 Paper content in Mixed Municipal Waste in Brno (Source: BUT UPI)

Due to the decreasing trend of MSW production and the increase of the amount of paper that has been decomposed, it is expected that the content of this component will decrease in MSW, confirming the residual paper data in the MSW with a considerable decreasing trend. This development also reflects the paper separation rate, which is estimated to be 70.5% for 2024 (Figure 26).

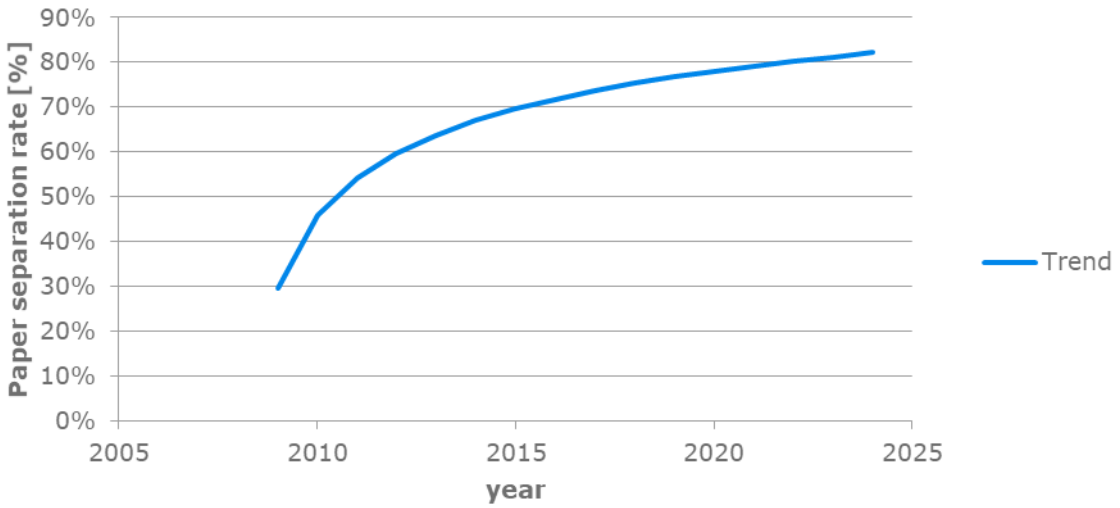

Figure 26 Paper separation rate in Brno (Source: BUT UPI)

Separation rate of paper in 2015 shown the histogram in

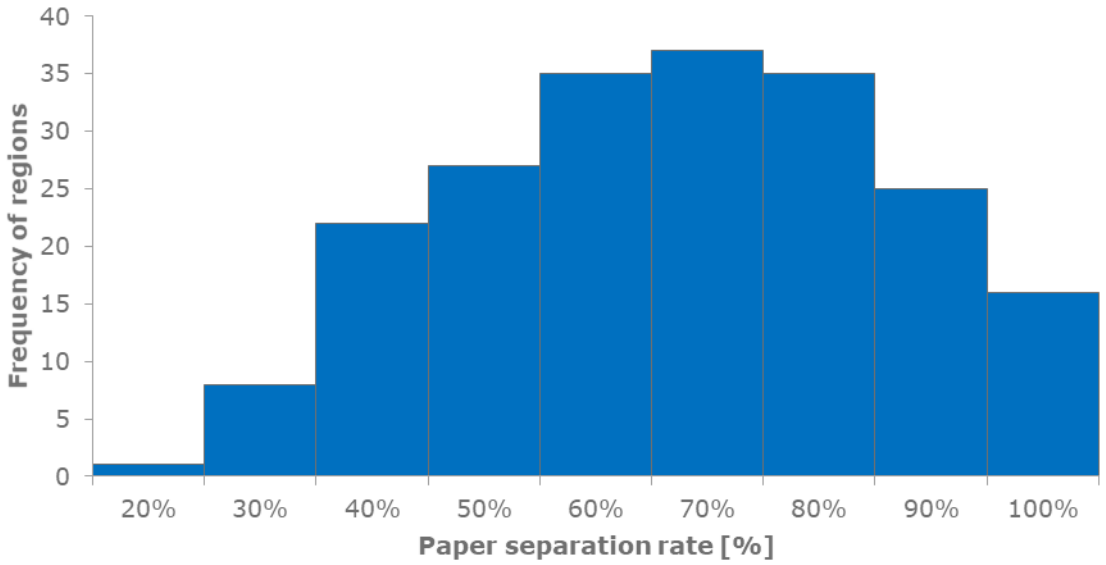

Figure 27 for all Czech regions. The city of Brno achieves a separation rate of 65.6%, thus not significantly different from the average MS from all the regions in the Czech Republic.

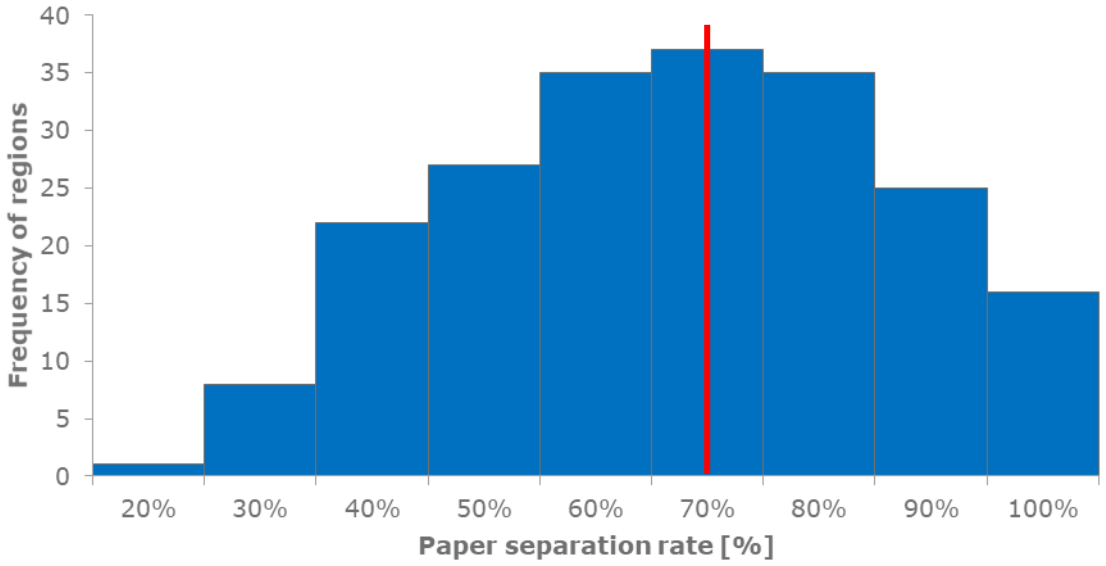

Figure 27 Paper separation rate – histogram (Source: BUT UPI)

Separated MW plastics production prognosis for 2024

Also, the production of separated plastic has a considerable **increasing trend** during the period under review, which was almost linear in its character. Estimates of plastic production for 2024 are about 3.1 kt, which corresponds to almost 60% increase compared to 2015 - the period with the latest available data (Figure 28).

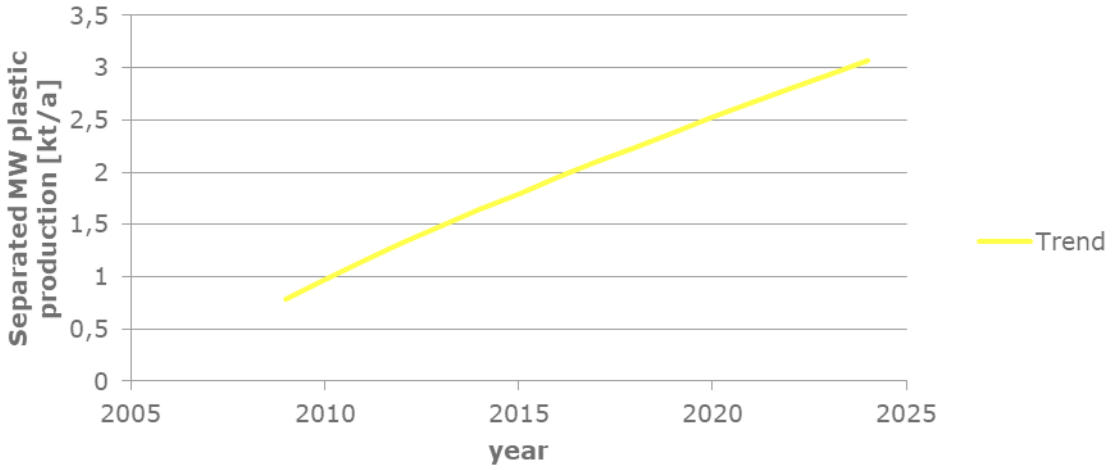

Figure 28 Separated Municipal Waste – plastic production in Brno (Source: BUT UPI)

Higher production of the separated plastic is reflected in the residual amount of this component in the MSW. The projected decrease in the amount of plastic in the MSW is 6.2 kt for 2024 (Figure 29).

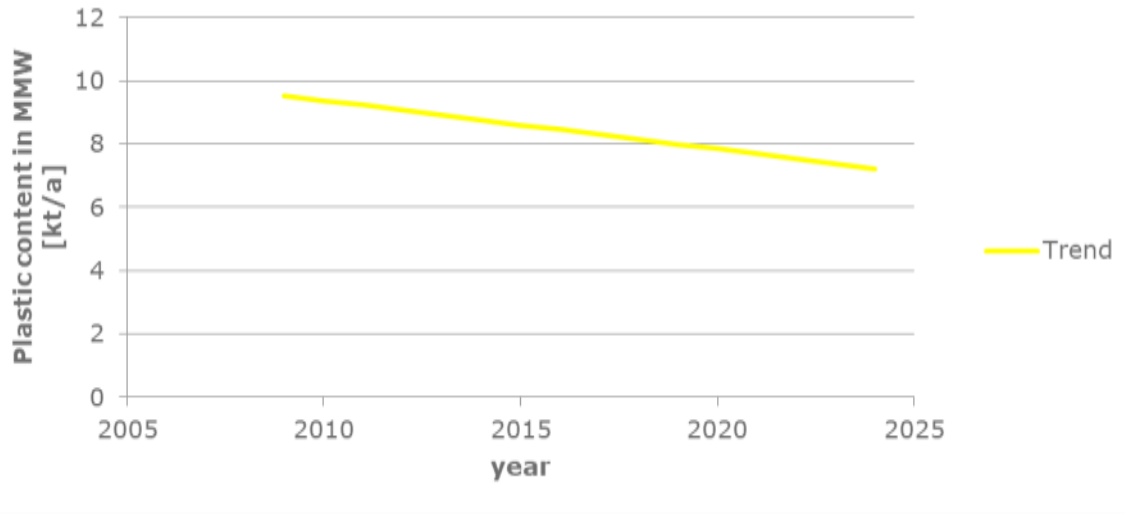

Figure 29 Plastic content in Mixed Municipal Waste in Brno (Source: BUT UPI)

For the separation rate, this development would mean an increase of up to almost 35%, which is below the average values within individual municipalities in the Czech Republic (Figure 30).

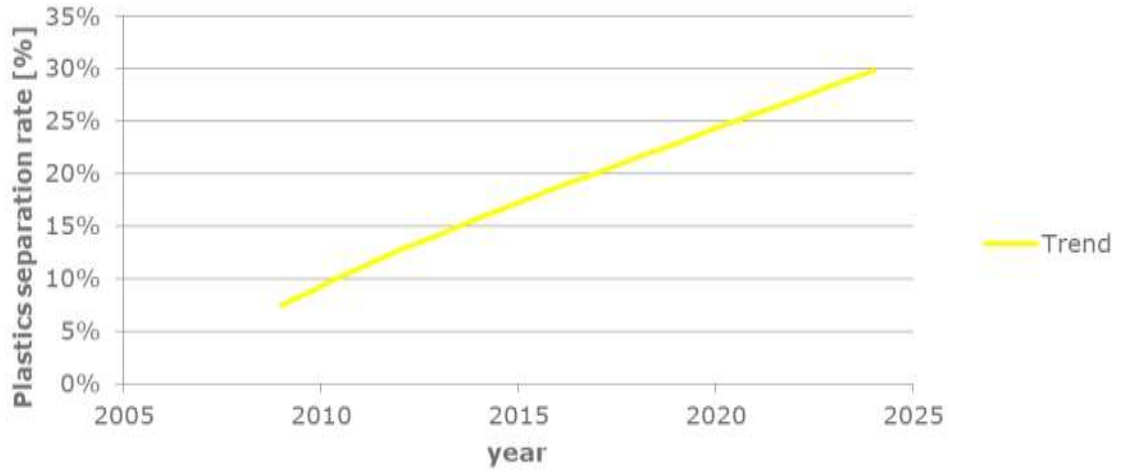

Figure 30 Plastics separation rate in Brno (Source: BUT UPI)

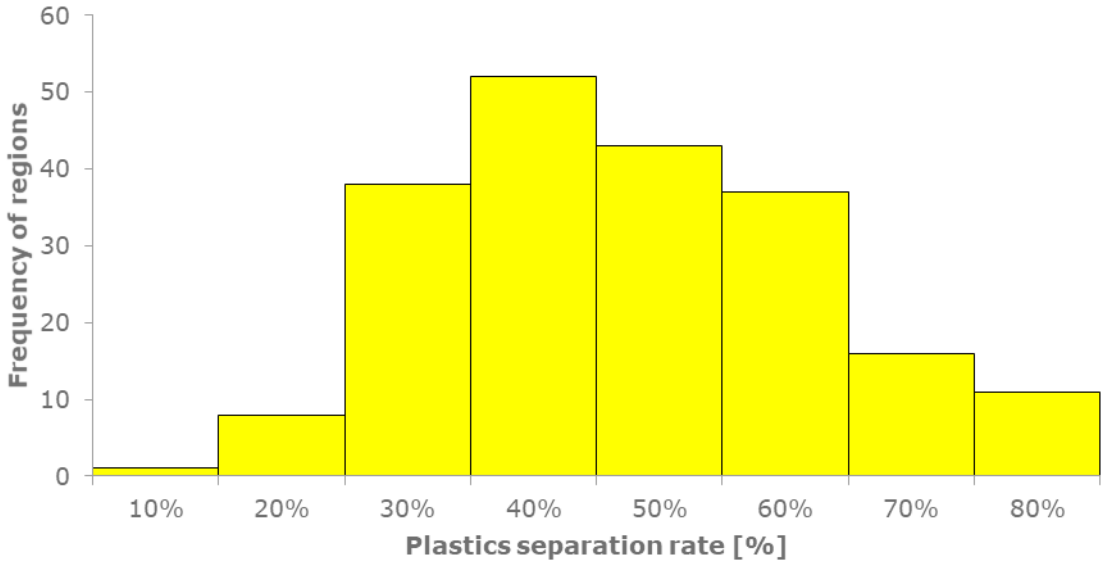

Figure 31 for all Czech regions. The city of Brno has reached 19.7% this year. It is thus ranked to significantly below average values and points to the potential for increased plastic separation.

