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FUTURE OF SOLID WASTE MANAGEMENT IN THE CZECH REPUBLIC

Master’s thesis

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Prohlašuji na svou čest, že jsem magisterskou práci vypracoval samostatně a s použitím uvedené literatury.

I declare on my honour that I have elaborated my Master's Thesis independently and I have used listed literature.

Vojtěch Brix

V Praze, dne 13. 5. 2020

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I would like to thank to my family for supporting me through my whole studies. Hopefully once I will be able to pay you all your care back.

Abstract

In this work the author identifies the potential of the Czech Republic to improve its waste management model. Regulatory push from the side of the European union for reduction of landfilling to up 10% (Czechia currently landfills about 50%) of generated waste creates opportunity to develop best in class sustainable waste management model. It would require adopting the modern technologies which has been developed for each step of waste processing hierarchy. Between European countries have been identified 3 approaches to waste management in compliance with the regulation– in Finland focusing on recovery, in Slovenia focusing on recycling and in Germany which is mixed strategy. Most suitable for Czech conditions is Finnish one which is also the most economical one. It would cost all stakeholders approximately 13-23 billion CZK to implement it and the result would be decrease in ecological footprint by 12-14%. Most ecological would be to focus on similar-to-Slovenia model which would costs about 33.5 billion CZK but deliver results of 31% ecological improvement in comparison to baseline (AS-IS status) scenario.

Key Words:
Waste management model, sustainability, feasibility study

JEL classification:
Q01: Sustainable Development
Q38: Government Policy
Q42: Alternative Energy Sources
Q53: Air Pollution • Water Pollution • Noise • Hazardous Waste • Solid Waste • Recycling

Abstrakt

V této práci autor identifikuje potenciál České republiky zlepšit svůj model nakládání s odpady. Regulační tlak ze strany Evropské unie na snižování skládkování na 10 % (v současné době v Česku asi 50 %) produkovaných odpadů vytváří příležitost k nastavení co nejlepšího možného modelu nakládání s odpady. To by vyžadovalo zapojení moderních technologií, které byly vyvinuty pro každý krok v hierarchii zpracování odpadů. Mezi evropskými zeměmi byly identifikovány 3 přístupy k nakládání s odpady v souladu s nařízeními EU – ve Finsku se zaměřením na "recovery", ve Slovinsku se zaměřením na recyklaci a v Německu, kde se používá smíšená strategie. Nejvhodnější pro české podmínky je Finský model, ten nejvíce ekonomický. Realizace tohoto modelu by stála všechny zúčastněné strany přibližně 13-23 miliard CZK a výsledkem by byl pokles ekologické stopy o 12-14 %. Nejekologičtější by bylo zaměřit se na obdobný model jako ve Slovinsku, který by stál asi 33,5 mld. Kč, ale ve srovnání se základním scénářem by přinášel výsledky 31 % ekologického zlepšení.
Klíčová slova:
Model odpadového hospodářství, udržitelnost, studie proveditelnosti

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Introduction

In the close future waste management in Europe will have to be changed because of the regulation. From new regulatory framework are arising requirements for treatment of waste and goals for reduction of landfilling. Therefore, the Czech Republic will have to reduce landfilling of the waste from approximately 50% to 10% up to 2030. On one hand, it could be seen as a “complication” for the country because it will have to massively invest into the model, on the other hand, it can be observed as an opportunity for Czechia to build up ecological, sustainable, and economically effective one. If it is an opportunity there should be adopted best in class technologies. The goal of this work is to identify technologies, describe use cases how peer countries tackled the problem and calculate the feasibility and costs for the public/private sector. In the end of the work will be proposed recommendations for the country in terms of optimal waste processing model and key success factors. The work will help to set direction how the Country can become a leader in ecological waste management and what would be the cost for achieving best practice. The goal is not to define precisely set the to-be status but, rather evaluate the options for future and set the vision for bright ecological future. However, that is not only regulation what pushing us to shift to more ecological way of waste management.

Every year is in the world produced around 2.12 billion tons of waste. If all this waste was put on trucks they would go around the world 24 times. (United Nations: UNEP Yearbook, 2009) That means that is one of the largest in volume commodity which we face on the daily basis in the world. Waste management is extremely unpopular topic because for most of the people it is somehow interconnected with dirt and odour. However, waste management is one of the key improvements which helped humanity to achieve the development to as-is status and level. Thanks to the waste management, we were able to prevent spreading diseases and made our cities cleaner and prosperous.

And now the waste can help us again to resolve our global issues especially in the area of environment protection and sustainability. On a daily basis, we can observe discussions about construction of renewable sources of energy (and theirs impact on the price of electricity) with underlying needs to reduce consumption of fossil fuels and exhausting of CO_2 emissions (endowed by EU regulatory push inasmuch common sense of people). In Czech Republic are the discussions even strong thanks to outdating of coal power plants and never-ending public disputes about construction of new production capacities in nuclear power plants. In the same tame about 50% of municipal solid waste ends up on the landfills without any utilization. (Cesky Statisticky Urad, 2017) Key question is why the government does not utilize this relatively cheap source of fuel and does not kill two flies by one hit. Environmental impact would be substantial, and the overall economy would benefit from that.

By coincidence we also live in the times of digital disruption of 4th industrial revolution in which we observe fast digitalization and development of Internet of Things. Digitalization can help us to reduce costs related to waste management, optimize the overall operating model and build awareness about recycling between general population. Even such unpopular topic such as waste has attracted series of start-ups and about 97% of global key industry representatives and leaders believe that the disruption is coming into the industry. (Marvopoulos, 2017) From the first look, it is obvious that the disruption has to be strong in the industry which have not changed for almost 20 years. Current digitalization trends are mainly focusing on elimination of inefficiencies and in the waste, management exists a lot of them. For example, is it necessary to empty all containers every Tuesday and Friday even if they are only full of one-third, would not be optimal to rather empty only the full one? Is it necessary to use human labour for sorting of waste and would not be rather optimal to use robots for that? Is not the 50% of solid municipal waste which ends up on landfills essential inefficiency in the process with respect to circular economy goal? In the last years scientist around the world developed or heavily improved multiple technologies such as Pyrolysis and Gasification of waste and thanks to that we can ecologically transform waste to different fuels. The waste recovery step (waste to energy), within the waste processing hierarchy, in the recent years was strongly improved. For example, countries like Finland used about 60% (Eurostat, 2018) of waste in 2017 to efficiently produce energy, why don't we do so?

Another disruption is arising from the geo-political situation and regulatory requirement. With the approval of Circular Economy Package in the European parliament it is not only potential which Czech Republic has but also a legally binding requirement. The common goal of the EU countries is to recycle 65% of all recycle waste, 75% of packaging materials and only 10% of generated waste dispose on landfills by 2030. (European Commission, 2017) For the Czech Republic it will mean reduce landfilling by 80% and almost double the nowadays recycled volumes of waste. In case of not compliance with this regulation the Czech Government would be probably facing sanctions and fines from European Commission. Second reason is geopolitical. Historically, a lot of waste has been also sent far way to Mainland China. The possibility to export the waste made countries in Europe and the Czech Republic more flexible in terms of need of processing. On the other hand, it just outsourced the problem and on top of that it was less ecological way hot how dispose waste because in China norms for disposal were less strict. This option is no longer available because Public Republic China imposed ban on the import of waste. Therefore, countries in Europe has to find optimal way how to process waste domestically.

Those three reasons are together creating background for need to develop a sustainable waste management model in the Czech Republic. We have large potential to improve our behaviour towards environment, achieve higher efficiency of the model and achieve maximal efficiency of the model. Required technologies are currently available on the market.

1. *Theoretical background*

1.1 Methodology of waste segmentation

In current world are used multiple methodologies for segmentation and categorization of waste, especially related to regional legislative. Those methodologies are created by government agencies such as Environment Protection Agency ("EPA") in the USA and Environment Agency it ("EA") in the United Kingdom, or by statistical bureaus such as EUROSTAT in EU and Cesky Statisticky Urad ("CZSO") in the Czech Republic. Second important source of segmentation approaches are academic studies and resources. Academic resources rather focus on more precise composition methodologies, methodologies, for analysis of solid municipal waste composition, described by McCauley-Bell. In the work the author presents "material flow method" focused on production and product lifecycle and based on them calculate the total potentially produced waste and the waste stream percentages (by weight) within the various categories of waste. Waste is understood as the final product of product lifecycle. Thanks to this methodology it is possible to calculate waste production in large regions and estimate total waste production. Secondly, the author has presented "output method" which is focused on the experimental data gathering. In simple words, suggested approach is to get the data directly in field by observations and direct measurement of waste produced. (Sharma & McBean, 2007) (McCauley-Bell, 1997) That method is widely utilized especially, in developed countries and for example in the EU it is compulsory based on the EU Waste Framework Directive. (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 2018)

Thanks to combination of institutional and academic it was possible to create complex framework for segmentation of waste. Primarily it will be taken into consideration European methodologies because they are legally binding also for the Czech Republic. In addition, based on the description it will be directly recognized if the there is potential for further investigation of them in terms of energy production or they have to be treated separately.

Each of the waste can be also classified according to its danger exposure to the society and environment. The assessment divides often waste into 3 major categories (i) Absolutely non-hazardous - wastes that are always non-hazardous; (ii) Mirror (non)-hazardous – wastes that may be hazardous; and (iii) waste absolutely hazardous – wastes that are always hazardous. (EA, SEPA, NIEA, Natural Resources Wales, 2015) This division is rather important to keep in mind for further investigation, because waste types based on the danger/hazardousness assessment have to be treated differently in the waste management process described in the section 1.1.2.

However, in general there exists significant discrepancies between individual methodologies thus there is needing to precisely set the boundaries between individual segments. For example, “construction and demolition waste can be included in industrial waste, in MSW, or defined as a separate category.” (Yamada, Pipatti, & Sharma, 2006) Therefore, the author will use the methodology described below.

1.1.1. Waste segmentation

Even on the first level it is possible to recognized significant differences between the US, the EU on the centralized level, and individual state methodologies. On the very top level, however, the best division was developed by United Nations. The methodology has been partially adopted by CZSO and thus it is useful for further use. It divides solid waste into three major categories:

1.1.1.1. Municipal solid waste

Municipal solid waste (“MSW”) is defined as waste or garbage produce in daily life of citizens of a given country. Various economic subjects such as households, institutions and businesses, or construction activities produce MSW during in its daily life. It is composed of many elements typically paper, metals, organic components, glass, and plastics. MSW is usually collected in small volumes by the local authorities or hired companies. (United Nations in Asia and the Pacific, 2015) More about related value chain in chapter 1.1.2. It is composed of both non-hazardous and hazardous components. Hazardous components are usually batteries, automotive parts and discarded medicines. The composition of MSW varies a lot region-to-region and also city-to-city. Major factors, which are influencing the total production of solid municipal waste are Population, Urbanization, Gross Domestic Product (“GDP”), and Public Awareness. (Khajuria, Yamamoto, & Morioka, 2010) Listed factors also significantly influence composition of solid. EU countries have in composition of its waste significantly lower volumes of organic components (28 %) that developing countries (54 %). Oppositely, in the EU the share of paper component is around 26 % in comparison to developing countries where is only around 13 %. (Troschinetz & Mihelcic, 2009)

Individual subcategories commonly recognized are based on the source of the waste as follows:

Table 1: Sources and Types of Solid Wastes

Source	Typical waste generators	Types of solid waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g. bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, hospitals, prisons, government centres	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches, and other recreational area, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off- specification products, slag, tailings

Source: United Nations

1.1.1.2. Industrial solid waste

Industrial solid waste ("ISW") is mainly generated in manufacturing industry and can be described as unwanted side product of operations. Major sources are specifically light and heavy manufacturing, fabrication, power plants and chemical plants. "*Typically this range would include paper, packaging materials, waste from food processing, oils, solvents, resins, paints and sludge, glass, ceramics, metals, plastics, rubber, leather, wood, cloth, straw, abrasives, etc*." (United Nations in Asia and the Pacific, 2015) Even though it is not obvious on the first look Industrial solid waste presents between 38 % (Latvia) to 75 % (Czech Republic) of total production of waste in a country. (Yamada, Pipatti, & Sharma, 2006) (Cesky Statisticky Urad, 2017)It is usually produced in large quantities due to the large scale of production. Conversely to the MSW, ISW must be managed directly by its producers and companies have responsibility for its treatment. (Ministry of Housing and Urban Affairs, Goverment of India, 2008) However, historically has ISW caused not negligible share of environmental pollution because large organization did not have comply with reporting about waste production and breach regulation and other limits. Nowadays, both European Commission and individual state levels regulation drives the change as EEA says: "EU and government policy across Europe is increasingly driven by the need to influence manufacturing practices in an effort to decrease the environmental impact of produces during their manufacture, use and end-of-life." (European Environment Agency, 2013)

As much as MSW production level is positively correlated with GDP and total population but its exact composition depends on technological level of a given country, and major industries in given country. (Yamada, Pipatti, & Sharma, 2006) Construction and demolishing waste are included in MSW and not in ISW.

1.1.1.3. Agriculture solid waste

Agriculture waste is waste generated during agricultural operations. Its composition is extremely brought from organic components such as animal excreta in the form of slurries and farmyard manures, harvest waste, spent mushroom compost, soiled water and silage effluent and inorganic components such as plastic, scrap machinery, fencing, pesticides, waste oils and veterinary medicines. (European Environment Agency, 2013) Agriculture waste, thanks to its significant share of organic components represents one of the major potentials for its utilization within energy or again reused in agriculture as fertilizer. In addition, it has great potential in cosmetics and other industries where selected sides products such as urea can be utilized thanks to its acidity. Individual categorise of ASW can be again both hazardous and non-hazardous. Most common pollutants are oils, chemicals and pesticides.

In developed countries agriculture waste represent only relatively small share, around 2 % according to EUROSTAT, of total waste production thanks to overall intensive production model. The potential of such waste has been identified few years ago and the EU started strongly support secondary usage of agriculture waste. Such methods are primarily composting and reuse or anaerobic digestion during which bio gas is produced. Agriculture waste processing has achieved significant successes and during last year there was a boom with bio-gas power plans and digestion. (Kubal, 2016) Similarly as ISW it is produced in large quantities and due to high concentration of water in ASW (because of that the waste is heavy), it is expensive to transport it on the long distances.

1.1.2. Holistic view on waste management

Solid waste management is composed of multiple steps, which do not vary according to the segment of waste. Whole system has not change significantly within last 100 years and it is pretty much common around the world. Standardized approach in waste management, so called solid waste management hierarchy or integrated waste management, is (i) generation (and Reduction); (ii) collection; (iii) storage and separation; (iv) reuse; (v) recycle; (vi) waste-to-energy systems (recover); (vii) final disposal and landfills. (United Nations Environment Programme, 2005) First three steps are unchangeable parts of the waste management process and forth to seventh are methods for waste processing. This hierarchy is even legally binding in the processing level in the Czech Republic and if there is possibility to process waste on the higher level a subject should do that, or it can be penalized. (PCR, 2001) In other words, it means that if a waste producer has two facilities for waste processing on different level (e.g. one for recycling of a waste and second for landfilling) the waste producer should dispose waste in the first (recycling) facility. Whole pyramid of waste management processing is in Figure 1.

Figure 1: Waste management hierarchy

Source: EPA, https://www.epa.gov/smm/sustainable-materials-management-non-hazardous-materials-and-waste-management-hierarchy *(i) Generation (and Reduction)*

Waste is generated from all individuals, business, and agriculture as was described previously. Generation volumes are highly correlated with income of given country it means that relatively richer countries generate significantly larger volumes per capita than low-income countries what is mainly interconnected with lower awareness about the environmental impact. Differences is possible to observe even between EU member countries how Halkos and Pertrou suggested. (Halkos & Petrou, 2018) However, how was identified by OECD in the develop countries after a breakthrough point in income per capita generated volume decreases. Main reasons for that are awareness of people and environmental concerns and no need to stress about basic necessities. (OECD; Cox Anthony, 2012) Key target of government and other institution is to reduce total generated volumes from two reasons firstly, it reduces cost of the whole waste management system (lower quantities have to be collected and processed) and secondly it decreases environmental footprint. (Tchobanoglous & Kreith, 2002) Important is also the aim of central institutions to decrease the toxicity of waste. If the right measures are implemented and there is good awareness about waste treatment between households share of toxic/hazardous waste radically decreases and thanks to that it is easier to process it. Government and municipalities use either positive incentive schemes to foster reduction of waste generation (buy out payments for specific types of waste) or penalties for not complying with reduction and recycling.

The whole process however starts even before the generation of waste by consuming a product. Most of the countries try to influence the volume of generated waste by changes in packaging and by turn to more sustainable materials. Thanks to that the whole following chain is positively influenced.

(ii) Collection

Collection is most visible part of the waste management system due to the it can be understood as a barometer of overall performance of a system. If it is not performing well such as in selected Asian and African cities it remains on the streets, however, its removal is not part of waste management but street cleaning system. (United Nations Environment Programme, 2005) Well-known parts in the collection chain are containers/communal storages for both recycling (separated recyclables) and mixed waste, compactor vehicles (in less developed countries handcarts). In different countries the system differs, in European countries it is common practice for recycling to keep all kinds of waste in separate containers (yellow-plastic, green-glass, blue-paper), however in Anglo-Saxon countries is widely used just one container for "recyclable" materials finally separated in Transfer/Separation Station. First approach requires high involvement of households and awareness development second rather higher costs in separation station. Refuse collection is time consuming and the whole process is composed of 3 parts (i) travel from/to collection area (ii) collection process and (iii) waste delivery to disposal site. Commonly is used house-to-house collection that is also the reason why it is most complicated in urban areas. (Tchobanoglous & Kreith, 2002) There have not been dramatic changes to these components since motor-driven vehicles replaced horse-drawn carts. (Merrill, 1998) The whole collection can operate either by private entitles (also case of the Czech Republic) or by state-owned enterprises.

(iii) Storage and separation

After collection waste is transported to transfer stations, which are typically responsible for separation of waste and preparation for further processing. Commonly is this part of waste management process called Mechanical Biological Treatment of Municipal Solid Waste ("MBT"). (Tchobanoglous & Kreith, 2002) Main aim of MBT is to reduce weight and volume of landfilled waste and separate reusable and recyclable components, which were not separated by citizens and companies during collection. Thanks to that MBT is rather complementary component to other technologies in the whole chain. During the process are "caught" residual recyclables and separation of them and prevent disposing them on landfills. During the MBT are separated from MSW mainly iron components, biological components, plastics and such components. (Department for Environment, Food, and Rural Affairs the UK, 2012) Major methods and technologies are listed in table 2.