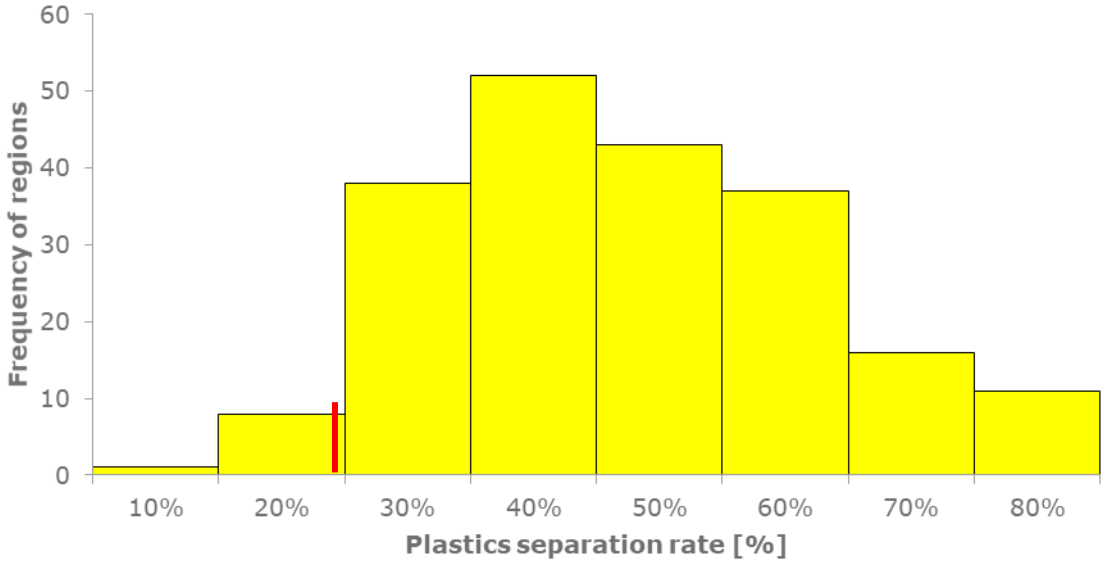

Figure 31 Plastics separation rate – histogram (Source: BUT UPI)

Separated MW glass production prognosis for 2024

The amount of separated glass in Brno in the monitored period 2009-2015 is around 3.2 kt and shows a slightly increasing trend. For 2024, the predicted glass amount is about 3.8 kt (Figure 32).

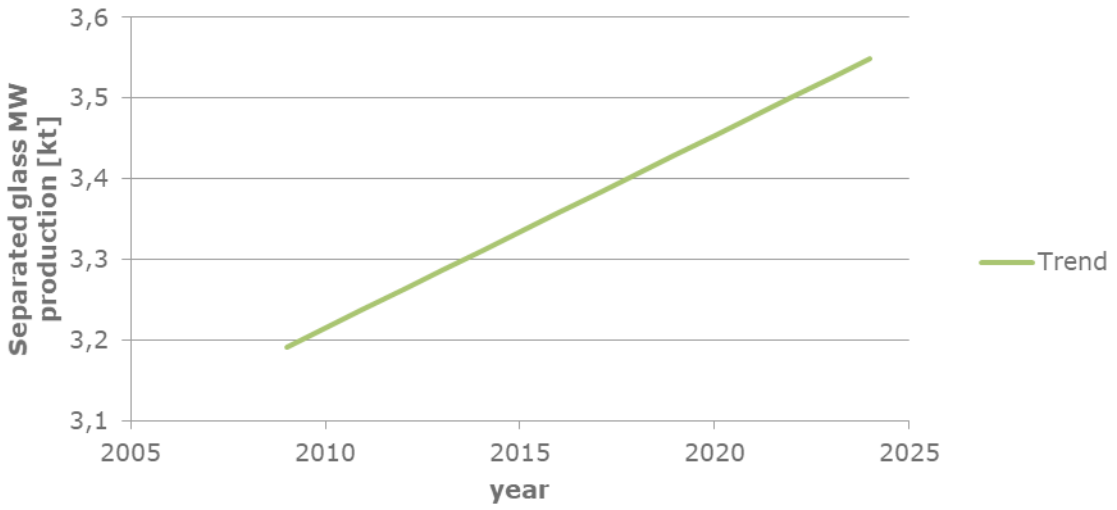

Figure 32 Separated Municipal Waste – glass production in Brno (Source: BUT UPI)

The amount of glass in the MSW does not show significant changes, a decrease was only in 2015. On the basis of *JUSTINE* balance, however, a 2024 decrease in the amount of this component in MSW is predicted to be around 4.3 kt (Figure 33).

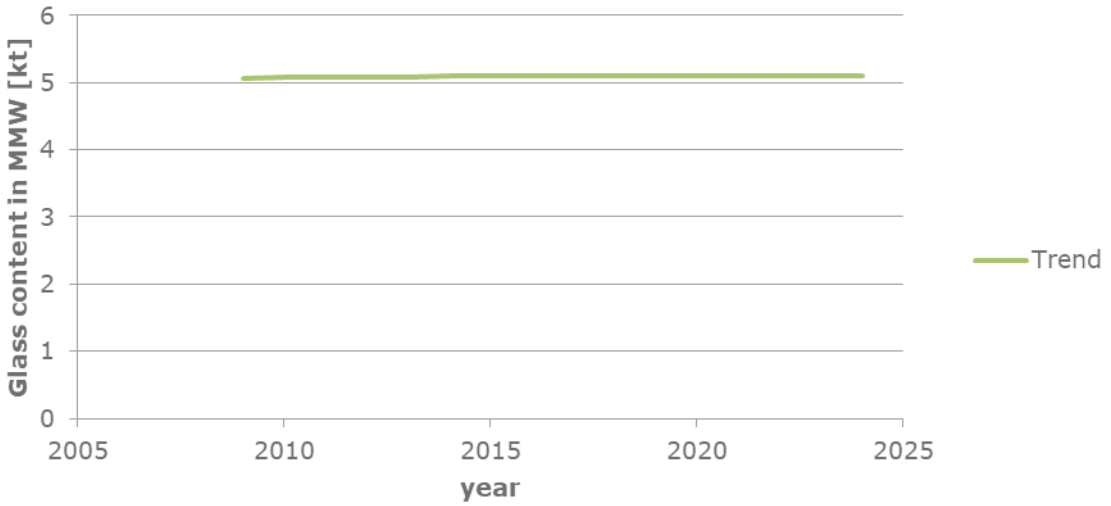

Figure 33 Glass content in Mixed Municipal Waste in Brno (Source: BUT UPI)

The separation rate is around 40% in the monitored period. By 2024, it is **expected to grow** to 47% (Figure 34).

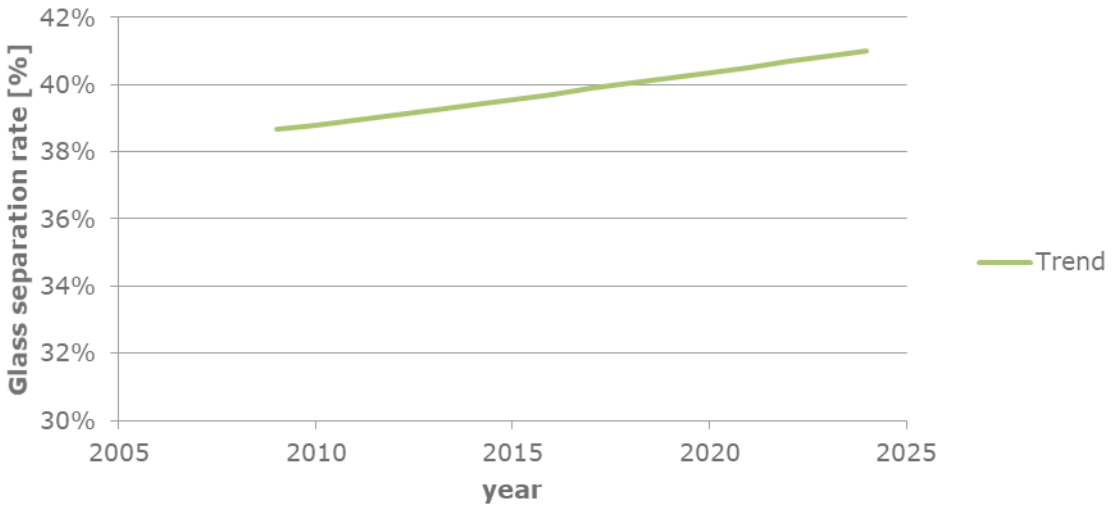

Figure 34 Glass separation rate in Brno (Source: BUT UPI)

Separation rate glasses in 2015 shows the histogram in

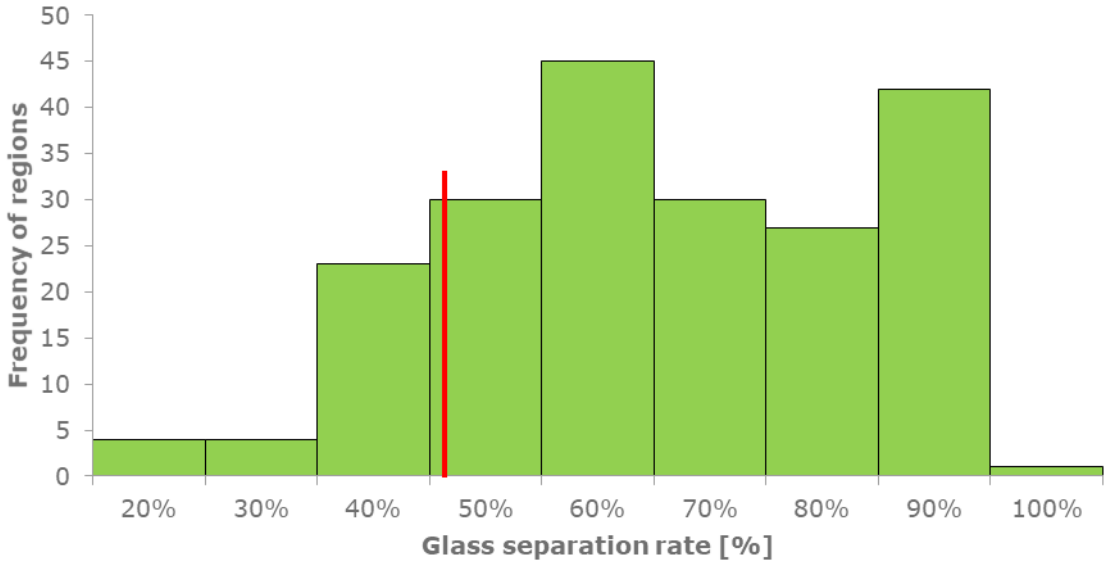

Figure 35 for all Czech regions. The city of Brno reached 41.5% this year. Thus they re-rank the under-average values of separation rate by individual regions in the Czech Republic.

Figure 35 Glass separation rate – histogram (Source: BUT UPI)

In the case of biowaste sorting, the question arises as to which waste stream the biowaste is diverted. Generally, it is assumed that part comes from the MSW, and the rest of the sorted biowaste was out of the waste register by this time and emerges as a new waste stream (household garden waste). The aim of the analysis was to estimate how much of the sorted biowaste comes from the MSW. BUT Brno performed an analysis based on data for all municipalities, which showed the following conclusions:

- The amount of MSW produced is not dependent on the efficiency and yield of the biowaste sorting in the municipalities.
- In a more detailed analysis, the change between municipalities with different types of development is not significant either. The correlation was not confirmed for municipalities with predominantly rural development or urban development.
- Overall, the analysis shows that the currently sorted biowaste does not come from the MSW, but the majority is given as a new mass flow.
- But the main difference is the absolute amount of sorted biowaste. In the municipality with the predominant village development, there is significantly more biowaste (200 kg/person) than in the municipality with the prevailing urban development (60 kg/person).
- In the forecast, waste with internal bonding was taken together, i.e. MSW, paper, plastic, glass. Bio-Waste was predicted separately. The potential for average separation of up to 200 kg/inhabitant for housing with family houses (0-8 inhabitants per unit number) and 60 kg/inhabitant for urban development is assumed. The histogram shows what part was filled with potential separation in 2015.

For Brno, the amount of biodegradable waste has reached 8.5% of the separation potential, which is

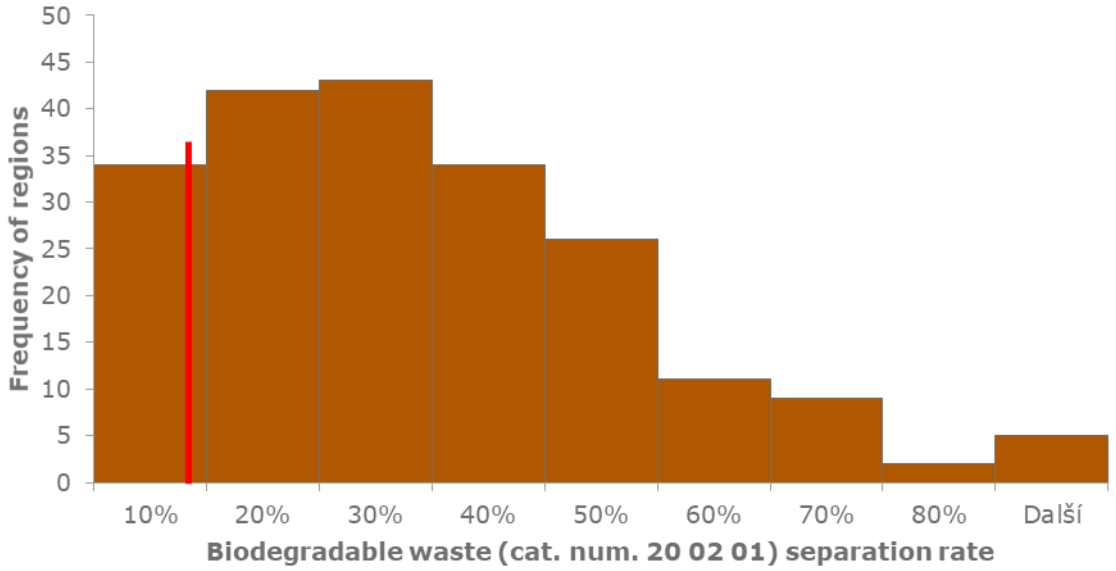

Figure 36).

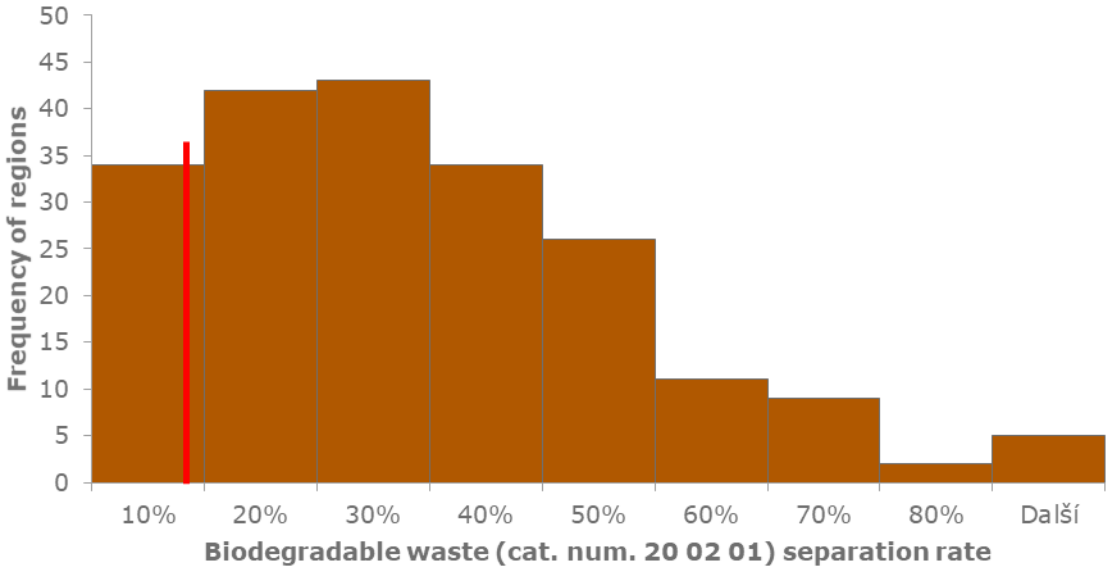

Figure 36 Histogram of biodegradable waste – separation rate in Brno (Source: BUT UPI)

Bio-waste production in the municipality with extended powers Brno shows a growing trend, which was modelled by a logistic curve. The maximum production limitation of the catalogue number 20 02 01 was set to the value of the separation potential (for Brno 35.2 kt) see in Figure 37.

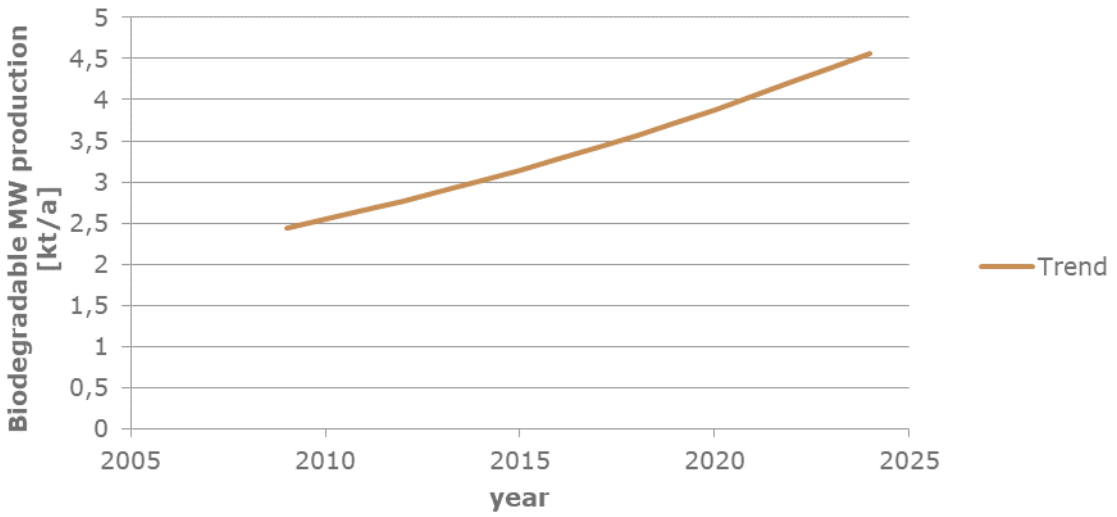

Figure 37 Biodegradable Municipal Waste production in Brno (Source: BUT UPI)

9.2 SWOT – Effective waste collection

With reference to section 4 selected concepts are briefly evaluated here in Brno WM context:

- **Metrotaifun** – Table 10
- **Underground SMART containers** –

- Table 11
- **Kerbside collection** –
- Table 12
- **Monitoring** of collection containers –
-
- Table 13
- An **advanced** system of **PAYT** –
- Table 14

Table 10 SWOT Metrotaifun

Strengths	Weaknesses
• Waste collection from one point – collecting vehicles routes minimized/committed • Modern and innovative solutions that correspond to the smart city concept • User-friendly solution	• The need for relocation of existing engineering networks • Investment demand • Operational demand
Opportunities	**Threats**
• Comfortable waste collection in high-standard residential areas • Minimizing waste collection costs • PAYT introduction even in densely-populated residential areas • Use of existing vehicles to transport full and empty containers	• Long project realization • Property investors involvement • Bad compatibility (administrative issues, technological solution) within adjacent territories (old and new housing)

Table 11 SWOT Underground SMART containers

Strengths	Weaknesses
• The aesthetic aspect of the installation of underground containers • Use of large volume of containers with acceptable walking distance • High concentration of separated waste at a particular spot • Inhabitants motivated to ZERO waste concept	• The need for relocation of existing engineering networks • Investment demand • Road performance for of heavy vehicles • It is necessary to use vehicles with a hydraulic arm • Longer walking distances to the containers in less-populated areas
Opportunities	**Threats**
• Residents can easily sort waste with recycling potential • The volume of containers is enough • Purchase of universal vehicles for the operation with containers and concurrently vehicles can be used for the technical provision of the city • PAYT introduction even in densely-populated residential areas • Dynamic (on-request) collection with increased operational cost	• Expensive repair and regular maintenance costs • High pollution risk in a potential accident

Table 12 SWOT Kerbside collection

Strengths	Weaknesses
• The regular collection at short intervals • Simple solution • Convenient for residents • Costs of introducing a kerbside system	• Planning issues • Time perspective • The high density of containers at single points • Unsightly view within the environment
Opportunities	**Threats**
• PAYT introduction even in densely-populated residential areas • Inhabitants motivation for separate collection	• Standard value-added system • Disapproved by the population to a large number of containers • Unavailability of containers • Operating costs for collecting • Variability of waste production

Table 13 SWOT Monitoring of collection containers

Strengths	Weaknesses
• The possibility of online monitoring of bins or containers • Collection planning • Evaluation and analysis of waste production	• Input and operating investment • Big data processing • Demanding technological solution • Updating
Opportunities	**Threats**
• PAYT introduction even in densely-populated residential areas • Optimization of waste collection • The potential for dynamic planning • Assessment of waste production and streamflow among analysed locations	• Data processing • Technological solution • The methodology of collection, analysis and evaluation • Error rate • Damage to sensors and containers

Table 14 SWOT Advanced system of PAYT

Strengths	Weaknesses
• The motivation of residents to a higher separation rate due to PAYT system • Easy to use • Excellent monitoring of waste production	• Investment cost • Functional connectivity of the system • Necessary checks on payment transactions (IT and customer system) • High processing fees • Technological solution
Opportunities	**Threats**
• Maximize sorting of interest commodities from MW • Minimize MMW production • Potential extending other services • Non-cash transactions	• Competition • Hacking and scams • Transferring money through third parties • Unwillingness to accept the system

The best case is to develop the SWOT analysis in more detail in the feasibility study and to find the most suitable solution for the Spitalka district.

10 Recommendation of the additional steps

Several **SMART technologies** and **concepts were reviewed** in the previous sections. Simple **SWOT analysis has also been introduced** with respect to Brno City. In the next step **potential application** of any of solution **should be elaborated** in more details.

Whereas the project Ruggedised focuses on the particular locality of Brno, a smart city solution is not an evaluation of one street, but above all the **integration of modern technological solutions into the concept of the whole city**. Even if Spitalka represents a demonstration area, where future SMART systems are to be implemented, in case of waste management, proposed solution has to be investigated in a broader context to enable implementation of such modern solution into other parts of the city. In several years Brno could be considered as a modern "SMART" city. Furthermore, Brno was one of the modern and competitive cities cooperating with the Ruggedised project. Even though the structure of Spitalka district in terms of occupants count, housing structure, and presence of businesses and services are not known yet, one can expect the rather low absolute amount of waste generated (which is given by the small area of the district even if population density will be high). This expected low amount of waste demands use of technology (e.g. vehicles), which can also operate in other parts of the city. Otherwise, the cost of service will be enormous.

It is recommended to:

- **Specify the area** in terms of expected population, housing structure and overall organization of the district. This will be the result of an urban study. This step also provides better insight into the expected waste production in the district.
- Narrow the list of **solutions and technologies**, which could be applicable in the Špitalka District. Interconnection with the existing system and future spreading into other districts should be addressed).
- Take advantage of up-to-date simulation tools to evaluate the positive and negative effects of implementing of each of the concepts. Here three pillars of sustainability are highlighted: **environment – economics – social acceptance**. It is also mentioned that **SMART concepts**, which are very often appealing to stakeholders, could significantly contribute to the future cost of the service. The simulation contributes to defining a concept as a trade-off of afore-mentioned pillars.

The research team (**BUT UPI**) can evaluate select examples by using their in-house developed tools that can work with real infrastructure, analyze existing plants, and predict developments from the point of view of overall waste management based on goals or legislative regulations. These include in particular:

- **The *NERUDA* tool**[39] - an optimization tool that can estimate the flows of selected waste streams, details the specifications in Appendix 1. An extension dedicated to vehicle routes optimisation within city infrastructure is available too.
- **The *JUSTINE* tool**[40] - a tool for analyzing current status and predicting the development of waste production based on historical trends, more detailed specifications in Appendix 2.
- **Techno-Economic models** - the research team has developed mathematical models eg for underground containers, transportation or collection, sorting lines, composting plant, waste to energy plant and others, which are an inevitable part of any feasibility study of such a concept.

Step 3 may be considered as a **Pre-feasibility** or **Opportunity study**.

[39] More information about tool in Appendix 1

[40] More information about tool in Appendix 2

11 Conclusions

RUGGEDISED is a smart city project funded under the European Union's Horizon 2020 research and innovation programme. It brings together three lighthouse cities: Rotterdam, Glasgow and Umeå and three follower cities: Brno, Gdansk and Parma to test, implement and accelerate the smart city model across Europe. Working in partnership with businesses and research centres these six cities will demonstrate how to combine ICT, e-mobility and energy solutions to design smart, resilient cities for all. This means improving the quality of life of citizens, reducing the environmental impact of activities and creating a stimulating environment for sustainable economic development.

The presented report summarizes basic **modern principles** in waste management. The main goal was to introduce readers with potential and smart solutions that can be accepted by the city of Brno. In the city of Brno is a **functional integration** of the heating plant with waste to energy plant, this solution can be considered as a **SMART solution**. The area of waste to energy plant prepared reconstruction of the collection centre in SAKO Brno. Construction of a modern sorting line is expected in the future, the project is ready for implementation.

A key step in this report was the creation of **questionnaires**. Summarization of outputs from the questionnaire should inform about waste management in others cities which were included in the project. All partner cities were contacted and asked for cooperation, i.e. Rotterdam, Glasgow, Umeå, Gdansk, and Parma. **A feedback was received from Rotterdam, Glasgow, Gdansk, and Parma**. The questionnaires were evaluated and the next round was a request in more details. The second round of questionnaires was received only from the city of Parma but not in full. Based on the evaluation of the questionnaire survey, the waste management in the selected cities was found to be well-developed. This is the field of waste sorting, the use of modern collection technology and the monitoring of collection and the use of optimization of collection routes. Three cities take advantage of a waste to energy plant operated in the city.