Table 2: Technologies in separation

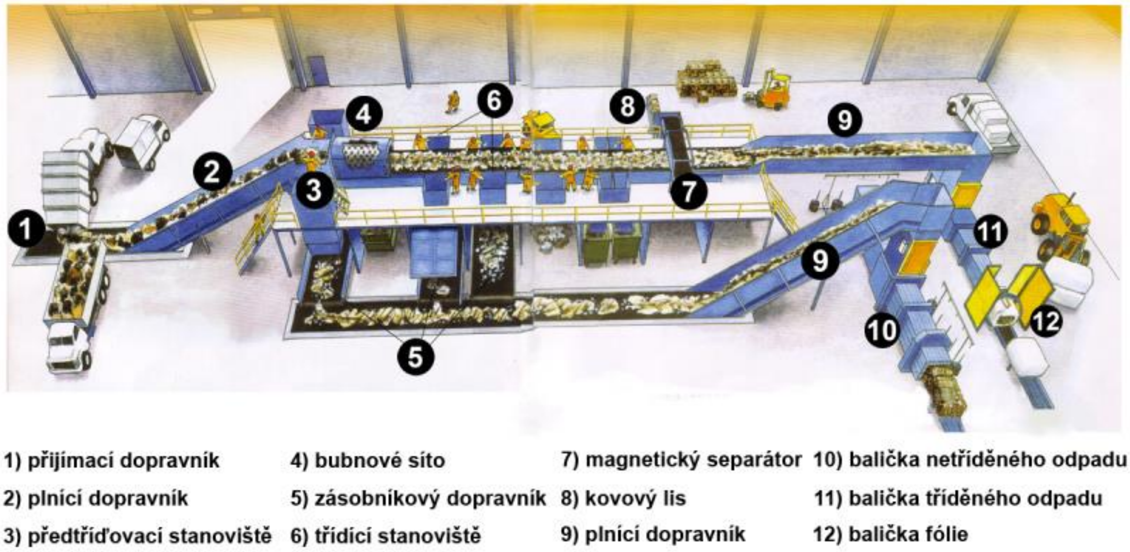
Separation Technique	Separation Property	Materials targeted	Key Concerns
Optical separation	Diffraction	Specific plastic polymers	Rates of throughput
Trommels and Screens	Size	Oversize – paper, plastic	Air containment and cleaning

		Small – organics, glass, fines	
Manual Separation	Visual examination	Plastics, contaminants, oversize	Ethics of role, Health & Safety issues
Magnetic Separation	Magnetic Properties	Ferrous metals	Proven technique
Eddy Current Separation	Electrical Conductivity	Non-ferrous metals	Proven technique
Wet Separation Technology	Differential Densities	Plastics, organics will float stones, glass will sink	Produces wet waste streams
Air Classification	Weight	Light – plastics, paper Heavy – stones, glass	Air cleaning
Ballistic Separation	Density and Elasticity	Light – plastics, paper Heavy – stones, glass	Rates of throughput

Source: Department for Environment, Food, and Rural Affairs the UK

MBT was the most popular in the end of 1990s in Germany but in last years it becomes less and less popular because it is not final technology for waste processing. The whole process in the MBT is harmonized around the world and its scheme is presented in Figure 2.

Figure 2: Mechanical Biological treatment line



Source: Univerzita Jana Evangelisty Purkyne, Enviregion *(iv) Reuse*

Reuse is relatively newly defined approach for waste processing. In legislature it is described as "*reuse shall mean any operation by which packaging, which has been conceived and designed to accomplish within its life cycle a minimum number of trips or rotations, is refilled or used for the same purpose for which it was conceived, with or without the support of auxiliary products present on the market enabling the packaging to be refilled; such reused packaging will become packaging waste when no longer subject to reuse;*". (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 1994) Reuse of waste is not related only to packaging but also to electrical appliances and similar products. One of the best examples are beer glass bottles which are in almost all European countries are backed up with deposit. In selected countries such as Germany are also backed up with deposit other products such as plastic bottles. The deposit significantly improved volumes of selected product on landfills. Standalone topic is reuse of garments and which is dramatically raising, especially in Western countries as reaction on the Fast fashion and affordable clothing. (Ekstrom & Solomonson, 2014)

(v) Recycle

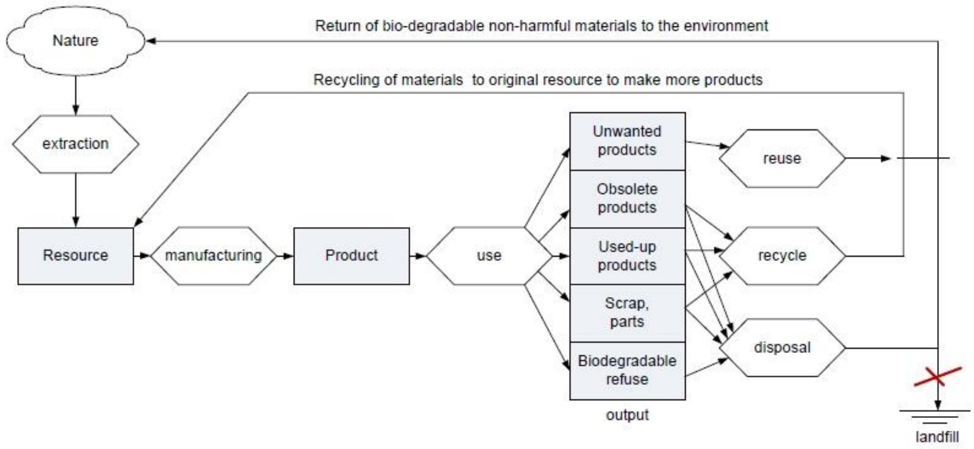
Recycling is one of the most popular method for reduction of volume of disposed waste. In the European legislature it is defined as *"recycling` shall mean the reprocessing in a production process of the waste materials for the original purpose or for other purposes including organic recycling but excluding energy recovery;"* (THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION, 1994). From the legislature it is obvious that it is necessary to separate recycling of organic and inorganic materials.

Organic materials recycling – MSW and other solid wastes contain large volumes of organic components which can be used for productive purposes rather than end up on landfills. Most common method for recycling of organic components is composting. The widely used definition of composting is as follows: "*Composting is the biological decomposition of the biodegradable organic fraction of MSW under controlled conditions to a state sufficiently stable for nuisance-free storage and handling and for safe use in land applications"* (Golueke et al., 1955; Golueke, 1972; Diaz et al., 1993). There are multiple methods of composting primarily dividing according to (i) size of processing – industrial composting vs. yard composting; (ii) technology which is used;

(ii) Aerobic vs. Anaerobic and; (iii) temperature used for composting - Mesophylic vs. Thermophylic. (Tchobanoglous & Kreith, 2002) Composting reduces waste weight and volume by up to 50 % and thus simplifies further usage of waste. Final product, compost, is again marketable primarily in agriculture as soil amendment or for production of nitrogen, phosphorus, and potassium fertilizers.

Inorganic material recycling – Inorganic material to be recycled can include paper, glass, cans, and plastics as well as other items. Materials for recycling can be sourced either directly when they are sourced (described in section Collection) or during industrial separation (described in section Storage and Separation) or directly on collection potions “gathering yard”. Gathering yards are primarily used for collection of hazardous waste or partially hazardous such as electrical equipment and appliances, vehicles, and other complex products. Most of such waste is decomposed to individual parts – plastics, irons and other materials and afterwards treated identically as other waste. (United Nations Environment Programme, 2005) Key terms which appeared are sustainable recycling and recycling loop as seen on Figure 3 which means that *“…or each truckload of recyclable commodities leaving a region, a truckload of recycled consumer goods must enter”.* (Tchobanoglous & Kreith, 2002) This concept was highly appreciated but rather utopia than reality. Under current circumstances most of the recycled materials is marketed and again used in manufacturing process. Final product can vary a lot from the original one. Commonly before they are sold to a manufacture they are milled, or another way harmonized and homogenized, washed, packed and prepared as raw material for manufacturing.

Figure 3: Closed recycling loop



Source: Pennsylvania State University, https://www.e-ducation.psu.edu/eme807/node/624 *(vi) Waste-to-energy systems (recover)*

Recovery is one of the last steps in hierarchy of waste management process. Large portion of population describes energy usage of waste as "combustion" of waste. However, due to different physical conditions during energetic processing of waste it should be describe differently. One of the major differences, which has base in both European and Czech legislature is required energy efficiency of the incineration. The Czech legislative defines as recovery of waste a process where energy efficiency of the incineration is above 0,65. If the efficiency is below such level it is not recovery of waste but final disposal. Key advantages of waste recovery equipment are energy generation and simultaneously production of inert fraction, which are sanitized from biological and chemical pollution. (United Nations Environment Programme, 2005) Waste-to-energy process includes variety of technologies such as combustion, gasification, pyritization, anaerobic digestion, and landfill gas (LFG) recovery. Some of those technologies has been discovered or significantly improved in recent years thus they might hide large potential. In addition, in the last years there have been and developed near-to-zero CO2 emission technologies like combined heat and power generation ("CHP"). During the waste-to-energy the final output can also has various forms – heat, electricity or fuel. (United States Environmental Protection Agency, 2019)

Key challenges which was the technology facing in 1990s and early 2000s such as high capital expenditures, resistance from the public and low efficiency has been overcome since 2010. Nowadays, it is becoming as one of the most favourable sources of energy because it is ecologic and similarly solving the issues with increasing volumes of waste. On top of that, the whole approach to the technology has shifted towards community approach and rather than constructing large waste-to-energy facilities it has been decided to construct multiple decentralized sources. Idealistic perspective is that the waste locally produced waste (let's say in a municipality) would go through the waste management hierarchy and what remains would be used for electricity and heat generation, supplied back to municipality's citizens and companies. (European suppliers of waste-to-energy technology, 2017) Similarly, could work bio gasification.

(vii) Final disposal and landfills

Least preferred way is final disposal of waste and last step in the integrated waste management process is final disposal of waste. Final disposal has again multiple forms such as incineration without (or with relatively low energy efficiency) or landfilling. Historically, there have been used also other methods such as ocean dumping of municipal solid, however, such methods have been abandoned almost all around the world. Even though, that none of the methods listed above is ecologically friendly and simultaneously does not bring any economic or other benefit to population it has to been understand that for selected refuses it is one of the best options. For example, most of the hazardous waste is incinerated because it simply creates the lowest possible negative ecological footprint as possible. (United Nations Environment Programme, 2005) Therefore, incineration will have its place in waste disposal as long as a technology would be able to make any toxic waste not-toxic. Thanks to incineration

Partially different story is about landfills. Waste disposal on landfills has been popular since ever because it is extremely cheap way of waste disposal. Historically, many landfills have been constructed with limited understanding of leaching of toxic essences to soil, physical and chemical processes in disposed waste and potential impact of both of that aspects on public health. However, similarly as incinerators has its place in the world some kinds of landfills have it, too. For example, monofills used for disposal of ash or secured landfills for disposal of hazardous waste will be hardly replaced. Different case are sanitary landfills where ends up MSW which has not been processed in previous steps of waste management process and uncontrolled land disposal sites or waste dumps. (Tchobanoglous & Kreith, 2002) European regulation and national regulation should try to reduce as much as possible landfilling. The difference to all previously mentioned ways is that if waste ends up on a landfill it won't generate any economic benefit only cost (usually in form of negative externalities[1]).

Major differences between countries and regions are mainly in quality of provided services in individual steps of the chain. Overall quality of waste management system is depending on the funding. (Tchobanoglous & Kreith, 2002)

Whole waste management system is expensive but in most of the countries general public observe it as somehow natural, because it is organized and managed by local or central government. Funding for the system is provided either via fees and charges and other direct charges for collection and disposal or via indirect charges. Direct charges are aiming directly on the waste generators and usually are in form of fees for

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[1] Externalities refers to situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided.
(OECD; http://www.oecd.org/dataoecd/8/61/2376087.pdf)

collection and disposal. In selected countries waste management is still observed as public good and thus its funding is interconnected with taxes or with charges connected with consumption of water and electricity. Especially in the last years grew the importance of incentives, subsidies, and penalties (European Environment Agency, 2013) because in multiple countries the waste management industry is undergoing a transformation thanks to new ecologic standards and sustainability orientation of western world. Implementation of new technologies is strongly depending on the incentives from central governments because most of the private businesses operating in the industry has slow motivation to innovate also because its oligopoly structure. (The Bundeskartellamt in Bonn, 2011)

Modern approaches to Integrated Solid Waste Management are focusing primarily on 4Rs of waste management generation Reduction, Recycling, Reuse, and Recovery. In comparison to remaining steps in the chain this 4Rs still hide potential for improvement. In the developed countries such as the Czech Republic collection can be problematically improved. There have been developed technologies such as Underground Automated Vacuum Waste Collection System, however, under current circumstances it is extremely economically ineffective in comparison to standard waste collection method if it should be retrofit to a municipality. In case of new development, it rather depends in size of the implementation of project. In other words, if the system should be deployed in large area its economic efficiency decreases because extremely high CAPEX per km and relatively low OPEX. (ADEME, 2017) Very same situation is with waste storages and separation of waste where has not been presented new technology since 1950s (except improvement on the current technology). As was mentioned above reduction is rather institutional and behavioural challenge, which can be influenced by better education and awareness in the population and thus it is not essentially part of the waste management process. Therefore, in the following trends and innovation analysis the author will focus primarily on Reuse, Recycling, and Recovery inventions and latest trends.

1.1.3. Trends and new technologies analysis in Reuse, Recycling, and Recovery

Within last few years, multiple new trends arose in the waste management process. Those trends are based on multiple drivers arising both from socio-cultural changes and economic reasons. Some of the key trends are driven also by legislative/regulatory changes. It is necessary to mention that most of new technologies are arising and reacting on the other trends. Technology is mainly addressing current demand for resolution of existing problems.

With the closer look on the integrated waste management process trends in the developed world (high income countries) it can be identified major mega-trends such as Sustainability, Circular economy, Behaviour analytics and nudging, Digital disruption, and Community. These trends are same for all parts of the of the value chain, but they have different implications and final impact.

1.1.3.1. Trends in reuse

First very important trend in the field of reuse is sustainability. Sustainability is defined as *"...rend of sustainability is built on the foundation of protecting our planet and its resources. It has become part of a global commitment to protect the environment while providing a future for many generations to come."* (Institute for Sustainability, 2014) First major trends which is affecting disposal of waste is digitalization. (Szaky, 2014) Digitalization, especially apps and online marketplaces has one major impact and it is decrease of transaction costs. This effect has been proven by multiple researches focusing on various industries such as transportation (Harding, Kandlikar, & Gulati, 2015) or online shopping (Bakos, 1997) and thanks to that more people can enter the market. This effect can be simply explained as allowing goods which could not be sold due to relatively lower quality and high search cost to enter the market thanks to elimination of search cost. With increasing penetration of smart phones in Western countries and sustainable way of living similar apps gaining popularity. For example, application Letgo can be mention as representative. From the personal experience of author similar platforms are one of the major market prices for young adults in western countries, however, they have not penetrated Czech market significantly yet.

With sustainability and circular economy is closely interconnected also the second technology. High priority and promising method for future in processing of waste, mainly the organic component, is composting. Composting has increasing priority because it is direct alternative for disposal of waste on landfills. During the composting controlled bioprocess, the organic waste is transformed into new product usually a nitrogen fertilizer. (United Nations Environment Programme, 2005) Major trend interconnected with composting is focus on decentralization of such production and rather focus on community-based composting. In ideal world all local organic waste will be collected and disposed in composting facilities or in anaerobic digestion facilities and afterwards used back for the better off of a local society. The product would be used either for fertilizing of public green areas (parks, fields) or sell back to local citizens. Leftovers would be sold to agriculture production. (Rothenberger & Zurbrugg, 2006) In recent years, both European union and the United States increase the support of composting, however, the results are delivered extremely slowly in Eastern Europe. In the European Union currently is composted about 17% of all waste generated but in Eastern Europe it is between 1-5% (Valavanidis, 2015)

Last but not least, important trend in Western countries is nudging and information/behaviour influencing of public. The trend is extremely similar for both recycling and reuse, however, for simplification it has been included only into reuse. Municipalities and government try to influence behaviour of citizens either directly or indirectly. Direct method is interconnected with development of deposit schemes for bottles and other waste. In Czech is well known deposit scheme for glass bottles, however, in other countries of world such scheme has different scale. Absolute leader within this category is Germany, Netherlands and the Nordic countries where the deposit schemes are implemented also on aluminium cans, plastic bottles. In Australia (New South Wales, Queensland, Northern Territory, and Australian Capital Territory) local governments have implemented container deposit schemes for all drinks. (Container Deposit Systems Australia, 2018) Indirect form is usually via building general awareness in public via different channels. For that can be used community mobile apps which helps to inform population about e.g. collection times scheduled (My Waste app), inform about current level of collected waste material and what local government makes to reduce ecologic footprint (Recycle for Greater Manchester) or online calculators which evaluate the impact of your recycling (EPA iWARM). The data from applications can be beneficial for municipalities because they can better schedule collections and improve overall performance of integrated waste management. (Mavropoulos, Anthouli, & Tsakona, 2013) Secondly, there exist more traditional methods such as TV commercial informing about recycling for example well Czech company EKO-KOM "MÁ TO SMYSL. TŘIĎTE ODPAD". However, direct communication with citizens such as experiment performed in Norway. (Milford, Øvrum, & Helgesen, 2015) Researchers distributed between households an informative letter with their production of waste and recycling level and comparison to city's benchmark. As the impact the total recycled waste increased especially in paper category. Additionally, 31% of people said they start to recycle and waste less. (Milford, Øvrum, & Helgesen, 2015)

Table 3: Summary of technologies in Reuse

Technology	Impact	Types of solid waste
App		Cost of relevant app can vary from 1-10 million CZK depends on functionalities included
Composting		Approximately 32 mil CZK for small yard composting facility with capacity 27 tons/day
Deposit scheme		Deposit schemes cost is impossible to estimate, and it is not publicly available any relevant analysis

Source: Own elaboration

1.1.3.2. Trends in Recycle

Recycling is one of the most developed parts in the value chain, however, in latest years it faces challenges. One of the major challenges is change in composition of waste. Historically, large portion of waste was composed from paper (newspapers and magazines) but adoption of digital media this part of partially disappeared from households' bins. However, new categories of waste have appeared which should be recycled, too. It is primarily E-Waste (white electronics such as mobile phones and laptops) which should be in scope for government and municipalities waste management projects in future. (Szaky, 2014) For E-waste it will be necessary to develop infrastructure which is not completely in place yet, build general awareness in public, and develop incentive schemes for private sector to improve its disposal process. Even though, most of the countries have implemented an E-Waste recycling taxes the status quo is not sustainable. As was mentioned before, even larger problem might be low awareness between people and thus low recycling level of E-Waste. (United Nations - Environment Management Group, 2017) Except the trend with E-waste, even in standard waste management process has been done some improvement within the last years. Firstly, the IoT and digitalization has allowed to develop smart bins. Smart bins have positive impact from two major reasons. It collects data about waste disposal in individual districts and it allows municipalities to react on changes. On top of that smart bins allow to optimize collection routs and thus increase efficiency of collection and reduce operating expenditures. (Enbysk, 2015) Second significant improvement (and current) trend was done in sorting of recycled waste. The sorting can be now extensively automated and thanks to that the output from sorting line achieve higher purity. Simultaneously it essentially decreases operating costs of sorting and replace low-added value work. New technologies used for sorting are for example optical sorting which is based on UV light-print of waste and colour sensitive cameras. Waste which can be sorted by this technology is mainly plastics, composites but currently is adopted mainly for glass. With utilization of this technology final purity can reach about 99.7% for flint glass. (Thomas & Lizzi, 2011) It should be also mentioned de-inking of paper. Thanks to that for example newspaper paper can be recycled around five times. (Thomas & Lizzi, 2011) To these technologies are closely related processing method and technologies which would not be available without high-enough purity of intermediate goods from waste. One of those technologies is cullet remanufacturing which allows to remanufacture from broken pieces of glass called cullet. *"…The cullet undergoes melting and remanufacturing of glass bottles or containers. Cullet is also used as substitute in building material and as raw material in insulation."* (Saleem, Zulfiqar, Tahir, Asif, & Yaqub, 2016)

Table 4: Summary of technologies in Recycle

Technology/trend	Impact
E-Waste disposal	Approximately 300 mil CZK CAPEX for 10 tons of capacity
Smart bins	Approximately price per one bin is 15 USD for sensors
Sorting technologies	Price of technologies is not publicly available
Cullet technology	Cullet is not industrially scale adopted yet

Source: Own elaboration

1.1.3.3. Trends in Recover

As was mentioned previously waste to energy or energy recovery is one of the major trends for future. By its definition it basically includes sustainability and circular economy paradigm. Energy is used for production of goods and after consumption of goods and disposal the waste is used, after separating of reusable and recyclable components, for production of new goods in form of energy. Thanks to that the dependence on fossil fuels can decrease. As in other categories in recovery exists two major approaches (i) direct waste to energy and (ii) indirect waste to energy processes. Direct method is primarily incineration of non-recyclable waste, which is shredded. Screened and dried. In the direct incineration the temperatures are usually minimally 850 degrees Celsius what destroys toxic part of the waste. Calorific value of waste depends on its composition, however, usually is about 1/3 of natural gas. This technology has multiple negative impacts such as the emission of SOx and NOx gases when combusted. (El-Sheltawy, Al-Sakkari, & Fouad, 2016) Therefore, in future direct incineration is expected to rather become only part of hazardous waste treatment, in developed countries, process for which its places are irreplaceable.

Oppositely to direct incineration, indirect incineration has high potential in future and clear majority of Western countries want to focus on development of its technologies. Technically it is considered as renewable source of energy and that is one of major reasons why those technologies are included in EU action plan for circular economy. (European Commission , 2017) New technologies in this segment are divided into two major categories including bioconversion and thermal conversion technologies. (Saleem, Zulfiqar, Tahir, Asif, & Yaqub, 2016) Thermal conversions are focusing on transformation of waste, especially plastics, tiers and crop residues on fuel gas, oil and other energy usable products. On top of that heavy metals are converted on harmless oxides and thus the method reduces overall ecological footprint of waste. In recent years major advancement has been achieve in three subcategories - Pyrolysis, Gasification, and Refuse Derived Fuels. (Saleem, Zulfiqar, Tahir, Asif, & Yaqub, 2016) For pyrolysis must be achieved temperature between 300- and 800-degrees Celsius during which the waste is converted into liquid or gaseous fuels along with residue char, which is a mixture of non-combustible material and carbon. (Kothari, Tyagi, & Pathak, 2010) Relatively low temperature required is advantage of this method, but the key disadvantage might be lower quality and higher demand for purification of output. During pyrolysis a gas called syngas is produced which can be used either directly as flammable gas in steam engines or cooled as liquid fuel transported and burned somewhere else. (Saleem, Zulfiqar, Tahir, Asif, & Yaqub, 2016) Oppositely to pyrolysis gasification happens with high temperatures above 750 degrees Celsius with access of air. With the higher temperature the overall toxicity reduces and most of the pollutant are eliminated, however, again most of the downstream gasification processes require to use some kind of cleaning and purification technologies. (El-Sheltawy, Al-Sakkari, & Fouad, 2016) Latest trend is to use for Pyrolysis and gasification plasma which heavily reduces toxic emissions in treatment of plastics and halogens. Last category is thermal conversions is refuses derived fuels. During this method only, the high calorific components (usually the light one) of waste remain in the waste mix. *"Firstly, the waste is collected in the shredder that break waste bags, in order to reduce their sizes. Then this shredded material is moved to a digestion tower where this waste is preserved for (almost 6 to 8) days. The first four days, the waste is kept in temperature between 60 and 65 ◦C, which is than increased to 70 ◦C for another two days."* (Saleem, Zulfiqar, Tahir, Asif, & Yaqub, 2016) The final product RDF can be used as a fuel in power plants or in plasma gasification and pyrolysis.

Bio-conversion technologies are focusing on processing of biological waste and its use for energy purposes. For municipal solid waste is mainly used Dry Anaerobic Composting. This technology is known in the Europe mainly as biogas power plants. During the process organic component of the waste is disposed into the digestions silos and it is allowed to react under anaerobic conditions. The chemical reactions generate methane, carbon dioxide numerous low-molecular weight intermediates such as organic acids and alcohols. (Haug, 1993) It is widely used for example in South Korea to manage food residuals (Silva & Naik, 2007) and it can be used as complementary technology for composting. It is closely related to community way of living trend because locally produced food and agriculture residuals can be used for production of energy for a community. Historically, clear majority of bio-gas power plants has been constructed close to major agriculture production facilities (or directly within them) as a relatively cheap source of energy. Major reason for that was sufficient supply of organic material which has been disposed in silos. In future, in line with smart technologies allowing collection of organic waste from households and small businesses this technology can be successful also for local sourcing of energy in municipalities and villages.

Table 5: Summary of technologies in Recover

Technology/trend	Costs of construction
Thermal conversion - Pyrolysis	Around 520 mil. CZK depending on the specification and capacity
Thermal conversion – Gasification	Approximately 2.1 billion CZK depending on specification and capacity for large scale plant (150 MW installed capacity) Approximately 110 mil. CZK per MW of installed capacity

RDF	Price of technologies is not publicly available highly depends on concrete specification of a plant and equipment included
Dry Anaerobic composting	Approximately 100 mil. CZK which can process 12000 tons per year

Source: Own elaboration

1.4. Overview of selected methodologies used

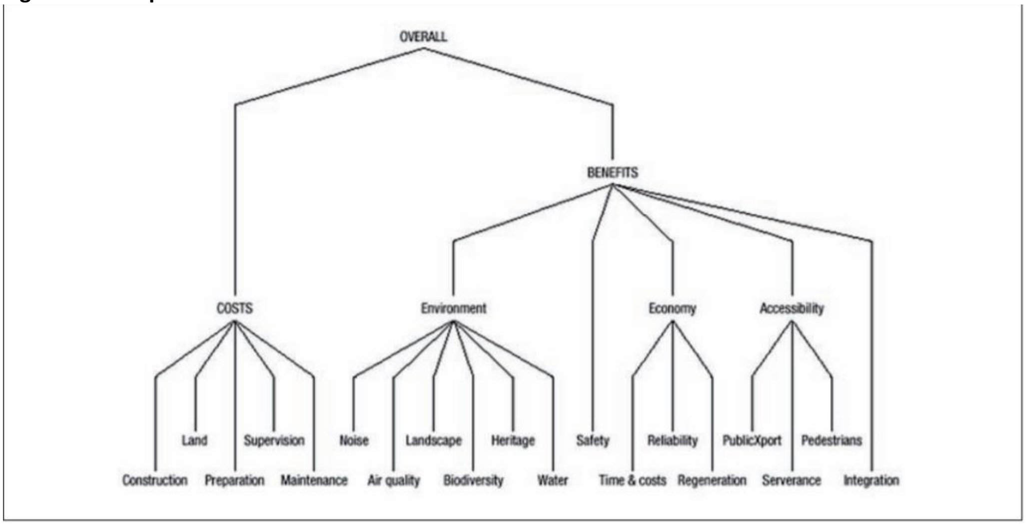
1.4.1. Multi-criterial analysis

Multi criteria analysis is a tool utilized both private and public institutions to analyse complex problems in structured framework. (London School of Economics and Political Science, 2011) In the context of this thesis there are three separate major pieces (i) Ecological impact; (ii) Economical feasibility / proximity; and (iii) Financial analysis. Financial impact was analysed separately, and the approach described in following chapter. For the ecological impact and economic feasibility was leveraged same approach arising from the framework. Each of the role models was analysed in performance matrix. Performance matrix is a table where an index is developed from individual variables and data points. To each of the variable can be assigned weight with aim to emphasize the more important variables over the less important (London School of Economics and Political Science, 2011). Definition of individual variables which are included into an index was based on an issue tree.

Ecological part of the multicriterial analysis (performance matrix) aimed to identify the most ecological model. Following the logic of issue tree, the author has created three clusters of variables each of them composed of three to four variables. To clusters were assigned weights. Details of methodology and variables including also input values are described in chapter *2.3.1. Ecological impact assessment.* Objective was to identify most ecological model thus individual parameters were analysed in terms that better performance was equal to higher output. Data were analysed in excel spreadsheet with a function PERCENTRANK which returns rank of the value in scale of the data array.

Secondly, the economic proximity towards the Czech Republic has been analysed. From the methodologic point of view the approach was almost the same as for the ecological assessment with one difference. The proximity was assessed by calculation of difference in individual variables between the Czech Republic performance and role model performance. The better result is thus the model closer to Czech conditions. In terms of data analysis was again constructed multicriterial performance matrix with weights assigned to individual clusters of variables. Details of methodology and variables including also input values are described in chapter *2.3.2. Multicriterial assessment of models' economical proximity to the Czech Republic conditions*.

Figure 4: Example of issue tree



Source: London School of Economics and Political Science

1.4.2. Cost-effectiveness analysis & feasibility assessment and NPV

One of the goals of the thesis was to evaluate different waste management models from perspective of costs and the potential what they deliver to the society. The analysis which was conducted was mainly cost-effectiveness analysis as described in literature for example as *"... analysis comprises one part of a very much larger literature on project appraisal, i.e. on assessment of the economic desirability of alternative 'projects' from a social perspective*" (Jamison, 2009). It the thesis there will be described three major models which have been compared to each other from economic perspective (business plan model). Each of them has its cost items based on selected technologies and potential revenues from output which the technologies for waste processing are generating. For the cost perspective were included all the cost categories which should be covered in cost-effectiveness analysis (i) Direct (production) costs; (ii) Indirect costs; (iii) Cost of financing. (Phillips, 2009) On the revenue side were considered only direct revenues generated e,g. by sales of electric energy or syngas. For the analysis was modelled holistic business plan considering eight major cost and revenue items for each technology such as maintenance costs and capital expenditures translated into depreciation described in literature. (Tchobanoglous & Kreith, 2002) (Kubal, 2016)

Overview of cost items is provided in chapter 2*.4. Business model and feasibility assessment with new technologi*es. In the chapter are also described all key assumptions from the model and individual items.

Secondly, after the business model was developed it is required to analyse the models impact from corporate finance perspective. Commonly used methodology for evaluation of project is Net Present Value ("NPV"). *"Net Present Value (NPV) is the value of all future cash flows (positive and negative) over the entire life of an investment discounted to the present. NPV analysis is a form of intrinsic valuation and is used extensively across finance and accounting for determining the value of a business, investment security, capital project, new venture, cost reduction program, and anything that involves cash flow"* (CFI Institute, 2019) NPV has standardized formula for two years period provided below where Z1 = Cash flow in period 1; Z2 = Cash flow in period 2; r = Discount rate; X0 = Cash outflow in time 0 (i.e. the purchase price / initial investment). For more than two periods the formula is equal to sum of all (n) discounted cashflows minus initial investment (cash outflow in time 0) (CFI Institute, 2019)

Equation 1: Net Present Value

$$NPV_{XYZ} = \frac{Z_1}{1+r} + \frac{Z_2}{(1+r)^2} - X_0$$

Source: CFI Institute

Net Present value methodology was selected because complex structural change of overall waste management ecosystem is long term investment and to identify real costs of such significant investment. In comparison to other methodologies such as Internal Rate of Return it provides simply explainable output the projects value rather than return simple percentage value. Other simply explainable options would be payback period; however, the project is expected to generate negative value and must finance by public funding. It is likely that payback period will be infinity without subsidies.

1.4.3. Interviews and coding

Interviews are one of the core techniques for gathering both quantitative and qualitative information and insides directly from stakeholders engaged in the market.

However, interviews can be dangerous from perspective of misunderstanding, simplifying and idealizing the output by a researcher. (Qu & Dumay, 2007) It this thesis the author used interviews for evaluation of proposed models and validation of findings and focused on qualitative information. The target was primarily to leverage interviews with selected stakeholders in the value chain of waste management and include the market view on the findings. Even though selected authors describe interviews as unreliable and not objective (Denzin and Lincoln, 2000), the author decided to conduct interviews to gather inside out perspective.

The interviews can be conducted in multiple approaches in terms of structure and level of flexibility within an interview. Based on Alvesson there are three basic interview methods arising from positions of interviewer, interviewee and the overall interview – (i) Neopositivism, (ii) Romanticism, (iii) Localism. (Alvesson, 2003)

Table 6: Positions in Interview

Position	Interview	Interviewer	Interviewee	Accounts
Neopositivism	As a tool for collecting data	As a capable researcher to trigger honest response	As a truth teller	As objective data and knowledge transfer
Romanticism	As a human encounter between the interviewer and the interviewee	As an empathetic listener to explore the inner world of the interviewee	As a participant to reveal real life experiences and complex social reality	As a pipeline of knowledge mirroring interior and exterior reality leading to in-depth shared understanding
Localism	As an empirical situation that can be studied	As people who are involved in the production of answers through complex interpersonal interaction	As people who are not reporting external events but producing situated accounts	As situated accounts that must be understood in their own social context

Source: Adapted from Table I in Alvesson (2003, p. 15)

Source: Qu & Dumay

Based on the table above the author decided to focus on neopositivism position because the goal was to gather market insides and details. In terms of validation, which might be rather conduct by romanticism position, has to clarified that the author did not present the results of his work. The approach was to ask about selected technologies / waste management models without any indications what is the result of the analysis.

The neopositivist method has three major options how to conduct the interview (i) Unstructured – opened conversation without need of sharing questions ahead; (ii) Structured – with strictly predefined script of standardized questions with predefined answers which are usually transferred into numbers and quantified; and (iii) Semi-structured interview – where discussion areas are shared in advance and afterwards in the interview exist some level of freedom to deep-dive into selected areas. (Alvesson, 2003)

Semi-structured interviews are one of the most used method (Qu & Dumay, 2007) and commonly used to gather insides by managers in real business life (Schwartzmann, 1993). Thus, the author decided to leverage Semi-structured methods. The author prepared an interview script which was used for all interviews. The areas which were covered in the interview script were (0) Regulation in the Czech Republic; (i) Innovative waste management technologies; (ii) Waste management models in Europe; (iii) Market Barriers in the Czech Republic; (iv) Key success factors for deployment of new model. In each section were prepared 4-5 sub questions which were afterwards discussed in the interview.

Biases from an interview can be caused by incorrect data gathering or by inclusion of research opinion into the data interpretation. (Denzin & Lincoln, 2000) To prevent any biases in the interview the author followed standardized guidelines for conducing and interview. During the interview it should be taken a record to ensure evidence for later analysis inasmuch notes. (Belotto, 2018) Each interview was recorded on personnel mobile phone of the author for later accessibility of data. The analysis is conducted via a coding methodology. Coding is method in which to individual words, phrases or sentences, “a meaning units”, that conveyed similar meanings are assigned labels with codes to rigorously analyse the transcript of interview. (Graneheim & Lundman, 2004) The coding methodology adopted from Saldana book The Coding Manual for Qualitative research which provides detailed methodologies for generating a codes and structured coding. In practice the author also leveraged color-coding on paper as useful for visualisation of the code categories. The Author did not use coding software because he does not have practical experience with such tools and the number of interviews did not required extensive coding. In the analysis from individual codes were created categories on which were identified concepts and theories as depict in table 7. (Saldana, 2009)

Table 7: Codes to theory / output methodology

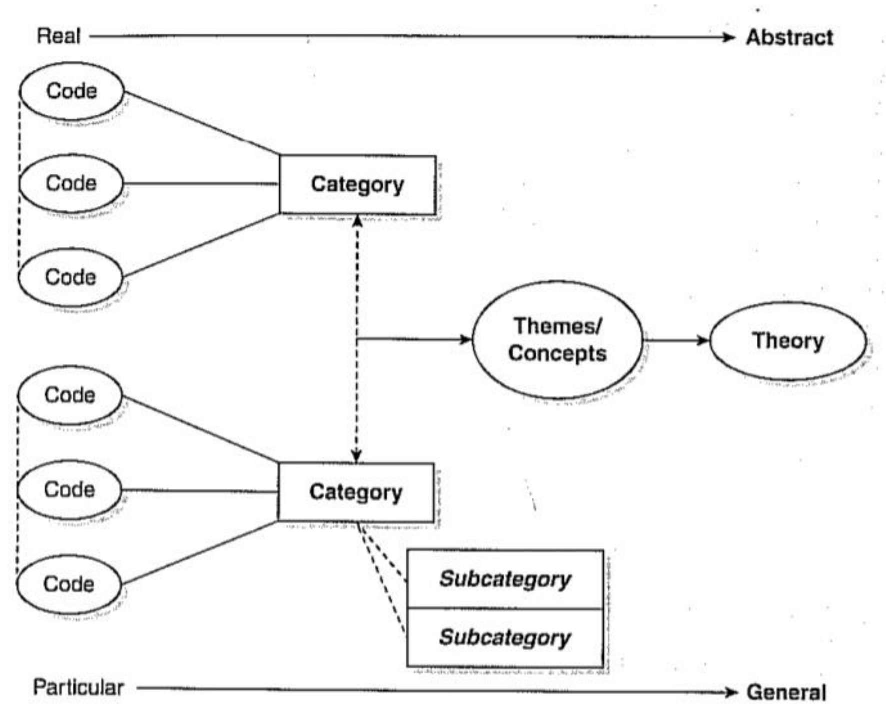


FIGURE 1.1 A streamlined codes-to-theory model for qualitative inquiry

Source: Saldana, The Coding Manual for Qualitative research

Finally, for good qualitative research is right selection of respondents. Identification of respondents is a three-step process in which stakeholders has to be identified, afterwards validate and in a last step concrete responsible person identified. First step, what should be elaborated is to develop good understanding of all involved parties related to the topic, in other words a stakeholder map. Stakeholders can be identified either from existing business register (and related NACE codes) (Hogan, 2004), which can however be incomplete in selected countries, or developed own stakeholder list of involved parties by own research. The list of possible interviewees can develop by leveraging of list from one external sources; for example, a list of the occupants of a business or science park (Westhead & Storey, 1997) or by association in private sector. In public sector it is possible to identify relevant bodies by revision of competencies of individual ministries, agencies and committees on individual webpages.