Section 4.7 deals with the evaluation of an appropriate solution for **Spitalka District**, which was conceived in the form of **SWOT analyzes**. Assuming the evaluation of only one street, it is necessary to consider the modern waste collection system and technologies, especially use intelligent underground containers, which have an aesthetic and operational aspect of an ideal solution. Also, it is necessary to determine what the assessment street or district character will be. Whether it is a residential development or a purely industrial quarter. And this fact has a big impact on the production and composition of waste. In the case of an industrial district, it may be the production of quality one-sided plastics, which can be a key product in the market.

Another key step was to create waste **forecasts with *JUSTINE* tool** for the city of Brno. The forecasts were based on historical data (years 2009-2015) and, with the help of modelling, a characteristic trend was created by 2024 (landfill ban). It has been found that the production of the separated component has an increasing trend, thanks to the provision of a decent collection infrastructure in the city. Until 2024, high rates of separation can be expected:

- Paper
- Plastic

- Glass
- Biowaste

With a higher level of separation, based on analyzes, the MMW is expected to decrease in 2024.

For the next step, a detailed evaluation of individual technological solutions in the form of the feasibility study should be done using advanced simulation tools. As an example, the tools created by BUT UPI (*NERUDA* Tool[41], *JUSTINE* Tool[42], Techno-economic model for selected technological solution) are mentioned.

[41] More information about tool in Appendix 1

[42] More information about tool in Appendix 2

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12 Appendix List

Appendix 1 – Basic information about *NERUDA* Tools
Appendix 2 – Basic information about *JUSTINE* Tools
Appendix 3 – Questionnaires (Gdansk, Glasgow, Parma, Rotterdam)
Appendix 4 – Questionnaires (Gdansk, Glasgow, Parma, Rotterdam) in more details
Appendix 5 – Basic information about cities (Gdansk, Glasgow, Parma, Rotterdam, Umeå, Brno)

Appendix 1 – Basic information about NERUDA Tools

What is NERUDA?[43]

NERUDA is a unique computational tool based on a simple principle implemented in a complex problem:

- It optimizes waste treatment strategy in a specific region from a waste producer point of view (regarding economics and environment).
- The region is divided in hundreds of nodes in order to be able to simulate unified waste market and interaction reated to competitive environment
- It integrates waste-to-energy facilities within energy concept of cities
- It analyses various waste treatment technologies

NERUDA – one tool – many ways of results presentation according to a customer‘s demand

The following subjects may contribute from its application:

- Strategy makers at country and/or regional level (government)
- Potential investors interested in new waste-to-energy plants
- Operators of existing plants

NERUDA – typical applications

- *Concepts at regional and countries level*

In 2013, NERUDA was applied to analyze the future demand for new WtE facilities in the Czech Republic. Forbidden landfilling was considered. The potential of heat delivery within existing district heating systems was adressed

- *Feasibility of investmentsin waste-to-energy*

Assesment of economic sustainability of projects in a specific locality. Risks such as change in production and quality of residual waste, which cannot be recycled, energy prices, legislation development and competitors strategies were evaluated.

- *Waste transport optimization*

Optimization of collection of waste commodities, finding a location for transfer stations and their capacities. Proposal of suitable technology for waste transport from producer to processor (road – railway – intermodal system). Daily Transport planning.

- *Unified waste market modelling*

Application of NERUDA tool for a region including more than one country. Impact modelling of different development of key parameters in individual EU countries (production, capacities, environmental taxes) for effective utilization and planning of Waste-to-Energy capacities.

NERUDA – Find more information about its scientific background!

ŠOMPLÁK, R.; PAVLAS, M.; KROPÁČ, J.; PUTNA, O.; PROCHÁZKA, V. Logistic model-based tool for policy-making towards sustainable waste management. Clean Technologies and Environmental Policy 16 (2014), pp. 1275–1286

[43] Do you need more details about our SW - www.upi.fme.vutbr.cz/en/activities/energy-simulation-tools-software

FERDAN, T. ŠOMPLÁK R, ZAVÍRALOVÁ L, PAVLAS M., FRÝBA L. A waste-to-energy project: A complex approach towards the assessment of investment risks, Applied Thermal Engineering, 89 (2015)), pp. 1127–1136

Appendix 2 – Basic information about JUSTINE Tools

Justine

Forecasting for supply-chain models Application in waste management

THEORY

What is it about?

JUSTINE represents a computational system for simulating and forecasting incomplete data problems in waste management. From general perspective, the tool can be applied to any problem, where forecasts are performed based on spatially distributed data from previous years. From a mathematical point of view, it follows the principle of regression analysis, applied to a region divided into several sub-regions and also their parts (see Fig. 1). It processes a variety of spatially distributed statistical data (data from different regions, Fig. 2) bound together through equations and constraints (e.g. mass and energy balances). This data is supposed to be incomplete (some local information might be unavailable or data from some regions are completely missing) and uncertain (the quality of some data may be poor or of lower relevance).

Task introduction

Different levels of details are taken into account: country level (L0), regional level (L1), micro-regional level (L2), municipalities (L3) etc.) (see Fig. 1).

The problem handled by Justine may be visualized by a 3D plot as depicted by Fig. 3. There are different types of waste (e.g. residual waste, separately collected waste consisting of plastics, paper, glass, see vertical axis and sections in Fig. 3). The aim is to forecast future changes in total production of key components, the distribution of components between residual waste and separately collected waste etc. (see Time axis). This is done at all territorial units (L0 to L3) at the same time.

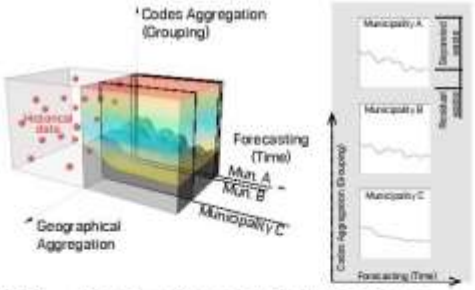

Fig. 3 The problem of forecasting illustrated in a 3D space

Outcomes

From general point of view the outcomes from the calculations are future predictions of key-parameters at all locations and integrated/aggregated values for higher organizational units.

More specifically, for our case of household waste it is:

- production of individual fractions and their distribution between observed streams,
- composition of residual waste and recyclables,
- lower heating value,
- separation rate for different fractions,
- separation efficiency for different fractions.

Additionally, performance of particular geographical unit is compared with other ones (benchmarking, future realistic targets specification).

APPLICATION example

One of the key applications of Justine from 2014 addressed household waste produced in the Czech Republic. So, this case is utilised to introduce the basic idea, principle and outcomes of the JUSTINE tool.

Fig. 1 Different levels of detail considered by Justine tool

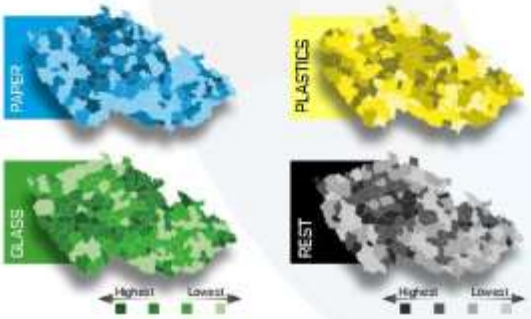

Fig. 2 Data on waste quantities represents a key input for the calculation

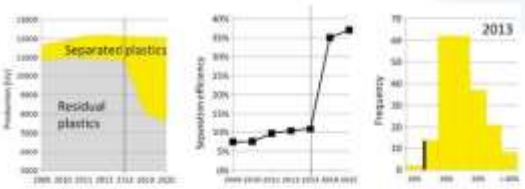

Fig. 4 An example of result: The production and separation efficiency of plastics in selected micro-region, results of a complex analysis

Fig. 4 demonstrates one particular result for a selected micro-region and selected fraction plastics. Fig. 4 a) shows the constant projected generation of plastic waste from households and ineffective plastics separation, as only 12% of its production was source-separated (i.e. separated directly by inhabitans) in 2013. Regarding the country level, this is one of the lowest values experienced in the, as documented by a frequency diagram for all 206 micro-regions (see the vertical line Fig. 4b). Considering slightly decreasing overall plastics generation, a future increase in plastics yield is expected (see Fig. 4a) and years 2019 and 2020), resulting in lower amounts of plastics in residual waste and significantly increasing efficiency (Fig. 4c). Similar outcomes were obtained for all territorial units.

More information about the Justine project:
www.upi.fme.vutbr.cz/justine

BRNO UNIVERSITY OF TECHNOLOGY FACULTY OF MECHANICAL ENGINEERING

© Are you interested? Contact us.

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Appendix 3 – Questionnaires (Gdansk, Glasgow, Parma, Rotterdam)

Appendix 3a – Gdansk Questionnaire

	FACULTY institute	Institute of Process Engineering				
	OF MECHANICAL of	Created by	Jiri Gregor, Jri Kropac		Approved by	Martin Pavlas
	ENGINEERING engin	Type of document	Ruggedized QST		Project number	xxx
		Revision	1	Date	13.01.2018	Brno

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

	Completed by:	Author: Joanna Tobolewicz, Pełnomocniczka Prezydenta Miasta	Institution: URZĄD MIEJSKI W GDAŃSKU	City: Gdansk	Date: February 2018	E-mail: joanna.tobolewicz@gdans
A	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY				Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?				yes	
A02	Is waste production registered for individual producers - house number?				yes	
A03	Do you have any data on individual waste codes/stream production and disposal available?				yes	
A04	Are there any public available data on individual waste codes production and disposal available?				no	
A05	Is municipal waste collection performed by garbage trucks?				yes	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)				no	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vaccum systems, Metro Taifun)				no	
A08	Is municipal waste collection monitored by GPS or other sensors?				yes	
A09	Are underground municipal waste containers used?				yes	over a dozen
A10	Are municipal waste containers weighed when emptied?				no	
A11	Are municipal waste containers tracked by any type of sensor? (fill level)?				no	
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?				no	
B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY					
B01	Is a separate municipal waste collection available for most citizens?				yes	
B02	Is paper municipal waste collected separately?				no	
B03	Is plastic municipal waste collected separately?				no	
B04	Is metal municipal waste collected separately?				no	
B05	Is tetra pack municipal waste collected separately?				no	
B06	Is glass municipal waste collected separately?				yes	
B07	Is biodegradable municipal waste collected separately?				yes	
B08	Is any other of municipal waste compounds collected separately?				no	
B09	Is there kerbside collection system operated?				no	
C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)					
C01	Is there any municipal waste sorting line operated in the city?				yes	
C02	Is there any municipal waste composting unit operated in the city??				yes	
C03	Is there any waste-to-energy unit operated in the city?				yes	
C04	Is there any mechanical-biological waste treatment unit operated in the city?				yes	
C05	Is there any transfer station operated in the city?				no	
C06	Is there any waste water treatment plant operated in the city?				yes	
C07	Is there any municipal waste landfill operated in the city (near region)?				yes	
C08	Is there any other type of municipal waste treatment operated in the city (near region)?				no	
C09	Is there any waste recycling plant operated in the city (near region)?				yes	
C10	Is there any central district heating operated in the city (near region)?				yes	
C11	Is there any waste collection yard operated in the city?				yes	
D	BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY					
D01	Are there standard fuel vehicles used (gasoline or diesel)?				yes	
D02	Are there LPG fuel vehicles used?				no	
D03	Are there CNG fuel vehicles used?				no	
D04	Are there electric vehicles used?				no	
D05	Are there hybrid fuel vehicles used?				no	
D06	Is fuel consumption of vehicles monitored online?				yes	
D07	Is engine speed of vehicles monitored online?				yes	
E	BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION					
E01	Is the collection performed according to regular/periodic schedules?				yes	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic collection)?				no	
E03	Have the routes been optimized by any software?				yes	
E04	Are the individual collection vehicles routes tracked by GPS?				yes	
E05	Are the vehicles weighted before emptying at the facility (sorting, line, WtE)?				yes	
E06	Have the emission from collection been analysed by any study?				no	
E07	Are the routes optimized aiming at emission reduction?				no	
E08	Are there any online information about the density of transportation available in your city?				yes	
E09	Are there any data about the density of transportation available in your city?				yes	
E10	Are the information about collection routes of individual vehicles archieved?				yes	
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?				no	
E12	Is there kerbside collection system operated?				no	

Appendix 3b – Glasgow Questionnaire

FACULTY institute OF MECHANICAL of process ENGINEERING engineering

Institute of Process Engineering

Created by	Jiří Gregor, Jiří Kropáč		Approved by	Martin Pavlas	
Type of document	Ruggedized QST		Project number	xxx	
Revision	1	Date	13.1.2018	Brno	