Detailed stakeholder map has been developed for waste management where are major stakeholder groups / clusters have been depict. Overview of shareholders is provided in section "*2.1.4 Key stakeholders and waste management processing in the Czech Republic"* with description of their competencies. The author has leverage both of the methodologies mentioned above to (i) identify major entities operating on the market based on the associations' members listing (e.g. Ceska Asociace Odpadoveho Hospodarstvi or Asociace Recyklace Stavebnich Materialu) and (ii) cross-check with business register (bisnode) and the NACE code provided there. The outliers were reviewed individually by web pages search.

In this the last step, the author leverages his personal and business network to identify the right people. That means that the author contacted a contact in the company or was introduced by one of his contacts. Initial contact person in a targeted company was asked simple closed questions to validate that the areas of the work are included in his competences. If he /she answered positively he/she was interviewed, if the contact answered negatively, he/she was kindly asked if it is possible to interconnect with responsible person. Thanks to that it was possible to minimalize number of interviews and prevent interviewing wrong responder.

The interviews were in Czech language, each of them last at least 90 minutes with aim to deep dive into the topics. In the evaluation analytical phase of the interviews the author created 128 codes in categories following the discussion areas shared with the interviewees in advance.

2. Practical part

In the practical part the author will analyse the waste management in the Czech Republic from the current perspective and outlook in the future. It includes what categories of waste are generated in the Czech Republic, what are the key trends and patterns and map the stakeholders. Secondly, it will compare the status quo to the European countries and identify possible models of waste management processing as much as successful case studies in from proxy countries. As the next step, the business case for the Czech Republic will be calculated and impact both from the financial and environmental perspective would be calculated. Last but not least, the findings will be validated within interviews and inquires with identified stakeholders.

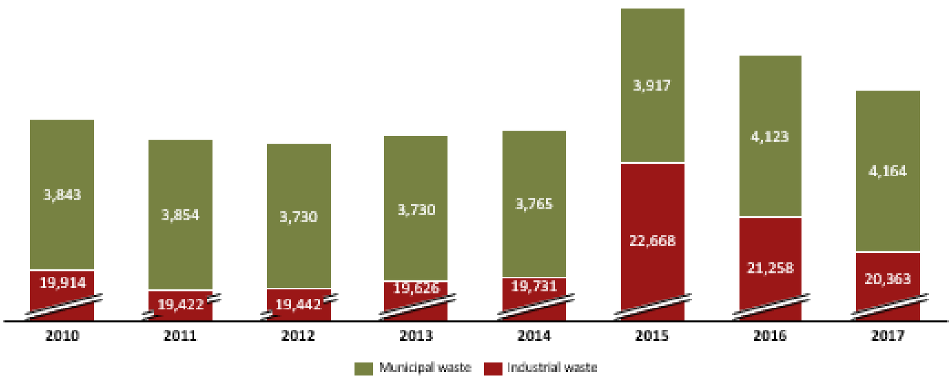
2.1. Waste generation in the Czech Republic

For development of proper model of waste management in the Czech Republic it is required to understand to the current generation in the Czech Republic, generation by region, composition of generated waste (which material are generated), general behaviour patterns such as recycling level and general awareness in the population, key stakeholders operating on the market, the overall model which is used in the Czech Republic, and actual trends in generations related to previously mentioned themes including also prediction of waste generation. In the following paragraphs the Author will analyse those indicators and in following chapters benchmark them with proxy countries.

2.1.1 Waste generation

In the Czech Republic the long-term trend is increasing production of all types of waste - solid municipal waste, agriculture and industrial. The data about generation of municipal and other types of waste are collected by Czech Statistical Bureau and publicised on regular basis on its website. Every year the bureau prepares a report “Generation, Recovery and Disposal of Waste in the Czech Republic” from which the data were sourced. In the last year with available data 2017, the total production of waste was 24.9 mTons of waste out of which 16.7% was municipal solid waste (4.2 mTons) and 0.5% agriculture waste (0.1 mTons). Remaining 83.2% was industrial waste out of which 44% was construction waste and 25% waste from manufacturing. (Cesky Statisticky Urad, 2017) Within last 5 years the total waste generation growth was approximately on the level 1.2% CAGR, however, it achieved only the level of pre-economic crisis level. What is important to mention the driver for waste generation is slowly shifting from industry to citizens and their municipal solid waste. 10 years ago the municipal solid waste was only 12.7% and production of solid municipal waste per capita per annum was lower by 39 kg what represents growth about 1.8% CAGR in the given period. (Cesky Statisticky Urad, 2017) In 2017, each citizen produced approximately 344 kilograms of municipal waste respectively 393 kilograms if municipal solid waste from industry is added.

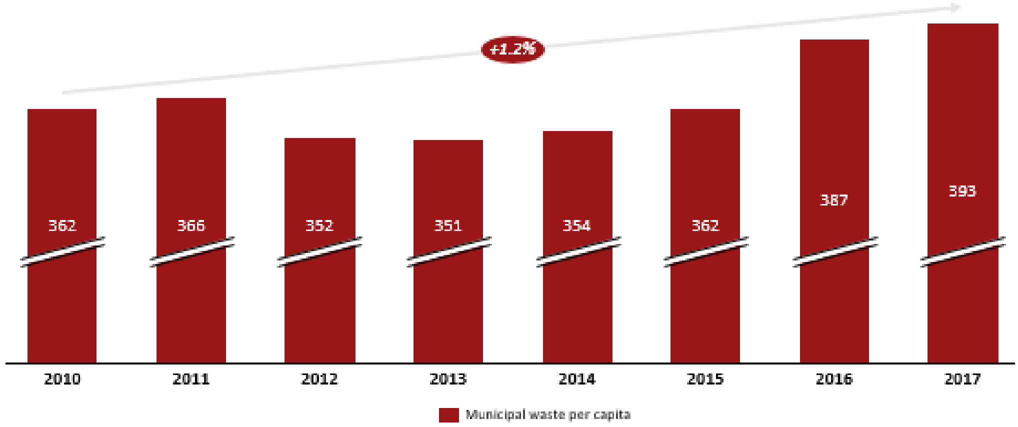
Figure 5: Waste production in the Czech Republic 2017 (kTons)



Source: Cesky statisticky urad, own elaboration

From the regional perspective most of the waste is generated in Stredocesky (611 ths. Tons per annum and 454 kg per annum per capita) and Moravskoslezky kraj (560 ths. Tons per annum and 463 kg per annum per capita). Both of those regions are highly industrialized with high population. On the opposite end of the scale are in the total volume generated are small regions Karlovarsky and Liberecky. Interesting is also generation of waste per capita which is third smallest with 343 kg per capita per year 50 kilograms below weighted average of the Czech Republic. It could imply that in the large cities the behaviour is more responsible in comparison to smaller cities and rural regions of the country. From the perspective of composition and recycling levels the waste does not have significantly different composition. Also, the behaviour patterns do not vary around the country, too. (Cesky Statisticky Urad, 2017)

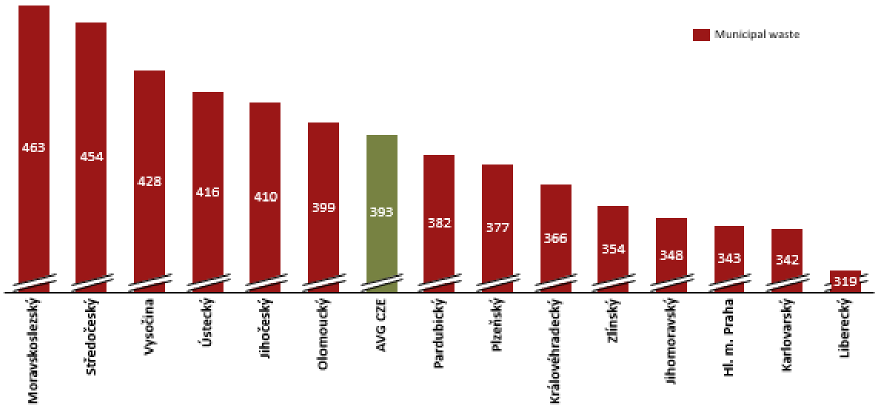
Figure 6: Waste production in the Czech Republic per capita 2017 (kg)



Source: Cesky statisticky urad, own elaboration

Following graph display the distribution among the regions. The highest production per capita is in the regions with relatively rich population in terms of GDP per capita or with significant industrial hubs such as Moravskoslezsky region with Ostrava and other cities. Only exception is the capital city Prague, and this can be explained by higher quality of living and behavioural patterns. In cities in general is relatively lower production of waste because of lifestyle and awareness about needing of recycling and packaging and sustainable way of living.

Figure 7: Waste in the Czech Republic per region per capita 2017 (kg)

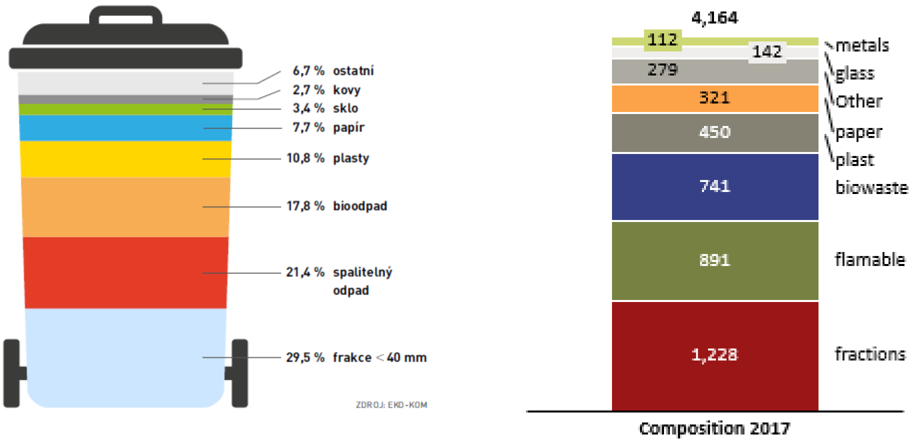


Source: Cesky statisticky urad, own elaboration

2.1.2 Waste composition and processing in the Czech Republic

In the Czech Republic the waste management, similarly as in many other countries around the world, separating even before the collection. That means that in the country are both containers for mixed municipal waste and containers for recyclable components. Firstly, let's look on the separated recyclable waste. In the last year, were separated during collection 558 ths. tons of municipal waste what represents approximately 13.7% of all municipal waste generated. The number is growing in long-term and within last 5 years volume of separated waste increased by 20%. What is mainly growing is separation of plastics, however, metals segregation is decreasing. More interesting is to have closer look on mixed waste. Within last years have been done multiple studies on its composition in the Czech Republic. Authors have identified that during there are differences during the year, and in between types of the neighbourhood, too. (Smid & Benešová, 2015) (Čermáková & Dockal, 2017) Differences in the overall results are negligible with studies delivered by the EKO KOM a company responsible for the recycling, introduced in detail in section 2.1.4.,. They have identified that approximately majority of weight (appx. 29.5%) of waste are fractions with granularity lower than 40 mm, what is basically mixture of all kinds of waste. (Benesova, 2001) Other important components are flammable waste 21.4% bio waste 17.8 and plastics with 10.8%. (EKO KOM, 2017) Others as follows in the table below. This date can identify final structure of the municipal waste in the Czech Republic as in the following graph.

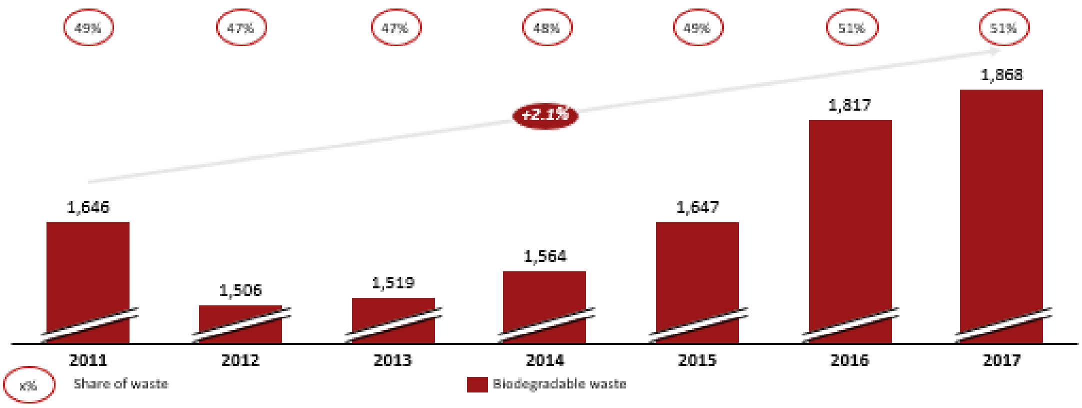
Figure 8: Fractions of municipal waste in the Czech Republic 2017 (%, kTons)



Source: EKO KOM, Cesky statisticky urad, own elaboration

Into the consideration should be also take the organic component of the mixed waste. Biodegradable waste component rapidly increasing from multiple reasons. One of them is steep reduction of yard composting in smaller cities and villages supported by decrease of home incineration for heating and cooking. Due to that development of decentralized composting network should be one of the priorities because in the future. Biodegradable waste is currently representing a little bit more than 51% of all waste disposed. The biodegradable waste is not in the Czech Republic separated in special containers such as in many European countries. Organic waste can be treated in multiple ecological ways and easily used either for composting and recycling or for energy recovery. However, to allow such utilization of biodegradable waste it would be required to establish supporting network for collection.

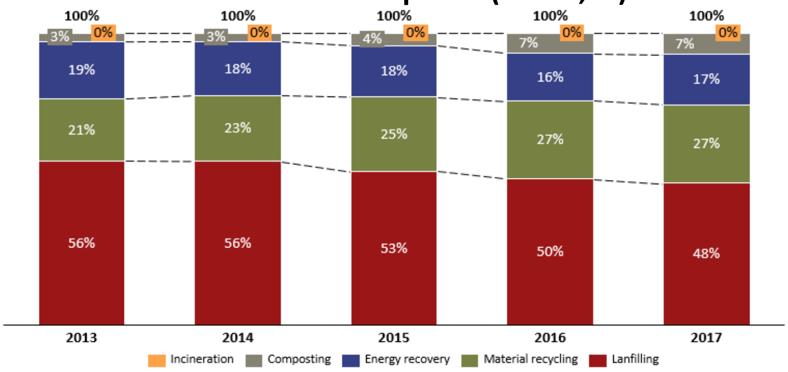
Figure 9: Organic waste generation in the Czech Republic (kTons, %)



Source: Cesky statisticky urad, own elaboration

From the processing perspective the statistics is not extremely positive in the Czech Republic. In the last year landfilling as the method of waste disposal decreased to 48% what is decrease only by 8% within last five years. In absolute terms the change was almost negligible (decrease by 50 thousand tons). It shows that in the last few years there have achieved very limited improvement in final disposal mix. All the delivered capacities for recycling and composting (growing on the level 9% respectively 28%) have been offset by the increase in waste generation. In the area of recovery and waste to energy methods have not been constructed any new capacities in the last years.

Figure 10: Waste treatment in the Czech Republic (kTons, %)



Source: Cesky statisticky urad, own elaboration

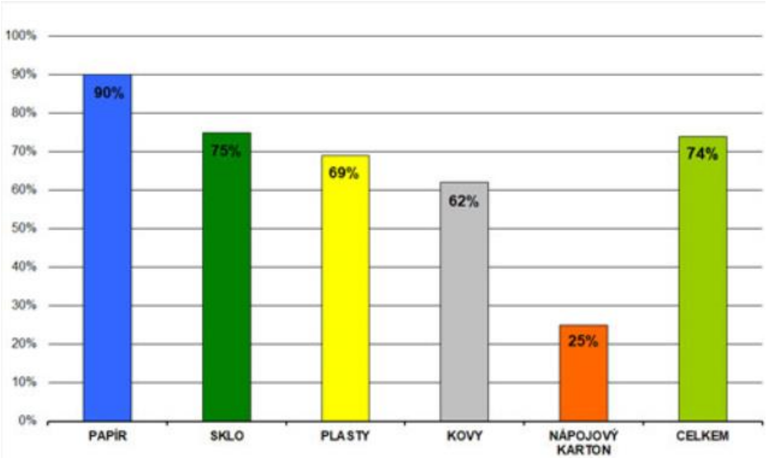
In the next years, the new project should focus on the composting technologies and recovery technologies because there is still potential of more 970 thousand tons of biodegradable waste for processing.

2.1.3 Behaviour patterns in the Czech Republic

Based on this estimate the total production of waste which is recyclable or would change and we can estimate how much recyclable waste dropped into the mixed municipal solid waste. We used triangulation method on the data from Czech Statistical Bureau we can calculate that approximately only 26% of total volume of plastics are separated and totally produced is around 528 thousand tons. Best situation is with glass which approximately 52% is directly separated out of totally 255 thousand tons. Remaining components of mixed solid municipal waste are included in the table below.

This would mean that only very limited volumes of waste are separated by citizens. As was discovered in the research different types of neighbourhoods have different level of willingness to separate waste. (Smid & Benešová, 2015) For the adoption of sustainable community-based waste management model in the country it would be necessary to increase general awareness about necessity of separation. It should be systematically improved the willingness of population in the cities to focus on recycling and separation of recyclable goods. Currently, the highest potential is in direct separation of organic waste and E-waste which can respectively should be treaded separately from standard waste. Packaging materials, oppositely to the organic waste, are very well treated in the Czech Republic. EKO KOM a company established by packaging manufacturers is responsible for recycling of packaging materials. Within the last year, 2017, they were able to catch about 74% of all packaging materials consumed in the Czech Republic. It indicates another fact about the behaviour of Czech population. For individual packaging material the detail is included in the Figure 10 which follows. The awareness about recycling is highly specialized and rather focusing on packaging materials than general products from plastics and other recyclable materials. To improve the overall performance of the population towards ecological way of living it is rather important to focus on other products from recyclable materials. The potential there can be estimated on approximately 0.5 million tons.

Figure 11: Packaging waste recycling 2017 (%)



Source: EKOKOM.cz

2.1.4 Key stakeholders and waste management processing in the Czech Republic

Waste management has multiple different players. In this chapter we will have closer look on the individual stakeholders. In the first part the governing and supervising level of the scheme will be identified followed by closer look on the players in the operation in the model. During the stakeholder analysis has been omitted people (the population) because they theirs power to influence the overall process is insignificant.

The author rather focused on the key players, institutions, actively participating in the value chain.

2.1.4.1. Ministry of Environment

In the Czech Republic the whole area of waste management agenda belongs under the Ministry of Environment. It executes supreme state supervision in waste management, prepares and proposes legislative standards in waste management; it is the producer of the Waste management plan of the Czech Republic and other strategic and policy documents on waste management binding for the whole country. (Ministry of the Environment, 2014) Ministry of environment also approves the construction of large processing facilities and steer the overall ecological impact and sets minimal requirements on the quality of service. One of the last important functions of the ministry is controlling of the compliance with legislation and established norms via its agencies.