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

Completed by:	Author	Institution	City	Date	E-mail

A	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY	Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?	YES	https://www.glasgow.gov.uk/index.aspx?articleid=16572
A02	Is waste production registered for individual producers - house number?	NO	
A03	Do you have any data on individual waste codes/stream production and disposal available?	NO	The data is not split in to EU waste codes
A04	Are there any public available data on individual waste codes production and disposal available?	NO	https://www.sepa.org.uk/environment/waste/waste-
A05	Is municipal waste collection performed by garbage trucks?	YES	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)	NO	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vacuum systems, Metro Taifun)	YES	Smart litter bins will be deployed in the future in the city
A08	Is municipal waste collection monitored by GPS or other sensors?	YES	Track You' installed on vehicles
A09	Are underground municipal waste containers used?	NO	
A10	Are municipal waste containers weighted when emptied?	NO	Only vehicles are weighed
A11	Are municipal waste containers tracked by any type of sensor? (fill level)	YES	As above - smart bins to be installed in city centre
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?	YES	Last data is from 2014/15. Not done annually due to
B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY		
B01	Is a separate municipal waste collection availbale for most citizens?	YES	
B02	Is paper municipal waste collected separately?	NO	Paper, plastic and aluminium are collected in one
B03	Is plastic municipal waste collected separately?	NO	As above B02
B04	Is metal municipal waste collected separately?	NO	As above B02
B05	Is tetra pack municipal waste collected separately?	NO	Residents can take tetra pack to recycle points.
B06	Is glass municipal waste collected separately?	YES	
B07	Is biodegradable municipal waste collected separately?	YES	Food and garden waste
B08	Is any other of municipal waste compounds collected separately?	NO	Card board can be taken to recycling points
B09	Is there kerbside collection system operated?	YES	
C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)		
C01	Is there any municipal waste sorting line operated in the city?	YES	
C02	Is there any municipal waste composting unit operated in the city?	NO	Outwith city boundary. Sent to private sector plant
C03	Is there any waste-to-energy unit operated in the city?	YES	Due to be operational 2018
C04	Is there any mechanical-biological waste treatment unit operated in the city?	NO	
C05	Is there any transfer station operated in the city?	YES	
C06	Is there any waste water treatment plant operated in the city?	YES	Run by Scottish Water
C07	Is there any municipal waste landfill operated in the city (near region)?	YES	Private sector site
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	NO	
C09	Is there any waste recycling plant operated in the city (near region)?	YES	Materials Recovery Facility (MRF)
C10	Is there any central district heating operated in the city (near region)?	YES	Several DH networks
C11	Is there any waste collection yard operated in the city?	YES	4 municipality operated sites and other private sites
D	BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	YES	
D02	Are there LPG fuel vehicles used?	NO	
D03	Are there CNG fuel vehicles used?	NO	
D04	Are there electric vehicles used?	NO	
D05	Are there hybrid fuel vehicles used?	NO	
D06	Is fuel consumption of vehicles monitored online?	YES	Recorded via 'Track You' system
D07	Is engine speed of vehicles monitored online?	NO	
E	BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION		
E01	Is the collection performed according to regular/periodic schedules?	YES	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand dynamic collection)?	NO	
E03	Have the routes been optimized by any software?	YES	
E04	Are the individual collection vehicles routes tracked by GPS?	YES	
E05	Are the vehicles weighted before emptying at the facility (sorting line, WtE)	YES	
E06	Have the emission from collection been analysed by any study?	NO	
E07	Are the routes optimized aiming at emission reduction?	YES	Fuel/ job efficiency is probably higher priority however
E08	Are there any online information about the density of transportation available in your city?	NO	
E09	Are there any data about the density of transportation available in your city?	NO	
E10	Are the information about collection routes of individual vehicles archieved?	YES	Track You' system used as above
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	YES	Track You' system used as above
E12	Is there kerbside collection system operated?	YES	

Appendix 3c – Parma Questionnaire

FACULTY of MECHANICAL ENGINEERING institute of process engineering

Institute of Process Engineering

Created by	Jiří Gregor, Jiří Kropáč		Approved by	Martin Pavlas	
Type of document	Ruggedized QST		Project number	xxx	
Revision	1	Date	13.1.2018	Brno	

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

Completed by:	Author:	Institution:	City:	Date:	E-mail:

	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY	Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?	YES	
A02	Is waste production registered for individual producers - house number?	YES	
A03	Do you have any data on individual waste codes/stream production and disposal available?	YES	
A04	Are there any public available data on individual waste codes production and disposal available?	NO	
A05	Is municipal waste collection performed by garbage trucks?	YES	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)	NO	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vacuum systems, Metro Taifun)	-	
A08	Is municipal waste collection monitored by GPS or other sensors?	NO	should be next year
A09	Are underground municipal waste containers used?	NO	
A10	Are municipal waste containers weighted when emptied?	YES	
A11	Are municipal waste containers tracked by any type of sensor? (fill level)	NO	
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?	YES	
B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY		
B01	Is a separate municipal waste collection availbale for most citizens?	YES	
B02	Is paper municipal waste collected separately?	YES	
B03	Is plastic municipal waste collected separately?	YES	togheter with metal
B04	Is metal municipal waste collected separately?	YES	togheter with plastic
B05	Is tetra pack municipal waste collected separately?	YES	with plastic and metal
B06	Is glass municipal waste collected separately?	YES	
B07	Is biodegradable municipal waste collected separately?	YES	
B08	Is any other of municipal waste compounds collected separately?	YES	Green waste from gardening
B09	Is there kerbside collection system operated?	YES	Glass and green waste
C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)		
C01	Is there any municipal waste sorting line operated in the city?	YES	
C02	Is there any municipal waste composting unit operated in the city?	YES	
C03	Is there any waste-to-energy unit operated in the city?	YES	
C04	Is there any mechanical-biological waste treatment unit operated in the city?	YES	
C05	Is there any transfer station operated in the city?	YES	
C06	Is there any waste water treatment plant operated in the city?	YES	
C07	Is there any municipal waste landfill operated in the city (near region)?	NO	
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	NO	
C09	Is there any waste recycling plant operated in the city (near region)?	YES	
C10	Is there any central district heating operated in the city (near region)?	YES	both form waste and from g
C11	Is there any waste collection yard operated in the city?	YES	4
D	BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	YES	
D02	Are there LPG fuel vehicles used?	YES	
D03	Are there CNG fuel vehicles used?	NO	
D04	Are there electric vehicles used?	NO	
D05	Are there hybrid fuel vehicles used?	NO	
D06	Is fuel consumption of vehicles monitored online?	NO	
D07	Is engine speed of vehicles monitored online?	NO	
E	BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION		
E01	Is the collection performed according to regular/periodic schedules?	YES	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic collection)?	NO	
E03	Have the routes been optimized by any software?	NO	
E04	Are the individual collection vehicles routes tracked by GPS?	NO	should begin next year
E05	Are the vehicles weighted before emptying at the facility (sorting line, WtE)	YES	
E06	Have the emission from collection been analysed by any study?	NO	
E07	Are the routes optimized aiming at emission reduction?	NO	
E08	Are there any online information about the density of transportation available in your city?	NO	
E09	Are there any data about the density of transportation available in your city?	NO	
E10	Are the information about collection routes of individual vehicles archieved?	NO	
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	NO	
E12	Is there kerbside collection system operated?	YES	

Appendix 3d – Rotterdam Questionnaire

FACULTY institute OF MECHANICAL of process ENGINEERING engineering

Institute of Process Engineering

Created by	Jiří Gregor, Jiří Kropáč		Approved by	Martin Pavlas	
Type of document	Ruggedized QST		Project number	xxx	
Revision	1	Date	13.1.2018	Brno	

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

Completed by:	Author:	Institution:	City:	Date:	E-mail:

	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY	Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?	YES	
A02	Is waste production registered for individual producers - house number?	NO	
A03	Do you have any data on individual waste codes/stream production and disposal available?	YES	
A04	Are there any public available data on individual waste codes production and disposal available?	NO	
A05	Is municipal waste collection performed by garbage trucks?	YES	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)	NO	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vacuum systems, Metro Taifun)		Time will learn
A08	Is municipal waste collection monitored by GPS or other sensors?	YES	
A09	Are underground municipal waste containers used?	YES	
A10	Are municipal waste containers weighted when emptied?	YES	Incidental
A11	Are municipal waste containers tracked by any type of sensor? (fill level)	YES	
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?	YES	2 times a year
B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY		
B01	Is a separate municipal waste collection availbale for most citizens?	YES	
B02	Is paper municipal waste collected separately?	YES	
B03	Is plastic municipal waste collected separately?	YES	
B04	Is metal (tin cans) municipal waste collected separately?	YES	7 loading stations for big part
B05	Is tetra pack municipal waste collected separately?	YES	
B06	Is glass municipal waste collected separately?	YES	
B07	Is biodegradable municipal waste collected separately?	YES	Not in flats
B08	Is any other of municipal waste compounds collected separately?	YES	Bulky waste -Textile/shoes
B09	Is there kerbside collection system operated?	-	not my department
C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)		
C01	Is there any municipal waste sorting line operated in the city?	NO	market party
C02	Is there any municipal waste composting unit operated in the city?	NO	market party
C03	Is there any waste-to-energy unit operated in the city?	NO	market party
C04	Is there any mechanical-biological waste treatment unit operated in the city?	NO	market party
C05	Is there any transfer station operated in the city?	YES	
C06	Is there any waste water treatment plant operated in the city?	YES	market party
C07	Is there any municipal waste landfill operated in the city (near region)?	NO	
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	NO	all market party
C09	Is there any waste recycling plant operated in the city (near region)?	YES	
C10	Is there any central district heating operated in the city (near region)?	YES	
C11	Is there any waste collection yard operated in the city?	NO	
D	BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	YES	
D02	Are there LPG fuel vehicles used?	NO	
D03	Are there CNG fuel vehicles used?	NO	
D04	Are there electric vehicles used?	NO	
D05	Are there hybrid fuel vehicles used?	NO	
D06	Is fuel consumption of vehicles monitored online?	NO	
D07	Is engine speed of vehicles monitored online?	NO	
E	BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION		
E01	Is the collection performed according to regular/periodic schedules?	YES	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic collection)?	YES	
E03	Have the routes been optimized by any software?	YES	
E04	Are the individual collection vehicles routes tracked by GPS?	YES	
E05	Are the vehicles weighted before emptying at the facility (sorting line, WtE)	YES	
E06	Have the emission from collection been analysed by any study?	NO	
E07	Are the routes optimized aiming at emission reduction?	NO	indirectly
E08	Are there any online information about the density of transportation available in your city?	-	not my department
E09	Are there any data about the density of transportation available in your city?	-	not my department
E10	Are the information about collection routes of individual vehicles archieved?	YES	partially
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	YES	
E12	Is there kerbside collection system operated?	-	not my department

Appendix 4a – Gdansk Questionnaire in more details

	FACULTY Institute		Institute of Process Engineering			
	OF MECHANICAL of	Created by	Jiri Gregor, Jiri Kropac		Approved by	Martin Pavlas
	ENGINEERING engin	Type of document	Ruggedized QST		Project number	xxx
		Revision	1	Date	13.01.2018	Brno

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

	Completed by:	*Author: Joanna Tobolewicz, Pełnomocniczka Prezydenta Miasta*	*Institution: URZĄD MIEJSKI W GDAŃSKU*	*City: Gdansk, PL*	*Date: February 2018*	*E-mail: joanna.tobolewicz@gdans*
A	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY				Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?				yes	
A02	Is waste production registered for individual producers - house number?				yes	
	Comments/Questions • *Is there any kind of PAYT (pay-as-you-throw) system in adopted in Gdansk?* • *If "YES" could you shortly describe the basic principles?* • *How the amount is reported considering answers A10 and A11 are negatives (no bins/containers weighing)?*					
A03	Do you have any data on individual waste codes/stream production and disposal available?				yes	
A04	Are there any public available data on individual waste codes production and disposal available?				no	
A05	Is municipal waste collection performed by garbage trucks?				yes	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)				no	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vaccum systems, Metro Taifun)				no	
A08	Is municipal waste collection monitored by GPS or other sensors?				yes	
	Comments/Questions *How long has it been in operation?* *Could you provide us more information about the solution/SW? What is the main principle of the SW? How the data is used? What types of reports does it provide, etc.?*					
A09	Are underground municipal waste containers used?				yes	over a dozen
	Comments/Questions • *Are they preferred in specific parts of the city?* • *Can they be considered as "smart" ones, i.e. with some advanced features - fill level measuring, weighing, citizen identification, etc.?*					
A10	Are municipal waste containers weighed when emptied?				no	
A11	Are municipal waste containers tracked by any type of sensor? (fill level)?				no	
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?				no	
B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY					
B01	Is a separate municipal waste collection available for most citizens?				yes	
B02	Is paper municipal waste collected separately?				no	
B03	Is plastic municipal waste collected separately?				no	
B04	Is metal municipal waste collected separately?				no	
B05	Is tetra pack municipal waste collected separately?				no	
B06	Is glass municipal waste collected separately?				yes	
B07	Is biodegradable municipal waste collected separately?				yes	
	Questions B01 to B07 • *Could you describe the collection system in more details? Does it mean that only biowaste and glass are collected separately and the other fractions, i.e. paper, plastics are not collected. Or are they collected together in one dry recyclable (co-mingled system)?* • *Was there a discussion how to set up the system optimally? What were the reasons for adopting system likes this?* • *Could we have some data about the performance of the system. What are the average yields of individual commodities per capita? How was the development of separation efficiencies of individual components? What is the rate of marketable fractions? What is the rejection rate at sorting line?* • *Where do you see pros and cons of this system?* • *Do you have some bonuses, subsidies or other financial support from the regional/country government to promote separation? If YES, to what extent?*					
B08	Is any other of municipal waste compounds collected separately?				no	
B09	Is there kerbside collection system operated?				no	
C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)					
C01	Is there any municipal waste sorting line operated in the city?				yes	
	Commnets/Questions: • *What are the annual capacity(ies) of facility/facilities?* • *Which types of waste are treated at sorting line? Is it only content recycling bin as specified in B02 to B04 or other streams (industrial waste)? What is the share?* • *What is the next step after sorting? What are the products (codes according to WRAP, EN specification etc.)* • *Basic balance: How much percent of the input goes to residue stream as rejection? (volume and weight). Partly asked in B07*					