2.1.4.2. Regional Authorities and governments

Regional Authorities are responsible for implementation of Waste management plan in the regional areas. They are allowed to develop their regional waste management plans; however, those plans have to be in compliance with the overall national goals and targets. The regional authorities execute the state administration primarily in administrative proceedings, issue approvals to operate a waste management facility and check how legal persons, natural persons authorized to do business, and municipalities comply with the legislative provisions and decisions of the Ministry and other administrative authorities in the field of waste management. (Ministry of the Environment, 2014)

2.1.4.3. ***Municipalities***

Municipalities are the first direct participant in the waste management because they are responsible for the process in its borders. They can either operates the collection and processing firm by themselves such as in case of the Capital city Prague or they higher external provider which for them deliver waste collection and processing services. Municipalities on the governance level crating local waste management plans which has to be again in compliance with state and regional one. They are the most important part of the governing chain due to the execution power. *"…The most important powers within their territorial jurisdiction include the granting of consents for hazardous waste management, consents to waive sorting or separate waste collection, keeping and processing of records on waste and methods of waste management, checking of compliance with legal provisions and decisions of central and other administrative authorities of waste management, in exceptional cases to impose an obligation to remove waste on the operators of waste disposal facilities, impose fines for breaches of obligations defined by the Waste Act or imposed by a decision based on the Act*." (Ministry of the Environment, 2014)

2.1.4.4. EKO KOM

As was mentioned previously EKO KOM is a non-profit organization established by manufacturers of packaging materials. Existence of the company is example of dual system in waste management. It is regulatory requirement[2] for manufacturers of packaging materials to participate on collection of them. (Janešíková & Šimek, 2011) The company is responsible for education of citizens about waste management, development of collection infrastructure and direct collection of waste, sorting of collected waste and processing of the sorted waste. (EKO KOM, 2011)The detailed scheme is in Figure 11 where blue lines represents flow of money and orange lines represent flow of packages. Thanks to this company, as was mentioned before, is well developed understanding about sorting of packaging materials in brought population. However, the responsibility ends on the edge between packaging and other products.

[2] Directive ES 94/62

Figure 12: Dual model and cashflows in the model

Source: EKOKOM.cz

2.1.4.5. Private companies

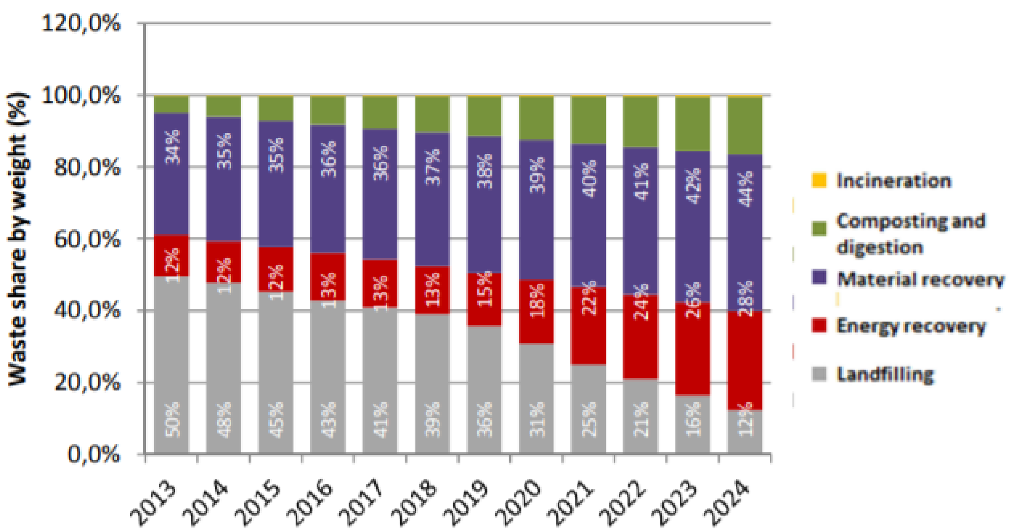
Private companies are important player in the waste management process. They are usually performing in multiple steps of the value chain and most often they are vertically integrated players. Local market is strongly consolidated especially because major foreign players have acquired smaller, usually city owned companies. Major players on the Czech market are Marius Pedersen, Ave, and Komwag. Those companies are hired by municipalities for provision of waste collection and supporting services such as composting. The business model is established on multiple revenue streams first is usually fee-based provision of services and second revenue stream is from the premium services provided to customers. Last important revenue stream is from processing of the waste. The companies either sell the waste to its processers such as incineration plants or resell it to other parties. This situation is partially creating significant complication for development of sustainable and community-based waste management scheme in the Czech Republic because those private companies have lower motivation to invest into the ecologic system. Due to that, it should be developed either subsidies scheme which would motivate the companies to participate in the innovative model or regulation which would require them to participate.

2.1.5 Key trends and future status in the Czech Republic

Based on the historical data and various coefficients Ministry of Environment calculated the forecast of municipal waste generation in the Czech Republic. The estimate showed that every year the production should decrease by approximately 0.18% year-to-year. (Ministry of the Environment, 2014) The pace reported by Czech Statistical Bureau is rather opposite and the community waste generation is growing 3.1% CAGR within last 5 years even though the pace is decreasing to 2.1% within las 3 years. (Cesky Statisticky Urad, 2017) It can be rather expected that the pace would follow current trends then statistics developed in 2014 by the ministry. However, the pace would rather be slowing down and in the last year will be the growth estimated only on 1.5% what is an average growth in the EU. (Eurostat, 2018)

In terms of structure it the ministry has also developed complex plan for development of sustainable waste management. The target for the disposal via landfilling has been set as only 12% of municipal waste generated by the 2024. (Ministry of the Environment, 2014) In the current year the progress in implementation of advanced sustainable methods was estimated to be higher by 13% and thus it can be said the compliance with set target is not achieved. Therefore, there should be developed clear roadmap for construction of production capacities and established schemes for subsidies.

Figure 13: Forecast of municipal waste treatment 2013-2024 in CZ (%)



Source: Ministry of Environment

From other major trends described in previous chapters, it can be expected that digitalization and deployments of smart technologies (IoT) will be delivered within few years. For example, smart bins have been tested in Kladno and in last months the pilot programs started to operate in Prague. (Koval & Anna, 2019)

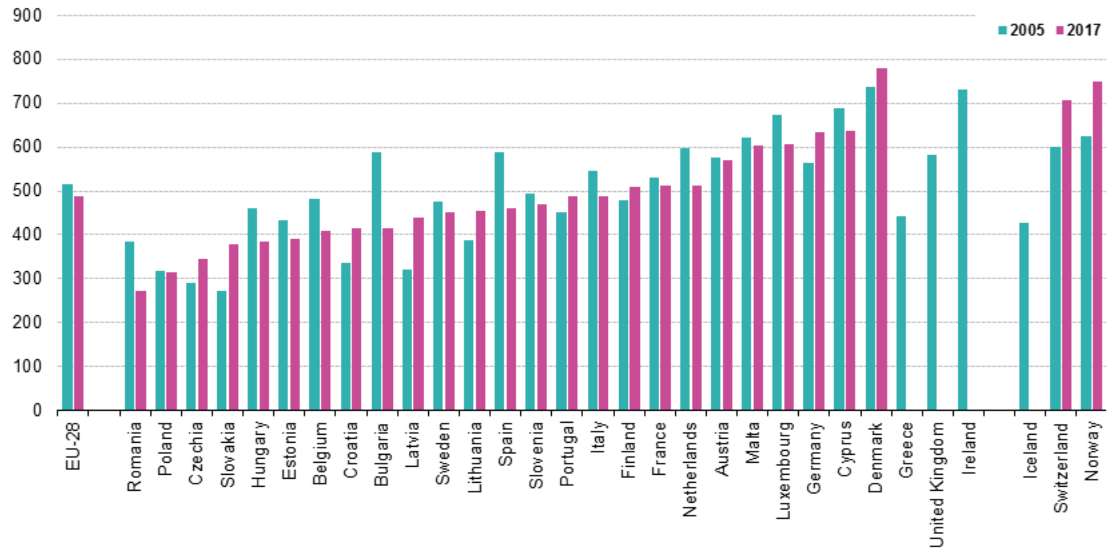
2.2 Czech Republic in the context of EU and proxy countries

To identify case studies based on which the country can inspire the next steps the successful stories has to be identified in the context of similar countries. Czech Republic can be inspired by the countries which are in similar conditions and market circumstance able to actively improve the ecological performance of waste management process.

2.2.1. Waste generation and composition in Europe

Level of waste generated in Czech Rep. in comparison to Europe is below average and reaching only 81% of European average which is 483 kg. (Eurostat, 2018) Most of the countries in the below of EU average are also Eastern European countries and former members of socialistic block. One of the major differences between the Czech Rep. and rest of those countries is the increasing volume of waste over the time. Generated volume has decreased between 2005 and 2017 in most of the countries (Romania, Poland, Hungary, etc.) what creates different demand on the system. Similar pace of growth faces rather Western countries such as Finland and Germany or Croatia and Lithuania.

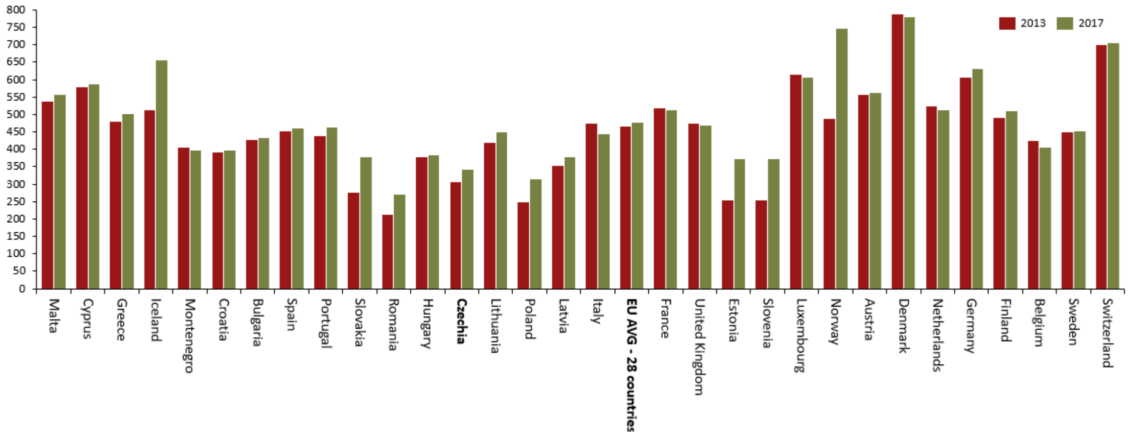
Figure 14: Municipal waste generated by country in 2005 and 2017, sorted by 2017 level (kg per capita)



Source: Eurostat

In the short time period of last 5 years most of the countries are more less stable in the waste generation per capita. The most similar generation growth pace has Germany, Lithuania, Latvia, and Finland. Each of those countries has grown 1 – 3% CAGR in the given time period.

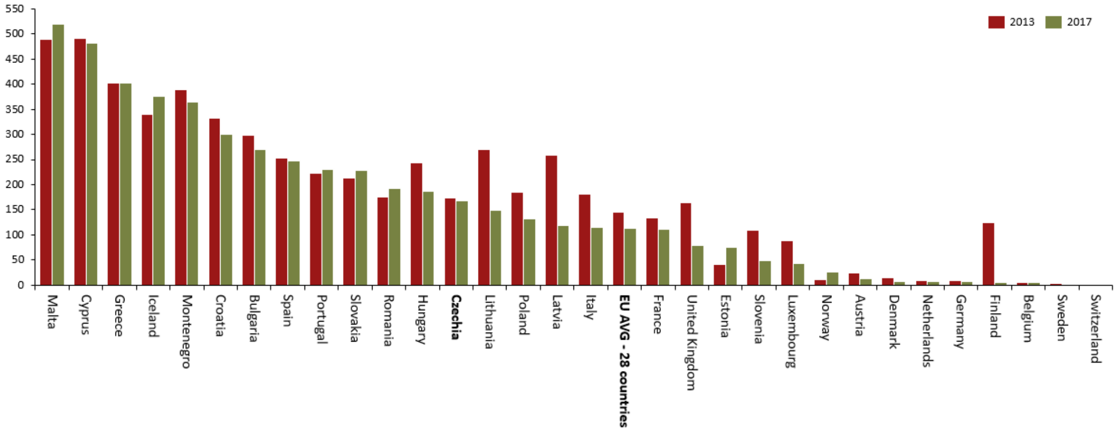
Figure 15: Waste generation per capita by country 2013 and 2017



Source: data Eurostat, Own Elaboration

As the next step it is necessary to observe which countries have made a significant progress in the waste management. In the European context there exists clear pattern and division of countries. Western countries and Nordics have significantly lower final disposal on landfills in comparison to Eastern (post-socialist) and Southern countries. The only outlier in this patter is Slovenia with highly developed waste management model. If we have closer look on previously identified countries, we can specify different patterns in the landfilling in last five years. Germany, one of the most advanced countries in terms of ecology, had even before 2013 close to zero landfilling. Oppositely to that Lithuania, Latvia and Finland has significantly reduced landfilling in the recent years. For example, in Finland the final disposal of municipal waste at landfills has decreased to 1/25 in 5 years in absolute terms what mean decrease by 96%. Lithuania and Latvia have decreased the disposal of municipal waste by 46% respectively 54%. (Eurostat, 2018) If we compare it we the proposed pace of the Czech Republic which was 9% within the same time period, it is obvious that the goal is not very ambitious. However, if we compare it with real performance in this are the result is even worse. Landfilling has decreased only by 2.5% of the total mix what is extremely below the potential and also EU's average which was around 12%.

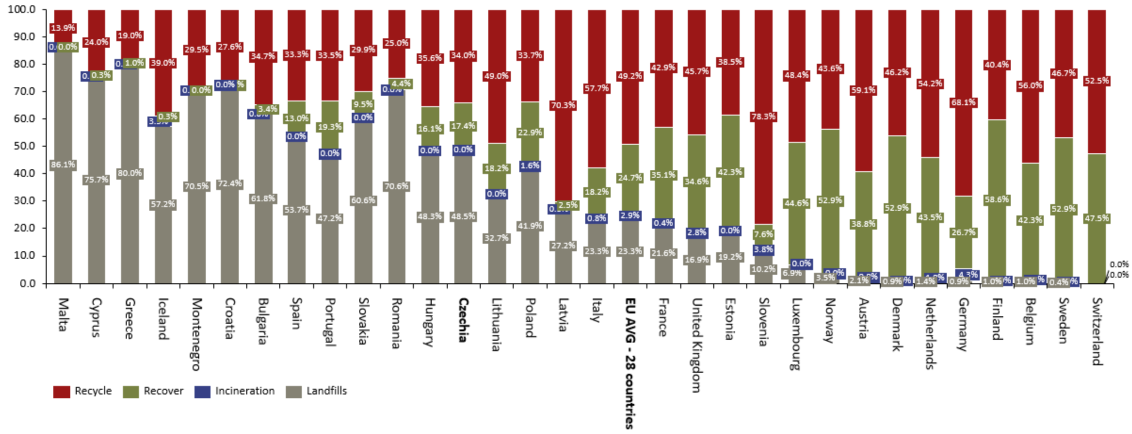
Figure 16: Landfilling kg per capita by country in 2013 and 2017, sorted by 2017



Source: data Eurostat, Own Elaboration

One of the last important information which is missing in the puzzle of European countries' waste management model is the disposal method. From the first look on the data it is obvious that there is not a single answer for optimal waste disposal mixture. For example, Slovenia has decided to go way of maximal recycling and currently it is the country which recycle most of the municipal waste produced, about 78%, in EU. On the other hand, Nordic countries, leaded by Finland with 60% share, have decided to focus on energy recovery. Previously identified proxy countries again show to us 3 different possible models which could be implemented in the Czech Republic, too. Firstly, it is "Slovenia model", extremely like Latvia, focused on recycling and minimal energy recovery and direct incineration. This model would require development of general awareness in population and increase overall participation of population in terms of separation before collection. Secondly, it is "Finnish model" in which the energy recovery would be considered as crucial for future. Model can be considered as CAPEX heavy because it would require construction of infrastructure (construction of decentralized plants and grid). On the other hand, this model can create from the Czech Republic energy exporter even after shutting down of coal power plants. Generation of electricity and its sales, however, would also cover part of the CAPEX and thus it might be attractive for Public-private projects (PPP). Last model, a "Germany/Belgium mode" can be described as the golden middle way. In this model the country would focus on balanced mixture between recycling and recovery. It would require both to build new infrastructure but in lower scale, and simultaneously invest into education of population. The model, however can be extremely ecologic and efficient because it recycles high portion of waste and the rest is used to produce useful output-energy.

Figure 17: Structure of waste processing and disposal by country 2017 (%)



Source: data Eurostat, Own Elaboration

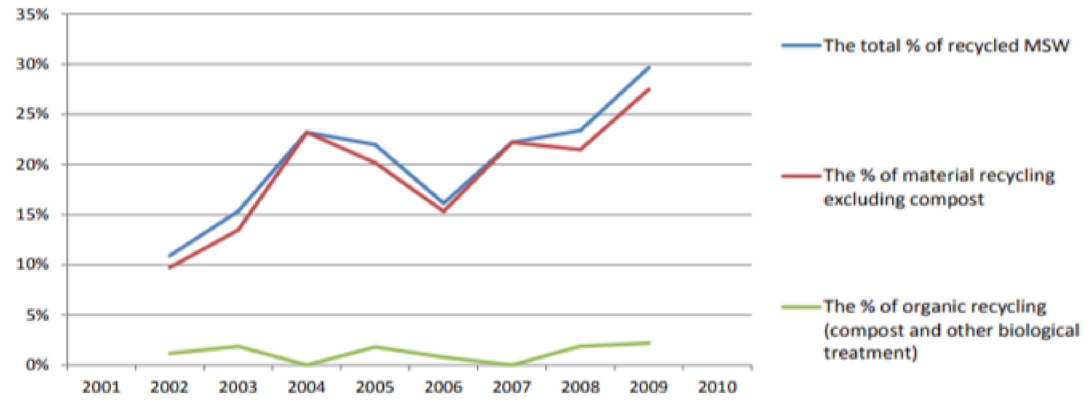
On the first look, for the quick achievement of results Finnish model seems to be the easiest for implementation because the biggest issue can be the education of population. Only the closer look on each of those models would help us to identify the best alternative for the Czech Republic and thus in the next section the case study of each of them will be provided.

2.2.2. Slovenian model

Slovenia has similar history as the Czech Republic and belongs between young countries in the Europe. The country has been established in 1991 as one of the successors of Federal People's Republic of Yugoslavia. Similarly, as most of the other post-socialist countries of the Eastern Block, it has brought to its beginning significant liabilities in terms of environment protection. In the 1995 the country has disposed about 90% of all municipal waste at landfills. (The Slovenian Foundation of Sustainable Development, 2014) In the late 1990s, Slovenia has developed first action plan for reduction of landfilling and improvement of waste management process and it was called Strategic Guidelines of Waste Management ("SGWM") This plan was prepared in view of EU Waste management strategy from 1989 and revisited in 1993 and its main objective, reduction of disposed waste by 40% by 2000, has been set. (The Slovenian Foundation of Sustainable Development, 2014) The goals have not been achieved, however, one of the cornerstones for further development of sustainable waste management, public awareness, has been developed.