C02	Is there any municipal waste composting unit operated in the city??	yes	
C03	Is there any waste-to-energy unit operated in the city?	yes	
	Comments/Questions • *New WTE should be in operation by 2021, Processing capacity of 160,000 tonnes* • *Could you provide brief specification of the project: Expected input stream - Rresidual waste/RDF from MBT, in case of both, please, provide shares?* • *What is the expected annual production of heat and electricity?* • *Will the heat be delivered to district heating system?*		
C04	Is there any mechanical-biological waste treatment unit operated in the city?	yes	
	The Gdansk MBT plant is described in an overview document from 2015 (http://www3.gdos.gov.pl/Documents/GO/Ekspertyzy/Ekspertyza%20MBP_ost%20etap_%2022-06-2015%20+%20za%C5%82aczniki.pdf) • *Are the stated data still up-to-date? (especially Tab. 265 and Rys. 62 in the document)* • *Is it planned any form of cooperation of the MBT plant with the new WTE plant? (e.g. RDF utilizing, input waste pretreatment, ...)* • *Are there any project or intention of new technologies operation or expansion of operation related to the described MBT plant?*		
C05	Is there any transfer station operated in the city?	no	
C06	Is there any waste water treatment plant operated in the city?	yes	
C07	Is there any municipal waste landfill operated in the city (near region)?	yes	
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	no	
C09	Is there any waste recycling plant operated in the city (near region)?	yes	
C10	Is there any central district heating operated in the city (near region)?	yes	
	Comments/Questions • *One DH or several DHs?* • *What is the overall heat demand in DHSs in Gdansk? Can we have a map of the DHs location? What media are used (steam or hot water)?* • *Is intended WtE plant supposed to deliv heat to any of these DHSs? In what amount (question C03)?* • *What are the other/conventional heat sources and what fuels are combusted?* • *What is the current trend in overall DHS demand? Are new consumers attracted or more are disconnected? Are there serious drops in demand due to more efficient use of energy in buildings, industry, and/or due to the implementation of decentralized renewable sources (local solar heating, heat pumps,etc.)?*		
C11	Is there any waste collection yard operated in the city?	yes	
D	**BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY**		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	yes	
D02	Are there LPG fuel vehicles used?	no	
D03	Are there CNG fuel vehicles used?	no	
D04	Are there electric vehicles used?	no	
D05	Are there hybrid fuel vehicles used?	no	
D06	Is fuel consumption of vehicles monitored online?	yes	
D07	Is engine speed of vehicles monitored online?	yes	
	Comments/Questions relevant to D06 a D07 (answer maybe partly covered by A08) • *Could you provide us more information about the solution/SW?* • *Could you describe in more details, what data is collected and how it is used?* • *Do you monitor a emissions pollutants?*		
E	**BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION**		
E01	Is the collection performed according to regular/periodic schedules?	yes	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic collection)?	no	
E03	Have the routes been optimized by any software?	yes	
	Comments/Questions • *What type of software do you use for optimization?* • *When did you start with routes optimization?* • *Why have you started routes optimization?* • *Are there any future challenges?* • *Do you address the density of transportation when planning (question E08)? If YES, how?*		
E04	Are the individual collection vehicles routes tracked by GPS?	yes	
E05	Are the vehicles weighted before emptying at the facility (sorting, line, WtE)?	yes	
E06	Have the emission from collection been analysed by any study?	no	
E07	Are the routes optimized aiming at emission reduction?	no	
E08	Are there any online information about the density of transportation available in your city?	yes	
E09	Are there any data about the density of transportation available in your city?	yes	
E10	Are the information about collection routes of individual vehicles archieved?	yes	
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	no	
E12	Is there kerbside collection system operated?	no	

Appendix 4b – Parma Questionnaire in more details

FACULTY OF MECHANICAL ENGINEERING	Institute of Process Engineering			
	Created by	Jiří Gregor, Jiří Kropáč	Approved by	Martin Pavlas
	Type of document	Ruggedized QST	Project number	xxx
	Revision	1	Date	13.1.2018 Brno

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

Completed by:	Author: Ing. Marco MORDACCI, Istruttore Direttivo Tecnico	Institution: Comune di Parma	City: Parma, Italy	Date: February 2018	E-mail: m.mordacci@comune.parma.it

A	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY	Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?	YES	
A02	Is waste production registered for individual producers - house number?	YES	

Questions/Comments
- *We suppose, that this answer is tightly bound with A10. The bins weighing provides data for any kind of PAYT system. Is this clue correct?*
  If "Yes", we have additional questions:
  Could you briefly describe the PAYT system applied to your city?
  What percentage of inhabitants is included into PAYT? Are any areas of city excluded? How is the system organized for apartments with more flats?
  What fractions are included/excluded?
  If "NO", how is the information used?

A03	Do you have any data on individual waste codes/stream production and disposal available?	YES	
A04	Are there any public available data on individual waste codes production and disposal available?	NO	
A05	Is municipal waste collection performed by garbage trucks?	YES	

Comments/Questions
- *What type of garbage trucks do you use?*
- *Can you specify volumes and types of garbage trucks?*
- *Do you use garbage trucks with a lifting arm for automatic operating with small containers e.g. 120 l or 240 l or other "advanced" system? https://www.youtube.com/watch?v=xNwSVKP6pBU*

A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)	NO	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vacuum systems, Metro Taifun)	-	
A08	Is municipal waste collection monitored by GPS or other sensors?	NO	should be next year

Comments/Questions
- *Could you shorty describe the project? What is the main motivation to monitor waste collection in the future? What percentage of trucks/containers/bins will be*

A09	Are underground municipal waste containers used?	NO	
A10	Are municipal waste containers weighted when emptied?	YES	

Comments/Questions
- *How is the weighing performed? Which system for weighing do you use: on garbage trucks, self-weighing containers bins, etc.? Do you have special electronic scales on lifting/hydraulic arms?*
- *What kind of identification systems is used to pair the information bin - citizens (relevance with B02)*
- *What fractions are weighted (only separately collected fractions - it means, (plastic + paper and cardboard + glass) based on answers B03 a B04.*
- *Do you weight some other waste or a waste fraction?*
- *What type of bins do you use in Parma dominantly? Is the system varied in different parts of the city (residential areas, city centre, etc.) Can we have some photos as examples? We have found some information about bins in the case study - do you use some extra or specific bins?*

A11	Are municipal waste containers tracked by any type of sensor? (fill level)	NO	
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?	YES	

Comments/Questions
- *Could you provide us with the data about analysis of municipal waste?*

B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY		
B01	Is a separate municipal waste collection available for most citizens?	YES	
B02	Is paper municipal waste collected separately?	YES	
B03	Is plastic municipal waste collected separately?	YES	togheter with metal
B04	Is metal municipal waste collected separately?	YES	togheter with plastic
B05	Is tetra pack municipal waste collected separately?	YES	with plastic and metal

Comments/Questions (B02 to B05)
- *The system, where three commodities Dry recyclables (plastic, metal - tin cans, tetra pack), Glass and Green waste are collected, is operated. Was there a discussion how to set up the system optimally? What were the reasons for adopting system likes this?*
- *Could we have some data about the performance of the system? What are the average yields of individual commodities per capita? How was the development of separation efficiencies of individual components? What is the typical composition of the dry recyclable bin? What is the rate of marketable fractions, What is the rejection rate?*
- *Where do you see pros and cons of this system?*
- *Do you have some bonuses, subsidies or other financial support from the regional/country government to promote separation? If YES, to what extent?*

B06	Is glass municipal waste collected separately?	YES	
B07	Is biodegradable municipal waste collected separately?	YES	
B08	Is any other of municipal waste compounds collected separately?	YES	Green waste from gardening
B09	Is there kerbside collection system operated?	YES	Glass and green waste
C	**BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)**		
C01	Is there any municipal waste sorting line operated in the city?	YES	

Questions
- *How many facilities are operated for MSW produced in Parma (One, or more?)*
- *What are the annual capacity(ies) of facility/facilities?*
- *Which types of waste are treated at sorting line? Only dry recyclables as specified in B02 to B04 or other streams?*
- *What is the next step after sorting? What are the products (codes according to WRAP, EN specification etc.)*
- *Basic balance: How much percent of the input goes to residue stream as rejection? (volume and weight). Partly asked in B05.*

C02	Is there any municipal waste composting unit operated in the city?	YES	
C03	Is there any waste-to-energy unit operated in the city?	YES	

Comments/Questions
- *IREN Waste to Energy Plant*
- *What is the design capacity of the facility? 130 kt/y, 70 kt/y household waste from Parma (?? kt/y) and surroundings and 60 kt/y industrial (https://www.youtube.com/watch?v=qpyBz-U68H4).*
- *Plant is in operation since 2013*
- *Residual waste is treated by mechanical-biological plant prior to its incineration in the WtE plant. including waste from Parma? What is the basic material balance of this MBT plant? What are the outputs streams and amounts?*
- *It delivers heat to district heating system of Parma (hot water)*
- *Does it also deliver heat to other consumers (industrial sector)?*
- *What is the net delivery of heat and electricity, e.g. in 2016?*
- *What is the R1 factor (Energy efficiency)?*
- *What type of flue gas cleaning is adopted?*

Water cooled grate (reciprocating type);
Horizontal Boiler;
Flue gas treatment system:
NOx Selective Non- Catalytic Reduction (SNCR);
First Reactor and First Fabric Filter;
Second Reactor and Second Fabric Filter;
NOx Selective Catalytic Reduction (SCR).
Reagents: ammonia, activated carbon, lime, sodium bicarbonate.
- *On the website (http://eng.gruppohera.it/group/business_activities/innovation_services/customer_technical_services/engeneering/plants_designed/page6.html) is the information that WtE plant is in testing mode? What is the situation in nowadays?*

C04	Is there any mechanical-biological waste treatment unit operated in the city?	YES	
C05	Is there any transfer station operated in the city?	YES	

Comments/Questions
- *Could you shortly describe the function?*
- *What is the annual capacity of transfer station?*
- *Which fractions are handled here (residual municipal solid waste, other fractions)?*
- *Where does the waste go? (type of facility, distance)*
- *What technology/type of transfer station is used (pressing into containers, type of containers)*

C06	Is there any waste water treatment plant operated in the city?	YES	
C07	Is there any municipal waste landfill operated in the city (near region)?	NO	
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	NO	
C09	Is there any waste recycling plant operated in the city (near region)?	YES	
C10	Is there any central district heating operated in the city (near region)?	YES	both form waste and from gas

Comments/Questions
- *IREN Waste to Energy Plant delivers heat to DHS of City of Parma (This heat will be channelled via a 7.5 km two-tube pipeline to Parma's existing district heating network).*
- *What is the overall heat demand in DHS and what share/portion of it delivers IREN WtE?*
- *What are the other/conventional heat sources and what fuels are combusted?*
- *What is the current trend in overall DHS demand? Are new consumers attracted or more are disconnected. Are there serious drops in demand due to more efficient use of energy in buildings, industry, and/or due to implementation of decentralized renewable sources (local solar heating, heat pumps,etc.)*

C11	Is there any waste collection yard operated in the city?	YES	4
D	**BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY**		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	YES	
D02	Are there LPG fuel vehicles used?	YES	

Comments/Questions
- *Could you please provide more details (number of LPG-driven vehicles compared to overall fleet (A05)? Are these vehicles preferably used in specific areas of the city?*
- *Are LPG vehicles only for LPG fuel or is it a combination of LPG and other fuels?*
- *Do you have some problems with LPG vehicles e.g. performance during the pressing or other disadvantages?*

D03	Are there CNG fuel vehicles used?	NO	
D04	Are there electric vehicles used?	NO	
D05	Are there hybrid fuel vehicles used?	NO	
D06	Is fuel consumption of vehicles monitored online?	NO	
D07	Is engine speed of vehicles monitored online?	NO	

E	BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION		
E01	Is the collection performed according to regular/periodic schedules?	YES	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic c	NO	
E03	Have the routes been optimized by any software?	NO	
E04	Are the individual collection vehicles routes tracked by GPS?	NO	should begin next year

Comments/Questions

- *Could you provide more information about the project? What is the expectation (monitor routes based on each operating steps e.g. transportation, loading of containers, weighing, waiting in a traffic jam)*
- *How will be the data used?*
- *What kind of tool will be involved? Are you going to use commercial SW. What kind? Who is the provider?*

E05	Are the vehicles weighted before emptying at the facility (sorting line, WtE)	YES	
E06	Have the emission from collection been analysed by any study?	NO	
E07	Are the routes optimized aiming at emission reduction?	NO	
E08	Are there any online information about the density of transportation available in your city?	NO	
E09	Are there any data about the density of transportation available in your city?	NO	
E10	Are the information about collection routes of individual vehicles archieved?	NO	
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	NO	
E12	Is there kerbside collection system operated?	YES	

Additional Comments/Questions

- *In case study - chapter - Zero waste makes economic sense is mentioned "* Whilst the costs of collection have increased with the introduction of a new fraction and door-to-door collection, bringing higher labour costs, the revenues from selling high purity materials jumped from €0.8 m in 2013 to €1.3 m in 2014, and the annual costs of waste disposal have been reduced by almost €3.5 m. Once again, in comparison to traditional waste management, zero waste strategies mean less cost for the authorities and less costs for the citizens."
- *It is an inspiring achievement and inspiration for the City of Brno. Would it be possible to share more details about the performance and economy of the system for further investigation?*
- *Question A07 - why the question is without an answer?*

Appendix 4c – Glasgow Questionnaire in more details

FACULTY OF MECHANICAL ENGINEERING — institute of process engineering

Institute of Process Engineering

Created by	Jiří Gregor, Jiří Kropáč	Approved by	Martin Pavlas
Type of docu	Ruggedized QST	Project numb	xxx
Revision	1	Date	13.1.2018
			Brno

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

Completed by:	Author: Christine Downie	Institution: Glasgow City Council	City: Glasgow	Date: February 2018	E-mail: christine.downie@glasgow.gov.uk