Since 2001, when the regulation “Order on the Management of Separately Collected Municipal Waste” has been adopted, households and other entities in cities are obliged to sort the waste. If citizens or other legal entities do not comply, they could be fined. In the first years the impact was not that significant as it would be expected, however, the break came after the year 2008 as it is visible in the Figure 17. (European Environmental Agency, 2013) All those actions together developed positive attitude of

Figure 18: Trend in Recycling of municipal solid waste in Slovenia (%)



Source: European Environmental Agency

citizens towards eco-friendly lifestyle. Simultanously has been implemented landfilling tax, and other environmental taxes, which was around 22 EUR per ton of waste however varied according to type of waste. (European Environment Agency, 2013) Alltogether, the income from environmental taxes has been the second highest in between the European countries. From those times Slovenia continues to develop strong regulatory framework and all the time is one of the pioneers with adoption and implementation European regulation related to the Environment Protection. For example, a voluntary instrument “Green Public Procurement” manual has been implemented as compulsory one. One of the major achievements was implementation of sorting of bio waste which significantly increased the recycling rate in cities of Slovenia. (European Commission, 2019) Thanks to the sorting of biowaste was possible to develop and relatively cheaply operate composting infrastructure. Last factor was ability to mobilize private and public money for investment into the infrastructure. The country was able to pump into the infrastructure approximately 4.9 billion Euros in between 2014-2019 out of which about 3.9 billion has been received from the European Fund for Strategic Investment.

From fractional perspective the waste in Slovenia has similar composition as in the Czech Republic. Approximately 20% of municipal waste is paper, 15% is bio waste, 14% is plastic waste, 7% is glass, 5% are metal waste, 39% fractions and other waste. About 50% of waste (including packaging and waste fractions) has been collected in separately what is one of the highest volumes in the Europe and confirming the previously described findings. (Slovenian Environment Agency , 2018)

Inspiring case study is also the capital city Ljubljana which has been awarded as the Green City of Europe in 2016. The city is on the right track to become one of the first zero waste cities in the Europe. As it is state in multiple reports: "*Ljubljana has managed to multiply its separate collection of compost, and recycling by tenfold and to reduce the amount of waste sent for disposal by 59% while maintaining waste management costs among the lowest in Europe.*" (Zero Waste Europe, 2015) Major stakeholder in the waste management is Snaga a publicly owned waste management company. This company has for example implemented door-to-door collection of recyclable waste. Thanks to that the rate of recycled materials increased more than 3 times and residuals decreased by 27%. (Zero Waste Europe, 2015) To that followed the second change and that was the frequency of collection. Based on the analysis of quantities collected it adjusted the schedules of collections and for example in selected areas it collected the waste only on bi-weekly basis. Thanks to this policy the cost of collection decreased to 66% of country average in 2014. (Zero Waste Europe, 2015) Even though this policy was opposed by many citizens Snaga was able to stand behind this approach and rather focused on the biggest achievement. Key for successes of Snaga was communication. The company opened reuse centers in the city and constantly work on the education of public. Currently, the company actively manage 3 web pages and communicates with citizens via social media. The city of Ljubljana also scrapped the plans for incineration plant and decided to focus on the zero-waste target by 2030 (Zero Waste Europe, 2015).

To summarize the model key point should be highlighted. Firstly, it is necessary to have established strong regulatory framework and action plan for treatment of municipal waste supported by implementation of taxation. The whole model is based on responsibility of citizens based on developed awareness in population via communication and penalty for not complying. Important is implementation of separate collection of biodegradable waste. Recycling is supported also by door-to-door collection and elimination of other transaction costs for citizens. In the treatment part of the value chain composting plants and other recycling facilities are profitable thanks to limited sorting. Cost optimization and overall low cost of the model is assured by strict cost responsibility and optimization of collection routs and decentralization of composting.

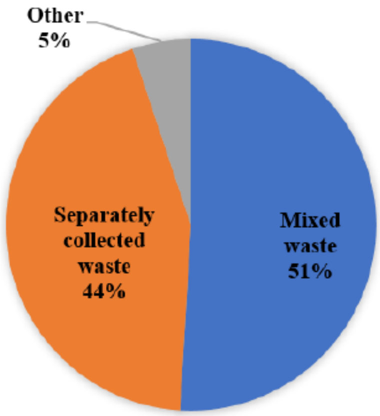
2.2.3 Finnish model

Finland has different history because it entered the European Union in 1995 and therefore the demand for improvement of the waste management has been shaped by the regulation since then. However, the problem of waste management is treated since 1979 when the first waste act has been created. In compliance with the European legislation the country has amended the act in 2011, 2014 and 2016 in according to latest requirements of the EU. On top of that some of the targets and goals have been set even more strict than it was required. (Piippo, 2013) Similarly, as in the other European countries the dual scheme has been implemented and it created responsibility for producers of packages to participate in collection, recycling and treatment of waste. Country's regulation is based on multiple instrument but the strongest one is taxation. Multiple taxes such as Waste tax, Drink packaging tax, municipal waste charges and oil tax has been implemented and ensure enough financing of the waste management model. The taxes are strongly shaping the whole model for example the waste tax, which is applied to all landfills, has increased by 30 Euros (75% increased) in between 2011 and 2016. Last important regulation has been adopted in 2016, when the ban on landfilling of all organic waste went into action. Oppositely to that the waste-to-energy models and indirectly supported by the government because there is no tax implemented on incineration of waste and waste recovery. Thanks to that it creates favorable business environment for private companies. (CEWEP, 2016)

The country is also one of the richest countries in the world, currently on the 27th place in GDP per capita world and 9th in the European union. (World Bank, 2017) Additionally, the country has established strong social and economic policies typical with high taxation and large share of public money so called Nordic model. The model allows the country (government) to promote its policies and programs by subsidy schemes or direct governmental expenditures/investment.

The whole system of waste management is extremely developed as it can be expected in developed country. Clear majority of citizens has access to containers for recycling of all common components of waste including also biodegradable waste. The collection, like in the Czech Republic, is mostly organized by municipalities and almost always outsource to private companies. In comparison to Slovenia Fins are less organized in terms of sorting because it is not obligatory to sort waste. In the Figure 18 is visualized this habit of citizens and this share is not significantly changing in the long-term. (Tilastokeskus, 2016) From the fractional perspective 19% of waste represents plastics, 22% organic waste, plastics 11%, metals 6%, and remaining 42% other waste. The policy in treatment of waste categories is strictly set that other waste is incinerated and about 10% of organic, plastic waste, and paper. Remaining 90% of fractions of waste are recycled. This creates cost efficiency in terms of sorting and processing of waste. (Tilastokeskus, 2016)

Figure 19: Breakdown of collected waste volumes in Finland 2015 (%)



Source: Statistics Finland

Treatment in Finland, as was identified above, is mainly focusing on the energy recovery from the waste. The energy recovery performed centrally in 9 waste-to-energy facilities with aim to maximize the efficiency and economies of scale of facilities. On top of that, there are 23 co-combustion power plants, located around the country, which use waste as the fuel for electricity production. (Horttanainen & Havukainen, 2016) Most of those plans are operated by private companies which are willing to invest into the model. However, thanks to the central treating of waste, it must be transported for long distances because most of the plants are constructed on South of the country. This fact increases the negative ecological footprint of the system. (Piippo, 2013) In 2016, in Finland was in produced 2.7 million tons of waste out of which was in total generated about 0.62 TWh of electricity and 2.6 TWh of heat. (CEWEP, 2016) It was only about, 0.8% of total electricity consumed in Finland, however, since than the installed capacity continues to increase inasmuch totally generated electricity.

To summarize Finish system, is traditionally focusing on minimalization of disposal of waste via landfilling. The ecological waste treatment has long history since 1970s and strong underlying support in the regulations. The regulation is key factor in Finland because it on one hand bans landfilling of organic waste and through taxation and other financial instruments strictly makes the business environment unfavorable to landfilling on the other hand it supports waste to energy and incineration of waste thanks to no taxation. The business environment is thus perspective for private companies which are willing to invest into the new facilities and plants for ecologic incineration of waste. The financial return of such project is ensured by focusing of economies of scale and large-scale plants. This system does not require significant responsibility of citizens and their propensity to sort waste, but it is expensive in terms of capital expenditures.

2.2.4 German model

Last model which should be described in detail is German which could be described as mixture of energy recovery and recycling. In the Western countries, especially Germany, sustainable and eco-friendly approach to waste management has long tradition. The country is one of the leaders also in implementation of regulation of waste management which supports green sustainable circular economy goals. German Federal Republic was setting up the direction of environmental policies of the European Union (and predeceasing organizations) since the 1960s. It was Germany, a first country in the Europe which has introduced dual system and make producers of packages responsible to participate in the waste management process in 1991. (European Environment Agency, 2013) This responsibility was not initially applicable for households, however, after implementation the Recycling Management and Waste Act the responsibility was assigned to households and local authorities, too. Currently, the country has one of the most developed regulatory frameworks globally. For not compliance with the requirements and proper processing of waste has been implemented fines even for citizens. (European Environment Agency)

From the organizational perspective Germany has highly developed collection system focused on direct separation during the collection. Thanks to the historical successful adoption of regulation the country has the requirements for recycling of packaging materials already in 2002. Even though that even in the collection part the country is relatively successful, 72% of packaging recyclable materials are separately collected, the country is market leader in separation of mixed waste. Major reason for that was heavy investment into the separation facilities since late 1990s what created extensive capacity for separation. (European Environment Agency, 2013) During the first decade the whole system was decreasing share of landfilling in final disposal reaching almost zero-level by 2010. Major disposal method after recycling was incineration without energetic recovery. The share on final disposal was approximately 22% which was one of the highest levels in Europe in that times. (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2018) However, heavy investment into the incineration did not pay back because with development of new technologies direct incineration was found as less ecological. After 2010, when the incineration level was reaching 37%, Germany start to focus on more sustainable ways of waste disposal and started to shift from incineration to energy recovery, and prevention of waste generation. (European Environment Agency, 2013) Even though, that the waste generation is relatively stable, and decreasing only marginally, the joint force with competitive technology decreases economical rentability of large incineration plants which were constructed in multiple cities. Large incineration plants are operating only between 60 and 80% of their capacity which partially prevent to achieve economies of scale and make the business profitable. Because of that German Federal government must subsides their operations heavily. (European Commission, 2016)

In the processing of biodegradable waste, the country originally decided for incineration of the waste. Up to 2010s the waste was mainly incinerated, but similarly like with the mixed waste it was decided to focus more on the recycling and reuse of waste. All around the country were constructed mid- and large- scale composting facilities which are providing most of its production to local farmers. (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2018)

Major focus, especially in recent years, was on the prevention of waste generation. Federal government launched multiple educational programs and decided to motivate citizens and business via its program for “conserving resources in public-sector”. Additionally, events such as European Week for Waste Reduction has been heavily promoted around the country with aim to decrease the waste volumes. However, as was mentioned before the results are mixed and the impact on total waste generation per capita is discussable. (Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2018) In the next years, the government propose the revision of waste reduction strategy and plan and it can be expected it will partially adjust the approach but still continue to significantly invest into the waste reduction.

2.3. Selection of case for the Czech Republic

Czech Republic has to decided one of the above described cases and follow the path. Based on the multicriterial matrix comparing the above described models and the Czech Republic status quo. The parameters included in the matrix were waste generation per annum per capita, growth of the waste generation, historical development of the waste management model (pace of switching for more ecological model), behavioural patterns (willingness to recycle and public perception), economics of the model. It has been identified that the most feasible model for the Czech Republic is Finnish model because especially the waste composition is closely similar to the Czech one, the country was able to shift its model towards avoiding landfilling in short time period. The model would be the best if the Czech Republic wants to achieve sustainable waste management model for reasonable costs and low subsidy schemes and impact on the state budget.

However, if the Czech Republic wants to achieve maximal ecology it would be better to focus on Slovenian model which in total generates lower volume of CO2 per capita than Finnish one.

For each model was calculated net present value (NPV) in billions of CZK in 5 years horizon. NPV was used as one of the indicators for economical perspective evaluation. Other indicators were for example revenues from the model, number of jobs created and contribution to the economy.

Table 8: Evaluation of waste management case studies (points, bCZK)

Country	Ecology level	Economy level		Result
		Multicriterial result	NPV (bCZK)	
Finland	74	88	-19.57	162
Slovenia	82	71.5	-29.57	153.5
Germany	71	64	-36.41	135

Source: Own elaboration

Methodologies for calculation and detailed approach are described in following chapters.

2.3.1. Ecological impact assessment

Ecological impact assessment was done by multicriterial matrix approach. All reviewed countries already undergone the transformation of waste management systems and thus the impact can be evaluated based on current performance of the system. Overall criteria were divided into three categories (i) Waste & Environment; (ii) IoT and digital; and (iii) People and Environment. In next chapters each criterion and data input will be presented. The goal was to identify the most impactful system delivering significant improvement to national ecosystem. Each category was assigned weight based on assumed importance.

2.3.1.1. Waste & Environment

Category was composed of five major variables with overall weight of 35%. The parameter evaluates waste management in country perspective and overall performance of system in local conditions.

(i) Waste generation per capita

Municipal waste generation level indicates overall awareness about importance of eco-friendly behavior or endorsement of ecological regulation by central institutions. Author is understanding the correlation of waste generation and wellbeing in a country, described for example by Kahujira & Yamamoto in 2010, thus the data were harmonized by GDP per capita.

Table 9: Waste generation per capita (kg / person)

Country	Finland	Germany	Slovenia
Value	504	627	466

Source: Eurostat, Own elaboration

(ii) Recycling share in final disposal

Recycling is the most ecological approach to final waste disposal as was describe in the previous chapters of the work. The model with the highest share of recycling is thus more ecological than models with focus on lower tiers of waste management hierarchy.

Table 10: Share of recycling on final disposal (%)

Country	Finland	Germany	Slovenia
Value	40%	68%	78%

Source: Eurostat, Local census bureaus, Own elaboration

(iii) Waste management system performance ranking

European Commission (with support of European Environment Agency) reviews performance of waste management systems in individual member states. Each year it drafts a report with overall score of the waste management system including also collection and other parts of value chain partially out of scope of this work. On top, the commission conduce surveys and interviews in evaluated countries to gather also opinions of citizens and bring in qualitative insides. The EC's ranking is on scale 0-10 with 10 state-of-art waste management model.

Table 11: European Commission evaluation of systems performance (points)

Country	Finland	Germany	Slovenia
Value	7.0	9.0	4.0

Source: Eurostat, EEA, Own elaboration

(iv) Landfills area

Fourth parameter which was selected was total area of landfills in regard to total area of a country. In the indicator are included also illegal landfills disposed by citizens or companies. The indicator was selected because it should indicate how effective is each model regarding to earlier steps of waste processing in waste disposal hierarchy. Additionally, it should provide fair view also on behavior and awareness of citizens to eco-friendly approach to waste processing.

Table 12: Landfills area in total country size (m2 / km2)

Country	Finland	Germany	Slovenia
Value	0.04	0.54	0.03

Source: Eurostat, Local census bureaus, Own elaboration

(v) CO^2 production reduction

Last parameter which was selected was reduction of CO^2 generation in last ten years. CO^2 production is generally considered as one of the major pollutants of our environment and contributor to global warming. Even though it is not directly interconnected with waste management models it can be used of proxy to identification if individual countries are targeting higher or lower ecological standards.

Table 13: CO2 production reduction in last 10 years (%)

Country	Finland	Germany	Slovenia
Value	29%	23%	42%

Source: European Commission, Own elaboration

2.3.1.2. IoT and Digital technologies in a country

Second category with three indicators is focusing on digital skills. Selected newly proposed technologies will require certain level of digital abilities in population to be fully leverage in improvement of waste management. On top, digital technologies usually increase access to information and help to improve population focus on sustainable way of living and reduce transaction costs relating to eco-friendly behavior. The overall weight for category was assigned as 30%.

(i) Digital services as share of GDP

Digital services as share of GDP indicates development of innovative industries in a country which could be also a driver of disruption in waste management. Digital capabilities in the industrial sphere are important for accessibility of technologies. On top it should indicate how a government is approachable to new solutions and educated in the area of innovations. Finally, digital companies are usually eco-friendlier and push sustainable way of doing business such as paperless, low-ecological footprint, recycling etc.

Table 14: Share of digital services on GDP of a country (%)

Country	Finland	Germany	Slovenia
Value	4.3%	3.8%	5.3%

Source: Eurostat, OECD, Own elaboration

(ii) Basic and above average digital skills

Population digital skills are closely related to possibility to leverage digital tools for innovative wage management such as mobile applications and IoT gadgets such as smart sensors. If digital services are more developed in a country the population should be also more likely to adopt digital technologies for waste management. Additionally, high digital skills usually indicate high development and income level which is often interconnected with higher awareness about need of environment protection and thus more likely to consider behave responsibly in waste management.

Table 15: Share of population with basic or above basic digital skills (%)

Country	Finland	Germany	Slovenia
Value	74%	67%	51%

Source: Eurostat, Gartner, Own elaboration

(iii) Global connectivity index

Global connectivity index is complex index yearly prepared by Huawei company evaluating connectivity and internet of things adoption in about 70 selected countries around the world. It evaluates countries' connectivity and smart technologies in all sectors incl. public, private and general population.

Table 16: Global connectivity index (pts)

Country	Finland	Germany	Slovenia
Value	64	56	48

Source: Huawei, Own elaboration

(iv) Innovative waste management technologies adoption

European Environment Agency on yearly basis evaluate waste management models and its quality. In regard to the review it also identifies and rank innovation technologies and approaches. Individual countries are afterwards ranked by the innovativeness of the model. The parameter was selected because it analyze models from both from qualitative and quantitative perspective by professionals with deep-expertise in the topic. On top it provides comparable data about European countries and selected role models.

Table 17: Innovative technologies adoption (pts)

Country	Finland	Germany	Slovenia
Value	13	7	5

Source: EEA, Own elaboration

2.3.1.3. People and waste

Third and last category is People and waste focusing on relationship of inhabitants of countries to nature and environment. As was described in previous parts of the work, soft factors such as awareness about ecological topics, relation to nature and education are enabler to development of sustainable waste management process in countries. Only people can be driver of an change in a country. Therefore, it can be assumed that countries with higher results in soft factors should be more likely to adopt more ecological waste management process. The overall weight for category was assigned as 35%.

(i) Secondary and higher education in a country

Level of education was selected because there exists empirical evidence between of correlation between achieved education. For example, European Commission studies proven that people with higher education has higher awareness and usually are even activity regarding environment issues. (European Commission, 2005) Additionally, the countries with higher level of education are more open face higher support of public towards improvement of ecological issues and usually also actively try to reduce ecological footprint. (European Commission, 2016)

Table 18: Share of citizens with secondary or higher education (%)

Country	Finland	Germany	Slovenia
Value	81%	80%	83%

Source: Eurostat, Own elaboration

(ii) Population observing climate changes

Second parameter was selected number of people observing climate changes. The parameter is identifying awareness of population in countries towards climate changes. It is helpful to specify that in the questionnaire the question was aiming on observing climate changes on their own life. It can be assumed that in countries where people are observing changes, they are more informed and more likely to act. That is creating pressure on governments to more consider ecological topics in the politics, too. As was described in previous parts on of the core important elements of waste management systems is development of awareness and informing of people.

Table 19: Share of population observing climate changes on own life (%)

Country	Finland	Germany	Slovenia
Value	61%	69%	61%

Source: Eurobarometer, Own elaboration

(iii) Personal relationship to nature

Third indicator depicting the environment topics focus is declaration of people to have positive relationship to nature. It was selected to identify habits of citizens. People who have positive relationship to nature are more likely to behave ecologically and for example sort (and correctly dispose) recyclable waste.

Table 20: Share of population declaring personal relationship to nature (%)

Country	Finland	Germany	Slovenia
Value	47%	55%	81%

Source: Eurobarometer, Own elaboration

(iv) EPI index

Fourth, and last people related indicators is EPI index. The index is focusing on measurement of environment health and policies as it communicates on its web "*...Environmental Performance Index (EPI) ranks 180 countries on 24 performance indicators across ten issue categories covering environmental health and ecosystem vitality. These metrics provide a gauge at a national scale of how close countries are to established environmental policy goals*." (Yale University, 2019) EPI index is developed bi-yearly by prestigious Yale University.

Table 21: EPI Index results (rank)

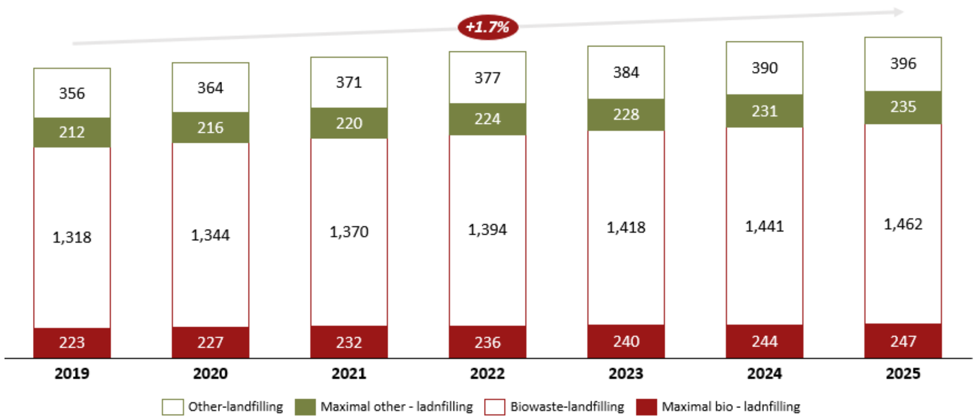
Country	Finland	Germany	Slovenia
Value	10	13	34

Source: Eurobarometer, Own elaboration

2.3.2. Business model and feasibility assessment with new technologies

In the last step of the work it is required which of the identified technologies and models are the most feasible from the business perspective. As was described in the section 2.1.5 the estimated growth of waste will be 1.7% and totally generated volume of municipal waste will be 4.8 mTons. The overall target which must be achieved, both because of the regulatory requirements and responsibility towards next generation and environment has been calculated. The maximal volume which can be disposed on landfills has been set by the EU as 10% of all municipal waste by 2030. Therefore, the Czech Republic has to be able to significantly adjust especially the generation of biodegradable waste. The fact would require mainly focus on collection, separation and ecological treatment of this fraction of waste. In the Figure 19 are presented the maximal capacities of individual components of the waste up to the 2025 to achieve the target. Maximal part represents volumes which can be landfilled even after 2030. Rest of volumes must be treated differently (either recycle or recover) after 2030.

Figure 20: Waste volume which has to be treated ecologically after 2030 (kTons)



Source: Own elaboration

This input is crucial for calculation of necessary capacities which must be constructed in the Czech Republic. In the next section the key assumptions and parameters which has been included in the business model are included.

2.3.2.1. Multicriterial assessment of models' economical proximity to the Czech Republic conditions

Assessment of proximity and feasibility of individual role models is necessary to identify the right fit for the Czech Republic. In the assessment the author focused on two major categories Economical and Energy proximity of a country to the Czech Republic and waste composition and structure and other qualitative aspects of the model reflecting the fit. Even though that the selected models can be highly ecological thanks to the cultural, economic and environmental differences might not be the optimal solution for the Czech Republic. Only bi-dimensional assessment will provide the best results for our country.

This economical dimension has been created from three indicators (i) Energy and Economy (20% weight); (ii) Proximity in waste (management) (35% weight); and (iii) Net present value of the solution (45% weight).

2.3.2.1.1. Energy and Economy

First part of the assessment was based on energy and economy proximity of role-model countries and energy demand. Economic conditions of each country are important for understanding of feasibility of the model. All the selected countries are facing same minimal regulatory requirements from the European Union in many dimensions of economy. Therefore, their closeness to the Czech Republic should influence the selection of the proper waste management model. However, the overall weight of this parameter was set as only 20% due to overall low influence of such criteria.

(i) Gross Domestic Product per capita

Gross domestic products per capita is a measure of a country's economic output per each individual citizen in the country. It is generally perceived as an indicator of richness of a country. With higher GDP per capita the country is observed as more well-off. The indicator was selected because if a country has similar GDP per capita it can be expected that is similarly rich as the Czech Republic. Thus, the country should be on similar level of development and is likely that overall feasibility of implementing same waste management model is possible.

Table 22: GPD per capita (EUR)

Country	Finland	Germany	Slovenia
Value	44,580	43,490	22,000

Source: World Bank, Own elaboration

(ii) Gross Domestic Product growth

GDP growth was selected to identify similarity in the well-being trend between the countries. If a country has similar growth in the GDP there are in the close maturity of an economy. On top of that, similar economic growth is expected to deliver somewhat close results on public accounts. If the growth pace is fast economies are facing better public finance conditions and should have higher willingness to invest.

Table 23: GPD growth (EUR)

Country	Finland	Germany	Slovenia
Value	2.6%	2.2%	5%

Source: World Bank, Own elaboration

(iii) Energy intensity

Energy intensity is defined by US Office of Energy Efficiency & Renewable Energy *"...measured by the quantity of energy required per unit output or activity…"* in other words *"Energy intensity is the ratio between gross inland energy consumption (GIEC) and gross domestic product (GDP), calculated for a calendar year"*. (European Energy Agency, 2019) As was described in the theoretical part, waste management can significantly help in energy generation and cover part of the local demand for a country. Models which are deployed in countries with close energy intensity to the Czech Republic are likely to be more beneficial and feasible from energy perspective also for local market.

Table 24: Energy intensity (pts)

Country	Finland	Germany	Slovenia
Value	181.5	111.1	178.2

Source: EEA, Own elaboration

(iv) Solution output / benefit for national economy

Solution benefit was used as dummy variable to evaluate the output of each model for the economy. As driver for the dummy variable was used the total energy produced which can be used in the economy.

Table 25: Solution output / benefit for national economy (pts)

Country	Finland	Germany	Slovenia
Value	3	2	1

Source: Own elaboration

(v) Deployment easiness

Deployment easiness was estimated based on number of facilities which would have to be constructed for each of the model. With local regulation and relatively long approval process for new constructions number of facilities will dramatically influence possibility to deploy the solution. On top, in the Czech Republic is continuous trend with centralization (e.g. new nuclear power plant) what leads to the assumption that more centralized models are more fitting to the Czech environment and would have higher support from public representatives. Number of facilities was translated into dummy variables.

Table 26: Deployment easiness (pts)

Country	Finland	Germany	Slovenia
Value	3	1	2

Source: Own elaboration

2.3.2.1.2. Proximity in waste (management)

Secondly the feasibility fit of a solution is influencing the waste management model suitability for the Czech Republic. That means mainly that the technologies deployed in the model-markets can deliver same results as they did in own countries. The overall weigh of the parameter was 35% of overall weight of the index.

(i) Waste composition proximity

First criterion is the similarity in the waste structure. It means that the municipal solid waste has as similar as possible components. With similar structure of the waste the model will require less adjustments and calibration for the Czech Republic. Composition of each country was reviewed on the share basis and the model with the closest difference was evaluated as the one with highest match. Results were implemented as dummy variable. Higher proximity received more points.

Table 27: Waste composition proximity (pts)

Country	Finland	Germany	Slovenia
Value	3	2	1

Source: Own elaboration

(ii) Proximity of waste management model to current Czech model

Proximity to current Czech model was evaluated by revision of individual parts of value chain of waste management. For example, in case of collection it was reviewed how systems in individual countries are working (door-to-door vs. centralized collection). After identification of local approaches to each step, they were compared to the Czech system in the given part of the value chain. Proximity was assessed on the scale 1-3 (one least proxy and three most close). In the end the, the overall score of each model was calculated and implemented to the model with the same logic of dummy variable with points 1-3.

Table 28: Proximity of waste management model to current Czech model (pts)

Country	Finland	Germany	Slovenia
Value	3	2	1

Source: Own elaboration

(iii) Waste management model flexibility

Third parameter to evaluate a fit for the Czech Republic was selected as flexibility of the modes. Flexibility is important because it can be expected that in the future the composition of waste will change with new consumption habits of the population. For example, in the recent years we can see first package-less shops in the Czech Republic. In case of significant change of waste generation structure or volume selected technologies can be inflexible to react and it will decrease the profitability and can generate large losses due to high stable fixed costs of the technology. The flexibility of a model is assessed by European Energy Agency.

Table 29: Waste management model flexibility (pts)

Country	Finland	Germany	Slovenia
Value	1	3	2

Source: EEA, Own elaboration

2.3.2.2. Key parameters and assumptions of business model / cost effectiveness analysis

Firs holistic assumption which is necessary for calculation is the ceteris paribus assumption. In the business model and calculation of future of waste has been assumed that there will not be significant shift in patterns of population. It means primarily that composition of waste will not significantly change. This assumption has been validated because in the last years the structure of waste has not changed significantly and if only for lower unit percentage points. Secondly, it must be expected that in the Czech Republic will not be extreme technological, population or economical shift. Change in each of those parameters would have large impact on the production of waste and thus make the whole model inaccurate. From the economic perspective it is necessary to assume that most of the financial parameters such as wage, interest rate and price level keep stable, too. In the following lines there are listed major parameters which has been included in the calculations and business plane of individual technologies.

2.3.2.2 1. Material - Price of waste

Price of waste is important parameter because waste can be considered as fuel for most of the technologies. In terms of waste treatment, the company has to purchase waste from collection companies. In the P&L statement of a waste treating company the waste would be recognized in Cost of Goods Sold concretely as the direct material used for production. Price of waste has been identified on the internet. Mixed municipal waste is usually sold for 1468 CZK without VAT. Biodegradable waste price is around 300 CZK without VAT. (Skladka Kartyne, 2019) Data about price of recyclable waste are not publicly available and thus has been set on the same level as mixed municipal waste but the real price will be probably higher.

Table 30: Waste processing capacity of technologies per year (Tons)

Gasification plant	Pyrolysis plant	Anaerobic digestion	Composting plant	Smart bins
109,500	30,000	12,000	9,900	N/A

Source: Individual technologies presentations (references in chapter 1.1.3.), Own elaboration

2.3.2.2.2. Wages

Wages have been identified in the two categories according to average wage in sector by NACE code. Firstly, there are employees who are working in waste processing and management industry. Those employees would be mainly in lower skilled jobs and e.g. companies facilitating composting, collection, and simple processing. The average wage in this industry is approximately 29 thousand CZK gross wage per month. (Cesky Statisticky Urad, 2018) Growth of the wage is expected to be around 4.6% up to 2025. Oppositely to that for advance processing methods especially energy recovery has been used wage from energy industry. In the energy industry are strongly higher around 46 thousand CZK in 2018 but it will not grow by the same pace like in the waste management industry. (Cesky Statisticky Urad, 2018) Those employees would work in any facilities related to energy recovery.

Table 31: Estimate of number of employees needed for each technology (#)

Gasification plant	Pyrolysis plant	Anaerobic digestion	Composting plant	Smart bins[3]
85	43	14	8	30

Source: Individual technologies presentations (references in chapter 1.1.3.), Own elaboration

2.3.2.2.3. Energy cost

Selected types of facilities such as composting plant are demanding high volumes of energy, especially, electricity and water. Price of water has been set on the current level 88.35 CZK per cubic meter. Electricity price was set 3.8 CZK per KWh according to actual prices. (info.tzb.cz, 2019) Consumption has been sourced from

[3] Based on the interview it was estimated the number of employees requiring for running the system, malmanagement, IT support. No direct labour required.

description of the technologies and external sources. It has been assumed that the growth in prices would not be significant.

2.3.2.2.4. Repair & Maintenance cost

Facilities and plants must be maintained. For each of the business cases has been calculated or set the Repair & Maintenance cost based on the data provided by engineering company or research. Data was not available for all new technologies, mainly for smart bins and gasification plant because. In those cases, the Repair and Maintenance costs has been set as 10 % construction cost or deployment costs in other words Capital Expenditures.

Table 32: Repair & Maintenance cost for each technology (kCZK/ per annum)

Gasification plant	Pyrolysis plant	Anaerobic digestion	Composting plant	Smart bins
69,180	51,880	10,296	240	34,080

Source: Own elaboration (assumption)

2.3.2.2.5. Depreciation & Amortization

The author used the method of linear depreciation for all new technologies except smart bins. Smart bins have usually short lifecycle around 2 – 4 years and low value thus they are not depreciated. However, the cost was included in Repair & Maintenance as a replace cost. Each of the technologies have different lifecycle which has been all the time sourced externally. The depreciation varies between 10 – 25 years. Repair and maintenance costs were sourced from individual technology presentations or cost benefit analysis which are sourced in chapters with respective technology in theoretical part of this work.

Table 33: Depreciation & Amortization cost for each technology (mnCZK/ p.a.)

Gasification plant	Pyrolysis plant	Anaerobic digestion	Composting plant	Smart bins
103.2 (20 years depr.)	25.9 (20 years depr.)	5.1 (20 years depr.)	3.2 (10 years depr.)	N/A

Source: Own elaboration

2.3.2.2.6. Other costs

Into the other costs has been included all other related expenses to the run, logistics, administration, legal costs etc. These costs are obligatory for doing business. The costs have been estimated according to research of similar subjects operating on the market in the Czech Republic. Enterprises with similar business has been identified, then the P&L statement has been analysed and weighted average has been calculated. That created a benchmark which can be used for the calculation.

2.3.2.2.7. Cost of financing

For large scale projects such as construction of gasification plant it has to be expected that financing will be sourced externally. With high probability the companies would opt for bank loans and guarantees. The total cost of external financing for such projects has been estimated on 5-7%. The costs are usually based on PRIBOR + risk premium rate. For real estate development projects and renewables, the risk premium is between 3.8-5.8% (Equa Bank & Société General CZ, 2019) and PRIBOR average – REPO rate is on average in last three years 1.2% (CNB, 2019). Project would require external financing if the costs overcome threshold of 100 million CZK.

2.3.2.2.8. Revenues

For technologies which can be sorted in the category of recovery is common to be somehow supported by feed-in tariffs. The energy which is produced has set a price for which is purchased from producers. Other facilities such as composting plant produce as output compost which is the marketable output. Smart bins, oppositely to the others, do not produced direct revenues, however, they generate indirect revenues in terms of optimization and opportunity cost.

Table 34: Revenues from revenue streams by technology (CZK)

Gasification plant	Pyrolysis plant	Anaerobic digestion	Composting plant	Smart bins
2,820 CZK/MWh and 73 CZK/l syngas	2,820 CZK/MWh	3,900 CZK/MWh	100 CZK	N/A

Source: TZB.info, Own elaboration

2.4.1. Optimal solution for the Czech Republic

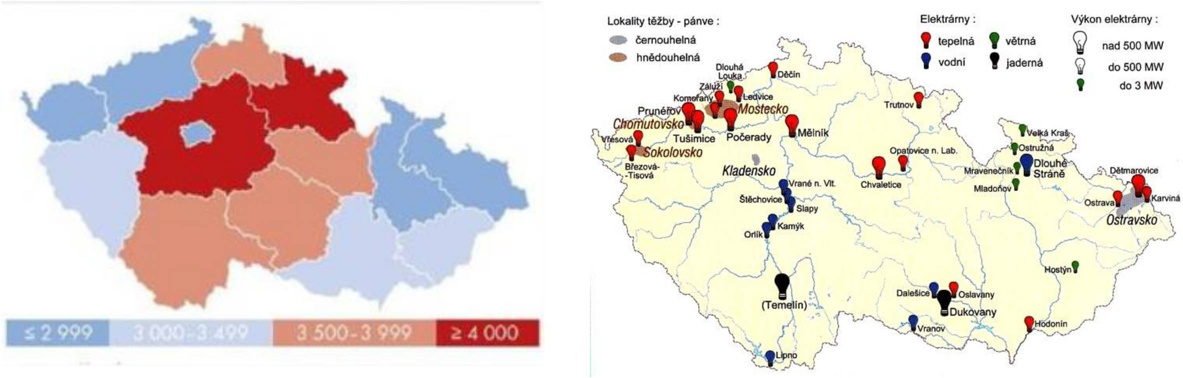
In the previous parts was described the demand which the Czech Republic faces about around landfilling because of binding European regulation. The goal which has to be achieved is reduction of approximately 80% of currently landfilled biodegradable waste an overall landfilling. Multiple technologies which are possible to use to tackle the issue has been presented and business case of them has been calculated.

2.4.1.1. Most economical model

From the business perspective is the most optimal to focus on construction and promotion of energy recovery facilities in the same way as in Finland. Firstly, it must be said that none of the technologies is rentable under current circumstances. Major issue it the price of raw material (waste) for run of a facility. Under current market circumstances there is issue in the market value chain because the waste collecting private companies usually do not process, or process on demand for additional fee, the waste. Most of the other costs are relatively low in terms of overall business.

In the Czech Republic is currently potential to construct a large-scale waste to energy facilities. The overall potential for construction of 3 large facilities with overall daily demand for waste 300 Tons if the Czech Republic want to comply with the EU regulation and for 5 facilities if the country wants to achieve maximal efficiency. Each of the facility would generate approximately 65.7 GWh of electricity and around 657 thousand liters of syngas which could be used for additional energy generation. 65.7 GWh of electricity could be used to cover consumption of 21 thousand households. (Cesky Statisticky Urad, 2017) In total that means that 5 plants would cover consumption of 105 thousand of households that means approximately 2 – 3 % of population. Highest potential for construction of them is in regions with high production of waste per capita, high demand for electricity per capita and simultaneously low generation of electricity per capita (because it reduces distribution losses). As it is visible from Figure 20 the highest demand is in central Bohemia and Kralovehradecky region.