	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY	Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?	YES	https://www.glasgow.gov.uk/index.aspx?articleid=145
A02	Is waste production registered for individual producers - house number?	NO	
A03	Do you have any data on individual waste codes/stream production and disposal available?	NO	The data is not split in to EU waste codes
A04	Are there any public available data on individual waste codes production and disposal available?	NO	https://www.sepa.org.uk/environment/waste/waste-
A05	Is municipal waste collection performed by garbage trucks?	YES	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)	NO	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vacuum systems, Metro Taifun)	YES	Smart liter bins will be deployed in the future in the
	Comments/Questions • *Could you shortly describe the project? What is the main motivation and expectation?* • *What type of bins will be deployed? What part of the city will be covered?* • *Which type of waste will be served by this smart bins?* • *Is the specification known?*		
A08	Is municipal waste collection monitored by GPS or other sensors?	YES	Track You' installed on vehicles
	Comments/Questions (also for questions D06, E07, E011) • *How long has it been in operation?* • *Could you provide us more information about Track You? We have found no details on the web pages. What is the main principle of the SW? What types of reports does it provide, etc.?*		
A09	Are underground municipal waste containers used?	NO	
A10	Are municipal waste containers weighted when emptied?	NO	Only vehicles are weighed
A11	Are municipal waste containers tracked by any type of sensor? (fill level)	YES	As above - smart bins to be installed in city centre
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?	YES	Last data is from 2014/15. Not done annually due to
	Comments/Questions • *Could you provide us with the data about the analysis of municipal waste?*		

	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY		
B01	Is a separate municipal waste collection availbale for most citizens?	YES	
B02	Is paper municipal waste collected separately?	NO	Paper, plastic and aluminium are collected in one
	Comments/Questions to B02,B03,B04 *The system, where three commodities Dry recyclables (paper, plastic, aluminium), Glass and Food and Garden waste are collected, is operated. Was there a discussion how to set up the system optimally? What were the reasons for adopting system likes this?* *Could we have some data about the performance of the system? What are the average yields of individual commodities per capita? How was the development of separation efficiencies of individual components? What is the typical composition of the dry recyclable bin? What is the rate of marketable fractions? What is the rejection rate at sorting line?* *Where do you see pros and cons of this system?* *Do you have some bonuses, subsidies or other financial support from the regional/country government to promote separation? If YES, to what extent?*		
B03	Is plastic municipal waste collected separately?	NO	As above B02
B04	Is metal municipal waste collected separately?	NO	As above B02
B05	Is tetra pack municipal waste collected separately?	NO	Residents can take tetra pack to recycle points.
B06	Is glass municipal waste collected separately?	YES	
B07	Is biodegradable municipal waste collected separately?	YES	Food and garden waste
B08	Is any other of municipal waste compounds collected separately?	NO	Card board can be taken to recycling points
B09	Is there kerbside collection system operated?	YES	
C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)		
C01	Is there any municipal waste sorting line operated in the city?	YES	
	Comments/Questions: *What are the annual capacity(ies) of facilty/facilities?* *Which types of waste are treated at sorting line? Is it only content recycling bin as specified in B02 to B04 or other streams (industrial waste)? What is the share?* *What is the next step after sorting? What are the products (codes according to WRAP, EN specification etc.)* *Basic balance: How much percent of the input goes to residue stream as rejection? (volume and weight). Partly asked in B02*		
C02	Is there any municipal waste composting unit operated in the city?	NO	Outwith city boundary. Sent to private sector plant
C03	Is there any waste-to-energy unit operated in the city?	YES	Due to be operational 2018
	Comments/Questions • *How is residual waste treated today, i.e. without WtE plant?* • *The plant is: RREC Viridor, Polmadie Road, Glasgow, G42 0PL* • *https://viridor.co.uk/our-developments/glasgow-rrec/how-the-facility-will-work/* *It is the third stage according to https://www.glasgow.gov.uk/CHttpHandler.ashx?id=31413&p=0 - Advanced Conversion Facility (ACF)):* "The ACF is the final stage of the process and ensures a high level of landfill diversion. RDF produced by the S-MRF is transferred to a series of thermal conversion units which heat material to very high temperatures in low oxygen conditions to produce a synthetic gas. This gas is then captured and fully combusted within a separate chamber to produce superheated steam which is transferred to a turbine to generate electricity. There is also potential to divert steam from the turbine to provide heating to support a District Heat Network" *Could you please confirm, that the specification is still valid? Have not been there any changes in the conception? Could we have a detailed description of the technology?* • *What is the capacity of the facility (200,000 t/y)? Expected input stream - RDF from MRF* • *What is the expected annual production of heat and electricity?*		
C04	Is there any mechanical-biological waste treatment unit operated in the city?	NO	

C05	Is there any transfer station operated in the city?	YES	
	Comments/Questions *Could you shortly describe the function? Will the function/operation change after new WtE starts operation?* *What is the annual capacity of transfer station?* *Which fractions are handled here (residual municipal solid waste, other fractions)?* *Where does the waste go? (type of facility, distance)* *What technology/type of transfer station is used (pressing into containers, type of containers)*		
C06	Is there any waste water treatment plant operated in the city?	YES	Run by Scottish Water
C07	Is there any municipal waste landfill operated in the city (near region)?	YES	Private sector site
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	NO	
C09	Is there any waste recycling plant operated in the city (near region)?	YES	Materials Recovery Facility (MRF)
	Comments/Questions • *Located within RREC Viridor Complex?* • *What streams are handled?* • *What is the basic material balance of this MRF plant? What are the outputs streams and amounts?*		
C10	Is there any central district heating operated in the city (near region)?	YES	Several DH networks
	Comments/Questions *What is the overall heat demand in DHSs in Glasgow? Can we have a map of the DHs location? What media are used (steam or hot water)?* *Is new WtE plant going to deliver heat to any of DHSs? In what amount?* *What are the other/conventional heat sources and what fuels are combusted?* *What is the current trend in overall DHS demand? Are new consummers attracted or more are disconnected. Are there serious drops in demand due to more efficient use of energy in buildings, industry, and/or due to implementation of decentralized renewable sources (local solar heating, heat pumps,etc.)*		
C11	Is there any waste collection yard operated in the city?	YES	4 municipality operated sites and other private sites
D	**BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY**		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	YES	
D02	Are there LPG fuel vehicles used?	NO	
D03	Are there CNG fuel vehicles used?	NO	
D04	Are there electric vehicles used?	NO	
D05	Are there hybrid fuel vehicles used?	NO	
D06	Is fuel consumption of vehicles monitored online?	YES	Recorded via 'Track You' system
	Comments/Questions (answer maybe partly covered by A08) • *Could you describe in more details, what data is collected and how it is used?* • *Do you monitor a emissions pollutants?*		
D07	Is engine speed of vehicles monitored online?	NO	
E	**BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION**		
E01	Is the collection performed according to regular/periodic schedules?	YES	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic col	NO	
E03	Have the routes been optimized by any software?	YES	
	Comments/Questions • *What type of software do you use for optimization?* • *When did you start with routes optimization?* • *Why have you started routes optimization?* • *Are there any future challenges?*		
E04	Are the individual collection vehicles routes tracked by GPS?	YES	
E05	Are the vehicles weighted before emptying at the facility (sorting line, WtE)	YES	
E06	Have the emission from collection been analysed by any study?	NO	
E07	Are the routes optimized aiming at emission reduction?	YES	Fuel/ job efficiency is probably higher priority
	Comments/Questions (answer maybe partly covered by A08) • *Have you addressed information about the density of transportation, when planning?* • *Have you used dynamic planning?*		
E08	Are there any online information about the density of transportation available in your city?	NO	
E09	Are there any data about the density of transportation available in your city?	NO	
E10	Are the information about collection routes of individual vehicles archieved?	YES	Track You' system used as above
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	YES	Track You' system used as above
	Comments/Questions (answer maybe partly covered by A08)		
E12	Is there kerbside collection system operated?	YES	

Appendix 4d – Rotterdam Questionnaire in more details

FACULTY OF MECHANICAL ENGINEERING | Institute of process engineering

Institute of Process Engineering

Created by	Jiří Gregor, Jiří Kropáč	Approved by	Martin Pavlas
Type of document	Ruggedized QST	Project number	xxx
Revision	1	Date	13.1.2018
			Brno

QUESTIONAIRE - RUGGEDISED PROJECT COOPERATION

Completed by:	Author: W.L. Kars, Koen Vermeulen	Institution: City of Rotterdam	City: Rotterdam	Date: February 2018	E-mail: wl.kars@Rotterdam.nl, <k.vermeulen@Rotterdam.nl

A	BASIC INFORMATION ABOUT WASTE MANAGEMENT IN YOUR CITY	Yes/No	Comments
A01	Is there a waste management plan or similar strategic document in place?	YES	
A02	Is waste production registered for individual producers - house number?	NO	
	Comments/Questions • *Is there any kind of PAYT (pay-as-you-throw) system adopted in Rotterdam?* • *If "YES" could you shortly describe the basic principles?*		
A03	Do you have any data on individual waste codes/stream production and disposal available?	YES	
A04	Are there any public available data on individual waste codes production and disposal available?	NO	
A05	Is municipal waste collection performed by garbage trucks?	YES	
A06	Is any advanced waste collection technology realized? (e.g. Vacuum systems, Metro Taifun)	NO	
A07	Is any advanced waste collection technology planned in the future? (e.g. Vacuum systems, Metro Taifun)		Time will learn
	Comments/Questions *No current project is currently under preparation?*		
A08	Is municipal waste collection monitored by GPS or other sensors?	YES	
	Comments/Questions *How long has it been in operation?* *Could you provide us more information about the solution/SW? What is the main principle of the SW? How the data is used? What types of reports does it provide, etc.?*		
A09	Are underground municipal waste containers used?	YES	
	Comments/Questions • *How many installations have you got? Are they preferred in specific parts of the city?* • *Can they be considered as "smart" ones, i.e. with some advanced features - fill level measuring, weighing, citizen identification, etc.?*		
A10	Are municipal waste containers weighted when emptied?	YES	Incidental
A11	Are municipal waste containers tracked by any type of sensor? (fill level)	YES	
	Comments/Questions *Does answer "YES" relate only to uderground containers (A09)? Is the fill level watched for any other bins/containers?* • *We found information about monitoring the fill level of containers (https://cities-today.com/rotterdam-increases-efficiency-of-waste-collection/), which sensors do you use?* • *Which type of containers is using sensors? Underground containers? Standards containers? Households containers?* • *Do you weigh separately collected fractions - it means - bio-waste, plastic, paper and cardboard, glass?* • *Do you use the electronic scale in lifting arms or how do you measure waste weight?*		
A12	Are there any analysis of municipal residual waste compounds available? From what year? How frequent?	YES	2 times a year
B	BASIC INFORMATION ABOUT COLLECTION OF MUNICIPAL WASTE IN YOUR CITY		
B01	Is a separate municipal waste collection availbale for most citizens?	YES	
B02	Is paper municipal waste collected separately?	YES	
B03	Is plastic municipal waste collected separately?	YES	
B04	Is metal (tin cans) municipal waste collected separately?	YES	7 loading stations for big parts
B05	Is tetra pack municipal waste collected separately?	YES	
B06	Is glass municipal waste collected separately?	YES	
B07	Is biodegradable municipal waste collected separately?	YES	Not in flats
	Questions B01 to B07 • *Could you describe the collection system in more details? Which fractions are collected together and which individually?* • *Was there a discussion how to set up the system optimally? What were the reasons for adopting system likes this?* • *Could we have some data about the performance of the system. What are the average yields of individual commodities per capita? How was the development of separation efficiencies of individual components? What is the rate of marketable fractions? What is the rejection rate at sorting line?* • *Where do you see pros and cons of this system?* • *Do you have some bonuses, subsidies or other financial support from the regional/country government to promote separation? If YES, to what extent?*		
B08	Is any other of municipal waste compounds collected separately?	YES	Bulky waste - Textile/shoes
B09	Is there kerbside collection system operated?	-	not my department

C	BASIC INFORMATION ABOUT FACILITIES IN YOUR CITY (REGION)		
C01	Is there any municipal waste sorting line operated in the city?	NO	market party
C02	Is there any municipal waste composting unit operated in the city?	NO	market party
C03	Is there any waste-to-energy unit operated in the city?	NO	market party
	Comments/Questions • *WtE Enerkem project under consideration. Could we have basic information update (capacity, input streams and composition, waste preparation)?* • *We also found information about incineration in Rotterdam - http://www.industryabout.com/country-territories-3/1656-netherlands/waste-to-energy/24156-rotterdam-rozenburg-incineration-plant - this plant is without production of energy (electricity/heat/steam)? Is the facility still in operation?* *If yes, does it deliver heat to district heating system of the City?* *Does it also deliver heat to other consumers (industrial sector)?* *What is the net delivery of heat and electricity, e.g. in 2016?* *What is the R1 factor (Energy efficiency)?* • *Do you use ship transportation for transportation to the incineration plant?*		
C04	Is there any mechanical-biological waste treatment unit operated in the city?	NO	market party
C05	Is there any transfer station operated in the city?	YES	
	Comments/Questions *Could you shortly describe the function?* *What is the annual capacity of transfer station?* *Which fractions are handled here (residual municipal solid waste, other fractions)?* *Where does the waste go? (type of facility, distance)* *What technology/type of transfer station is used (pressing into containers, type of containers)*		
C06	Is there any waste water treatment plant operated in the city?	YES	market party
C07	Is there any municipal waste landfill operated in the city (near region)?	NO	
C08	Is there any other type of municipal waste treatment operated in the city (near region)?	NO	all market party
C09	Is there any waste recycling plant operated in the city (near region)?	YES	
C10	Is there any central district heating operated in the city (near region)?	YES	
	Comments/Questions • *One DH or several DHs?* • *What is the overall heat demand in DHSs in Rotterdam? Can we have a map of the DHs location? What media are used (steam or hot water)?* • *Is WtE plant delivering heat to any of these DHSs? In what amount (question C03)?* • *What are the other/conventional heat sources and what fuels are combusted?* • *What is the current trend in overall DHS demand? Are new consumers attracted or more are disconnected? Are there serious drops in demand due to more efficient use of energy in buildings, industry, and/or due to the implementation of decentralized renewable sources (local solar heating, heat pumps,etc.)?*		
C11	Is there any waste collection yard operated in the city?	NO	
D	BASIC INFORMATION ABOUT COLLECTION VEHICLES IN YOUR CITY		
D01	Are there standard fuel vehicles used (gasoline or diesel)?	YES	
D02	Are there LPG fuel vehicles used?	NO	
D03	Are there CNG fuel vehicles used?	NO	
D04	Are there electric vehicles used?	NO	
D05	Are there hybrid fuel vehicles used?	NO	
D06	Is fuel consumption of vehicles monitored online?	NO	
D07	Is engine speed of vehicles monitored online?	NO	
E	BASIC INFORMATION ABOUT COLLECTION SYSTEM AND ITS ORGANIZATION		
E01	Is the collection performed according to regular/periodic schedules?	YES	
E02	Are the collection routes planned based on actual high of waste in the containers or bins (on-demand/dynamic collec	YES	
E03	Have the routes been optimized by any software?	YES	
E04	Are the individual collection vehicles routes tracked by GPS?	YES	
	Comments/Questions • *What is the main motivation for monitoring collection trips?* • *Do you use dynamic planning collection for each day?* • *Do you address the density of transportation when planning? Is it important parameters for dynamic planning?* • *What software do you use for optimization of the collection trips?*		
E05	Are the vehicles weighted before emptying at the facility (sorting line, WtE)	YES	
E06	Have the emission from collection been analysed by any study?	NO	
E07	Are the routes optimized aiming at emission reduction?	NO	indirectly
E08	Are there any online information about the density of transportation available in your city?	-	not my department
E09	Are there any data about the density of transportation available in your city?	-	not my department
E10	Are the information about collection routes of individual vehicles archieved?	YES	partially
E11	Are the information about collection routes of individual vehicles available for future investigations/analyses?	YES	
E12	Is there kerbside collection system operated?	-	not my department
	Comments/Questions • *What does it mean "market party". We are not sure with the meaning.*		

Appendix

Gdańsk

Gdańsk, home to 460,000 inhabitants, is a Polish city on the Baltic coast, the capital of the Pomeranian Voivodeship . It is Poland's principal seaport and the centre of the country's fourth-largest metropolitan area. Gdańsk has a temperate climate, with cold, cloudy, moderate winters and mild summers with frequent showers and thunderstorms.

“Gdańsk 2030 Plus Development Strategy” is a document which outlines the vision of growth and progress in Gdańsk by 2030. The top priorities defined in the strategy, using participatory methods, are: learning, cooperation, mobility, and openness. Gdańsk is also a role-model city when it comes to the implementation of open-data standards. In the last quarter of 2014 the “City of Gdańsk Manifesto of Openness” was proclaimed. Gdańsk representatives declared that the city would continuously open municipal and public data resources for citizens and industry in order to provide access to data gathered, processed, and stored with the use of public funding. In the RUGGEDISED project, Gdańsk, as a follower city, will study the smart solutions installed in the lighthouse cities in view of its own future implementation.

The projects included in the replication plan will be implemented in the Gdańsk Śródmieście (“Downtown”) district, which encompasses the old town. The quarter covers 5.65 km2 and is populated by 29,630 inhabitants, which gives it a population density of approximately 5,244 persons per square kilometer. The smart solutions proposed here will be deployed on the grounds of the replication plans elaborated within the scope of Gdansk´s “Next Economy” proposal. Their role is to offer activities complementary to building insulation, thermo-modernisation, and heat-network connections, which will offer an innovative edge to typical construction/refurbishment investments.

Glasgow

Glasgow is a city of transformation. From the birth of the industrial revolution and the heavy industry associated with the “workshop of the world”, to its cultural reinvention in the 1990’s, Glasgow has never stood still.

Today, Glasgow is taking part in the most important transformation in its history – to become one of the most sustainable and smart cities in Europe.

In 1765, James Watt strolled through Glasgow Green and conceived the idea of the separate condenser for the stream engine, viewed by many as the eureka moment that started the industrial revolution. This revolution gave untold benefits to people from all around the world, but also resulted in huge problems for the environment and society.

Glasgow will again be at the forefront of a new industrial revolution – the Green Revolution, which will deliver not just a greener world, but a more sustainable economy and a fairer and just society. Glasgow aims to be a leading city for renewable technology, and is using its historic strengths in engineering and education, to deliver a low carbon economy that will not only deliver a greener environment, but will deliver a better life for all our people.

Through RUGGEDISED, Glasgow will continue on its journey – transforming from an industrial city to a sustainable, resilient and low carbon city, focused on the future, growing from its past, and delivering a greener and smarter city.

RUGGEDISED in Glasgow will focus on the development of a Smart Street. The street is located in the city centre along a section of George Street and Duke Street, in an area of mixed residential, academic, community, retail, and industrial buildings. It will seek to address the challenges Glasgow faces from ageing infrastructure, fuel poverty and air pollution; by integrating planned regeneration and development with smart city capabilities.

The Smart Street will include: district heating, an innovative roof mounted solar PV canopy, ducted wind turbines, energy arbitrage, power storage, EV charging, and smart grid controls.

Parma

Parma is an Italian city of 192,000 inhabitants located in the Emilia-Romagna region, halfway between Milan and Bologna. Parma's smart city vision is to accelerate the city's sustainability and innovation. To implement its vision, Parma signed the Covenant of Mayors (2013) and the Mayors Adapt Initiative (2014). The City has a zero waste strategy and in 2015 new energy regulations for the city were issued to increase energy efficiency and the use of RES. The new policy and plan for urban planning and regeneration protects and promotes the city's environmental integrity and cultural identity.

By working with the other partners of the project, Parma will bring about a decisive change in the behaviour of citizens, in view of a more conscious and smart use of energy and mobility. This will be attained by integrating the knowledge and the experience gained in RUGGEDISED with a number of other local and European projects whose common goal is to aggregate citizens and stakeholders around the notion that sustainability is indeed a collective commodity. Thanks to the ground-breaking activities that RUGGEDISED will set in motion, Parma expects to be a model replicator and an inspirational example for other Italian and European mid-size cities.

The Parma University Campus is the scientific centre of the University of Parma. It covers an area of about 77 hectares located in the south of the city, with several buildings for teaching and scientific research. A strategic and innovative project, called Mastercampus, has been developed for the regeneration of the area. The project sees the area as a model district for the experimentation of innovative and integrated solutions to be later extended to other areas of the city. It currently includes 35 projects of 16 research departments in seven main thematic areas: energy management, environment, innovative construction, ICT, green economy, wellbeing health and lifestyle, architectural and urban forms, liveability and sociality.

Rotterdam

Taking into account socio-economic and climate challenges, Rotterdam is safeguarding the future of its inhabitants. To be ready, the City of Rotterdam, supported by strategic global consultant Jeremy Rifkin and his TIR Consulting Group LCC, has defined an investment strategy, Roadmap Next Economy, to make sure that the necessary economic transition in the region will be achieved.

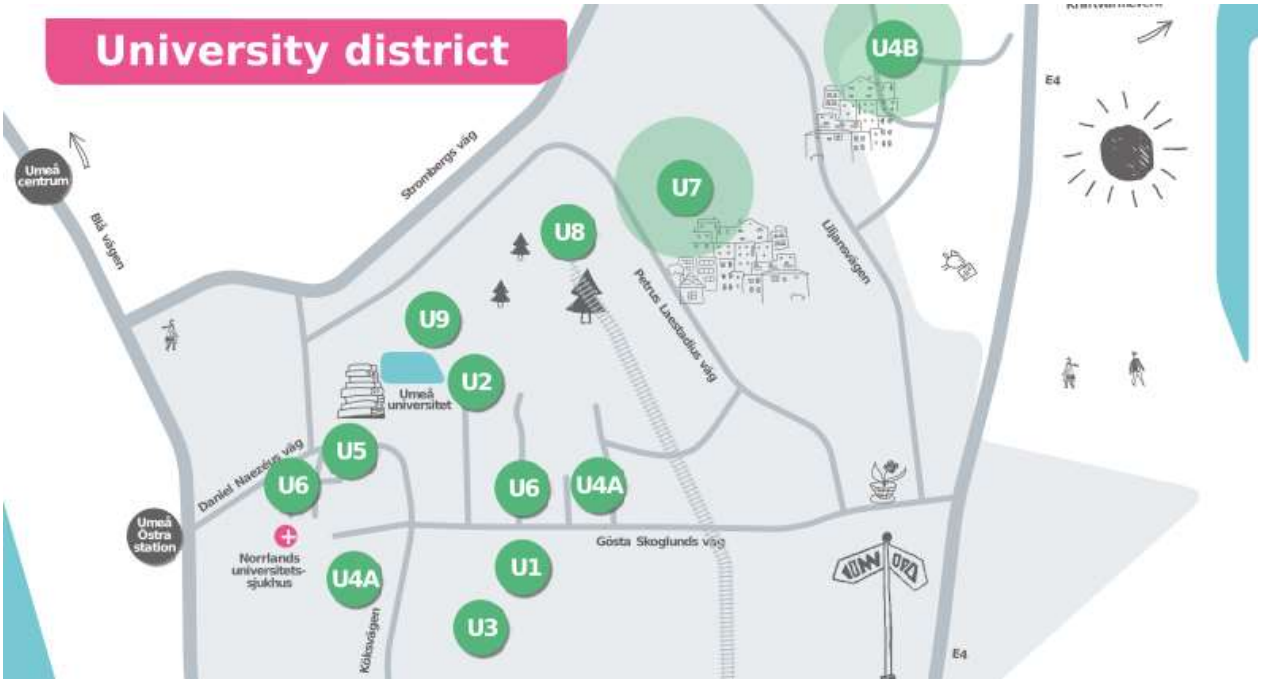
The transition from a mainly fossil fuel driven economy to an economy based on the use of sustainable energy sources will be bolstered within the next decades, providing opportunities to significantly stimulate a circular economy. This development will be strongly boosted by the dynamic and rapidly growing ICT-sector. The use of internet, big data, robotics and sensor techniques will have enormous disruptive effects on existing business models. Through the RUGGEDISED project, the city will look for ways to respond to these changes in order to be competitive and ready for the future in such a way that the inhabitants of the City of Rotterdam profit in the best possible way.

With enthusiasm Rotterdam wants to introduce the Heart of South area as the Rotterdam Lighthouse district for the RUGGEDISED project in which it will implement 13 smart solutions.
The South of Rotterdam faces relatively severe social-economic challenges accompanied by a young and multi-cultural population. The area is currently dominated by a car-oriented infrastructure where citizens and visitors sometimes feel estranged. Through RUGGEDISED the Heart of South district will undergo a serious transition in the upcoming years, consisting of the sustainable renovation of an out-dated shopping centre, the renovation of the public transport hub as well as various large-scale multifunctional buildings amongst which a swimming pool, an arts building, exhibition halls and a congress center. Furthermore, the public space in the area will be drastically redeveloped. With this project the city of Rotterdam will prepare the district for the future with the aim to achieve maximum energy efficiency and CO2 reduction while simultaneously looking to have a major social economic impact in terms of job creation, levels of participation of citizens and quality of life.

Umeå

Umeå is a fast growing city in Northern Sweden with progressive and environmentally-friendly citizens. Located 600 km north of Stockholm, the 11th largest city in Sweden has a subarctic climate, with short and fairly warm summers, but lengthy and freezing winters.

Umeå is a centre of education, technical and medical research in Sweden, with two universities. It counts 123,.000 inhabitants with two-thirds of the population born outside the municipality, and around one tenth from outside of Sweden. Umeå citizens are among Sweden's most educated, and are known to be very environmental engaged. Smart city thinking is at the core of the City of Umeå's overall vision of continued social, economic and environmentally sustainable growth. RUGGEDISED will facilitate a unified 'smart district', which is underpinned by planned regeneration and new developments, existing smart city capabilities and committed public and private sector investments.



In RUGGEDISED, Umeå will focus on an Innovation District that is situated immediately to the east of Umeå city centre, the University city area, which includes a mix of residential, academic and research facilities from two universities, a regional hospital, and community, recreational and commercial buildings. The neighbourhood is characterised by its young, student-influenced, population with 40,000 daily visitors. As such, the neighbourhood is one of the least car-dependent neighbourhoods in Umeå. The area will triple its inhabitants during the time of the project. Amongst the smart solutions implemented, the RUGGEDISED project will look at peak load variation management, shared use of energy and a smart, open- data city decision platform.

Brno

Brno, with 378,000 inhabitants, is the second largest city in the Czech Republic and is situated at the centre of the South Moravian Region. It has a strategic geographic position within Central Europe with excellent transport accessibility. Brno is a modern, dynamic and fast-growing centre of industry, research and innovation. In addition to being a city of universities, Brno also claims a high quality of life as a cultural, sporting and historical centre, complimented by a beautiful natural environment.

The Smart City Brno Concept was approved by Brno City Council in October 2015. The motto is that Brno is “a city which cleverly, sensibly and effectively uses modern technology and approaches, leading to an improvement in quality of life, supporting effective governance, preserving natural resources, and enhancing energy sustainability”. RUGGEDISED will be a way to make this happen, by enabling the study and replication of smart solutions from the lighthouse cities.

There is more than 500 ha of unused properties in Brno. Over 200 ha are industrial brownfields, most of which are located near the city centre. These areas have the potential to create new revitalised districts. Brno is currently developing a revitalisation and innovation plan for the brownfields and is setting out the best strategy to complete the smart city districts. In the RUGGEDISED project we are focusing specifically on these two locations:

- "Špitálka" – is an industrial area 1 km away from the main train station in the historical centre of Brno. A building complex of factories has operated since 1930 and generates electric power by using natural gas. Špitálka is a part of a large industrial area formed by brownfields that surround the center of Brno.
- Trade Fairs Brno Company - offers more than 130,000 sq m of net exhibition area, ranking it among the world's largest exhibition centres. This exhibition centre first opened in 1928 commemorating the first decennium of Czechoslovakian independence. Since the 27th of December Brno is the only shareholder of the Trade Fairs Brno Company. The area has the potential to create an environment where new technological innovations meet academia and the private sector.