Figure 21: Demand for electricity per capita (KWh), Power plants in the Czech Republic



Source: Cesky statisticky urad, https://kapselshalflanghaarz.blogspot.com

On top of that, especially in central Bohemia are currently only hydropower plants and hence there is potential to construct production capacities.

The total cost of the project would be approximately 10.5 billion CZK (2.1 billion CZK per plat). From the financial perspective the project is not rentable for the producer under current feed in tariffs. Each year each plant would generate loss approximately 48.5 million CZK which would have to be subsides by the government or regional authorities. However, as was mentioned before if the waste is provided for free, each plant would operate in green numbers. Every year the free cashflow was calculated as 112 million CZK. Payback period of one plant is approximately 18 years which is in comparison to other technologies used for generation of electricity significantly longer period. For example, the payback period of coal-firing power plant can vary between 6-12 years (Coal Power Economics Study Group of North China Electric Power University, 2017)

On top of that, the NPV of the project is only approximately 1.3 billion which significantly suboptimal for the investor.

What would could make the investors more attracted by the project is either direct subsidy of the project or increasing the feed in tariffs for the electricity from this source to the level of biogas power plants which is currently 3,900 CZK per MWh. If the price of feed in would be set on this level the payback period would decrease to the approximately 9 years 9 months. Also, the net present value of the project is positive even though not significantly.

For the treatment of biodegradable waste should be constructed anaerobic digestion power plants. Similarly, as in the case of large gasification facilities, they are not profitable. Under current circumstances each plant would need approximately 300 thousand CZK per year to be in positive cash flow. To cover the whole market for waste by 2025 110 of such plants would have to be constructed in the Czech Republic. That means approximately one plant to each city in the country. In optimal situation to achieve (almost) zero landfilling status would be necessary to construct 170 of them. The total CAPEX for the project is 440 and 680 million Czech crowns. Those plants would generate additional 880-1360 GWh per annum what would cover demand of 270 – 415 thousand households in the Czech Republic. Thanks to the decentralization of production it would be optimal to construct such smaller plants in distanced locations from the major energy sourcing areas such as Plzensky Region and Vysocina. Vysocina is optimal from another major reason because there is strong agriculture industry presence which generates bio waste.

To summarize the model total capital expenditures would vary between 6.74 and 11.18 billion CZK. Every year would be generated 1077 GWh and 1688 GWh of electricity, what represents 1.5-2.3% of overall demand in the Czech Republic. It sounds like small number, however, if it is recalculated it would mean covering of demand of 333-520 thousand households. From the operational perspective it would require to be subsidized by government by 180 – 280 million CZK to be on par in P&L statement. However, to attract investors the good practice from other countries is to provide either bank guarantees or directly grant the construction. The grant could be expected between 10-30% of CAPEX. Therefore, the total price for government to finance such model would be 1.54 – 4.43 billion CZK in 5 years horizon under good practice in the operation. On top of that, thanks to the feed in tariffs the customers would pay between 2.3 - 3.6 billion CZK for green electricity. Thus, the final bill for the sustainable waste management model almost free of landfilling in the Czech Republic between 13.4 and 22.3 billion CZK.

However, the impact would be positive. We would be able to close either one large coal-firing power plant or 2-4 smaller. Czech Republic would be less dependent on the coal, the overall losses because of distribution would be lower and the production of energy would shift towards decentralized sustainable model. Additionally, the decrease of production of CO_2 would be approximately 14% in comparison to baseline (current production) because releases of CO2 and other gases from landfills would be almost eliminated and closing of coal-firing power plans, which have heavily more negative effect on the environment, would be impactful, too.

2.4.1.2. Most ecological model

Second objective was to identify what model would be the best for the environment in the Czech Republic. The model would be closely related to previously described Slovenia model which is mainly focusing on the recycling. Ultimate goal would be decrease environmental impact and thus should be start with better separation of organic waste. In this case the first necessary step is to develop infrastructure and motivate people to separate the waste. For the infrastructure the first requirement is to purchase containers for separation. Based on the market sizing and confirmation via interviews it has been estimated that to keep current approachability of those containers approximately 50 thousand of them would have to be purchased. From the capital expenditures it means approximately 560 million CZK with price 11,400 CZK. (Sompo s.r.o., 2019) Additionally, new fleet of specially equipped collection vehicles (around for the whole market 300) (representative, 2019) would have to be purchased for total price 900 million CZK. The total CAPEX in the first year would be, including also estimate 250 million (representative, 2019) for sorting lines and first level processing facilities, 1.71 billion Czech Crowns. Operational expenditures including 5 employees[4] per one vehicle, repair & maintenance, fuel (it is expected to be either e vehicles or CNG cars to minimize the ecological footprint) and other operating costs would be approximately 974 mil. CZK p.a. Lastly for success of such program it would be necessary to run large scale campaign in media and educate the people. For that would be used traditional advertising, similar campaign with direct letters, as was described in section 1.1.3.1., and mobile apps. In first year, the cost was estimated about 150 million CZK and following years 50 million. Together, the first-year cost would be approximately 2.85 billion CZK and total cost in 5 years 6.6 billion CZK.

In the processing of waste, for the mixed waste would be again build the large-scale gasification facilities but only 3 of them because rest of the waste would be sorted and recycled. There is currently no better technology available in terms of processing of the mixed waste. The CAPEX for them is the same 6.3 billion CZK and yearly subsidy including feed in tariffs would be 473 million CZK. In the five years horizon the total costs would be 8.7 billion CZK.

Lastly the biowaste would have to be processed. Thanks to the sorting of the waste it is possible to construct multiple composting facilities almost in every bigger city. In

[4] Including staff required for sorting, maintenance, back-office support and others.

total it could be constructed about 114 composting plants each of them for approximately 32 million CZK. Each of those would employ approximately 12 employees and yearly would be able to process about 10 thousand tons of biodegradable waste. Even though that the cost of doing business is relatively the prices for compost are even lower and thus the business is not profitable each year the government would have to subsidize such business by approximately by 1.5 million CZK what would cost tax payers about 866 million in the 5 years horizon, including CAPEX 4.5 billion CZK. The whole ecosystem should be supported also by anaerobic digestion plants which about 70 should be constructed. The CAPEX related to the construction would be close to 7.4 billion CZK and state subsidy up to 1.6 billion per annum (8.3 bCZK in 5 years)

The overall cost of the ecologic model would be around enormous 33.5 billon CZK. It means that every citizen in the country would have to pay about 60 CZK extra every month to cover the costs. In Prague for example the price for municipal waste management would increase by 30%. However, the Czech Republic would be officially one of the most ecological and environmentally friendly country in the world. The estimated impact would be reduction of release of CO_2 and other gases by approximately 31% in comparison to baseline. Landfilling would be reduced almost to zero.

As part of the model should be implemented also the deposit scheme for plastic bottles and liquid packaging board to maximize the impact. Cost of implementation of such scheme is hard to estimate but it would be in lower billions of Czech Crowns.

2.4.2. Validation of findings – qualitative part

With aim to validate the findings the author approached subject matter experts from public sphere inasmuch from private companies. Interviews were run in one to one setting and took approximately one hour. Qualitative research was done in form of open question and discussion about findings and situation in the market.

2.4.2.1. Interviews with governmental institutions

Author has approached Ministry of Environment with question about the possibility of interview. The Ministry has answered after few weeks and suggested to have meeting after the term of submission of this work. Before it the inquiry was denied because of capacity reasons of employees of the Ministry. Secondly, CENIA agency has been approached with similar request and meeting has been scheduled. However, the agency has only informative character and the employee does not have any direct power or information about this problematic. The employee was helpful and tried to help with scheduling a meeting with responsible department in the Ministry but by the day of submission of this paper no meeting has been scheduled. Therefore, the author cannot provide any opinion from the side of government and responsible state authorities.

2.4.2.2. Interviews with private companies

The author has scheduled 4 interviews with two companies directly involved in the waste management process, especially collection, sorting and first level treatment, (Marius Pedersen and AVE CZ) and two energy group which is partially involved in the waste processing and owns multiple incineration plants (Innogy and E.ON). Sadly, in the end only 2 interviews happened one with an energy player and one with a waste management company. It has been agreed that the representatives of companies as much as which companies they came from do not want to be mentioned in the work and the results of interviews will be presented in the anonymized form.

2.4.2.2.1. Interview with a Board -1 level employee of a waste management company

The interview was held with a company representative responsible for waste business in the Czech Republic.

Firstly, the discussion was related to the current legislation and regulation. According to the subject the regulation is one of the biggest issues. Under the current regulatory framework, the companies are neither motivated nor pushed to behave in line with the requirements of the European Union. As long as there will not be change in the regulation, what he evaluated as unlikely in the short time, there would not be significant shift in the behavior of various market players. It was mentioned that crucial is the motivation in terms of subsidizing or other support in costs participation for the companies is problematic to change the current model of waste management. He said that that government do not actively discuss with the companies possibilities how to improve the model of waste management, how it is common for example in Nordics, and there is relatively low willingness to shift towards more sustainable and ecological model. The biggest constraint is obviously the price.

The current market situation was described as extremely price sensitive where local authorities and municipalities tender the contractor mainly and sometimes only on based on price criterion. Especially in smaller cities and regions is than the margin relatively low and there is no capital leftover for investment into the new technologies. Secondly, under current labor market conditions there is a complication in terms of hiring people and increasing minimal wages creates pressure on the margin from the bottom line, too. The situation on the market is unsustainable, in the long term, and if there would not be increase in prices for the service they might not continue to operate in selected locations around the country because simply it would not be rentable for them.

In terms of identified potential technologies he said that in multiple locations they operate composting facilities, however, there is low demand from municipalities to cover additional costs for that. From the opposite side, he said, that on the market is not enough demand for compost because large chains of hobby markets are able to sell compost for lower price due to production scale. On top of that, in the Czech Republic is not developed enough market and citizens are not used to go and purchase compost from such facilities and rather visit hobby markets. Demand from municipalities is also relatively low because municipalities do not spend enough money on public parks and green areas, rather do minimal maintenance. For industrial usage of compost is also low demand because large agriculture players purchase fertilizers from large chemical industry companies with ensured high level of nitrogen. SMEs in agriculture business are usually self-sufficient in terms of production of fertilizers.

In terms of other investment into the smart bins and other equipment he mentioned one problem and it is duration of contracts. In most of the municipalities, in which private companies are providing the service, are two major problems. First problem is low understanding of digitalization and advantages. Representatives of such cities are almost everywhere still focused solely on the traditional model “Tuesday-Thursday” collection and not open to change. Major barrier to the change of the pattern is “fear from change and what would the voters say” mindset. Second problem is the year-to-year contracting. Most of the current contracts are signed for one year with renegotiation of price end terms. Therefore, on the market is uncertainty and the companies are not willing to invest into the technology if they are unsure about the next year contract. Currently, most of the investment is rather focused on improvement of fleet and renew of fleet, investment into sorting technologies, which makes the waste purer and the price is afterwards higher for resale. They have never considered to invest into the large processing facilities because they do not have enough expertise and experiences in the field.

Separate collection of organic waste as it is common in other countries has been proposed multiple times, as he said, however, with almost no response from the side of municipalities and the state. Such project would require improving awareness between the population and development of supporting infrastructure, which is currently not in place, and no one is willing to cover the costs. Costs are the basic problem in the whole model. It was mentioned that they are ready to provide such services once there will be enough demand for them. About the calculations he mentioned that it seems realistic, but he is not in detail with the numbers, but he would expect even more up to the double. Key is to change the regulation and funding into the model.

2.4.2.2.2. Interview with an energy company representative

The representative oversees heat plants portfolio in a local entity of one of the leading energies & utilities group in Europe and the Czech Republic.

In the beginning we mainly discussed the possibility of construction of large-scale waste to energy facilities in the Czech Republic. He said that multiple companies in the market were also considering the option and developed detail business case because it would fit into their strategy, but they have decided that the return on investment is too low. Major problem he identified in existing market and our energetic heritage from the socialism era. In the Czech Republic is highly developed network of heating power plants and district heating[5], which is on one hand relatively ecological, on the other hand most of the facilities and plants has been constructed in 60s and 70s of the last centuries and has been at least partially renovated after 2000. Because of that there is basically no market for such plants because no one would invest in such facility to compete with another heating plant. On top of that, it would be against the national energetical strategy. The potential is in renovation of existing plants, however, most of them is not suitable for transformation into large gasification facility. The situation was basically described as "pat" because old technologies are still working and have not fully paid back, and might never will, because of emissions and payments for CO_2 allowances and lower efficiency of the technology, but simultaneously they create strong competitor to new projects. The situation is supported by almost no greenfield in the country for district heating. He also disclosed that the numbers provided by Czech Statistical Bureau are biased because in the reality significant share of separated packages and recyclable materials are incinerated. Reason for that is eldering technology in those facilities which was constructed with some requirements on the calorific value of waste. After the push for sorting and reduction of plastics and paper in the composition of waste the calorific value felt to low and "it does not burn anymore". He said that they have to buy separated waste, mainly plastics, and mix it back into the waste to increase the calorific value. According

[5] Centralni zasobovani teplem a teplou vodou

to him this practice is same throughout the market in all incineration plants including Malesice.

The company sees significant potential in biodegradable power plants and decentralization of generation, even though that they do not have almost any of such facilities. In the last years they have delivered multiple projects "on key" to agri-businesses which were interested in biogas plant on demand. He mentioned multiple times that for successful business case of such project it is must to have stable supply of bio waste because otherwise on the market it is complicated to source it in sufficient quality and volume and transportation on long distance heavily reduce rentability of such facility.

This interviewee seen the same issue as the first one in the legislation and regulatory framework. The company would need to face higher feed in tariffs, or other form of subsidizing of production of energy from waste, to start to consider increasing the capacities and building new facilities. According to his opinion one of the first steps would be increasing the landfilling tax because otherwise waste to energy is not competitive under current market circumstances. It was mentioned that politicians have low motivation to change current model and they are influenced by something so called landfilling lobby.

From the business case perspective, he evaluated the calculation of recovery technologies as "a bit optimistic" for the Czech Market. Especially the CAPEX would be higher because the land has not been included in the calculation and to construct such facility in the Czech Republic usually significantly exceed the budget. Support for the state would be thus a bit higher about 10%. In the operational perspective he said that the calculations are more approximately right, but it depends on the exact specification, equipment and other factors. However, on average the numbers he evaluated as reasonable.

3. Conclusion

In the last chapter the author will summarize the findings, describe the key success factors, and propose next steps and implications for the Czech Republic. As was previously described the Country has multiple options how it can shape its future each of them with different cost levels and impact on the environment.

3.1. Summary of findings

The Czech Republic has to achieve the committed goals within the next decade and there are two basic ways how to approach it either go for the less ecologic but more economic version or vice versa. Most economical would be to focus on processing of waste in the recovery stage. That means focus on waste-to-energy technologies with low carbon dioxide footprint and develop network of decentralized anaerobic digestion plants and centralized gasification plants. Oppositely if we prefer to opt for most ecological model it is optimal to focus on recycling and reuse of waste. Czech government would have to support separate collection of bio waste, composting, however, some centralized plants, because they are the best (ecologically and economically) for processing of fractions and inorganic mixed waste, and anaerobic digestion plants.

3.1.1. Economical model

Economical model is based on the best practice developed in Finland. The country has faced similar problem and in relatively short time period was able to shift towards sustainable one. Finland is solely focusing on energy recovery which is significantly simpler and requires less investment into supporting infrastructure. Within the model the Czech Republic is going to focus on waste to energy facilities mainly large gasification plants and anaerobic digestion plants. Thanks to the two innovative technologies the country will have the best in class processing model and will be able to achieve sustainable ecological waste management model. Simultaneously, the technologies will be able to deliver results in terms of reduction of CO_2 emissions in comparison to current baseline scenario. That will be achieved mainly thanks to reduction of release of CO2 from landfills and because of possibility to close one of the large coal-firing power plants. That would be possible because the facilities generate energy which will be distributed into the local region.

From the business perspective, under the current regulation, it is not profitable business and thus the government would have to create incentives for companies to enter the business. Subsidies has been calculated for the model and they are included as OPEX expenditure for the government. CAPEX expenditure can be financed by the private or public companies or the government. Crucial for success is to have the fuel for facilities, waste, for free because it significantly cheaper to operate such facilities. It can be estimate that there will be additional costs such as connection of plants to the grid, infrastructure development and other similar costs, however, they have been excluded because they are only relevant to individual projects and location of the facility rather than to the holistic view on the waste management model.

Table 35: Summary of Economical model (bCZK, %)

Scenario	CAPEX	OPEX p.a.	TOT cost in 5 years	Impact
10% Landfilling	6.75	1.35	13.4	12%
0% Landfilling	11.2	2.22	22.3	14%

Source: Own elaboration

3.1.2. Ecological model

Ecological model of waste management in the Czech Republic should be based on the best practice developed in Slovenia. They have decided to maximize recycling possibilities with measures such as door to door collection of waste, clear and regular communication with citizens and building of general awareness in population. For the Czech Republic, in case of most ecological model, to establish sorting of organic waste before collection. In other words, there would have to be additional container for organic waste next to the glass and plastic one. On top of that, new infrastructure for collection of them would have to be developed. Heavy investment would also require communication towards citizen and educating of citizens to separate the waste. Multiple campaigns in traditional media channels inasmuch in new channels should be done to develop awareness. In the processing part, all over the country would be build composting facilities supported by anaerobic digestion facilities because biowaste hides the biggest potential. For mixed waste and fractions would be again build gasification stations.

From the economic perspective, the price tag is approximately by 2 higher for government than the economical option. It is mainly because large portion of the infrastructure described above would have to be financed by government. It is unlikely that private companies would invest into educational campaigns or infrastructure development. The cost could be decreased by multiple measures which impact is complicated to estimate without exact data insider data from companies. First one is implementation of smart bins which can strongly reduce operational cost of collection and thus reduce operational costs. Second one is decreasing the production via new instruments such as implementation of deposit schemes on plastic bottles and drink paper packages. It could be expected that such measures would reduce generation of waste and shift part of the costs on site of manufactures of packages and retailers. However, the model would deliver amazing result. Ecological footprint would be decreased by 31% in comparison to baseline. Again, it would mean mainly reduction of CO_2 release.

Table 36: Summary of Ecological model (bCZK, %)

Scenario	CAPEX	OPEX p.a.	TOT cost in 5 years	Impact
0% Landfilling	17.6	3.2	33.5	31%

Source: Own elaboration

3.2. Recommendations, key success factors and implications

Both options have set of basic recommendations and steps which should are same for them. Those will be listed firstly followed by recommendations specific for individual models. The key success factors are rather focusing on the government and adoption of policies because as was identified in case studies and validated in the interviews the major driver for change is regulation. Without regulation, subsidy schemes and instruments for support of model it is impossible to achieve the goal whichever is optimal for the country. Secondly, the must is to ensure financial resources for projects.

3.2.1. Both models – European regulation

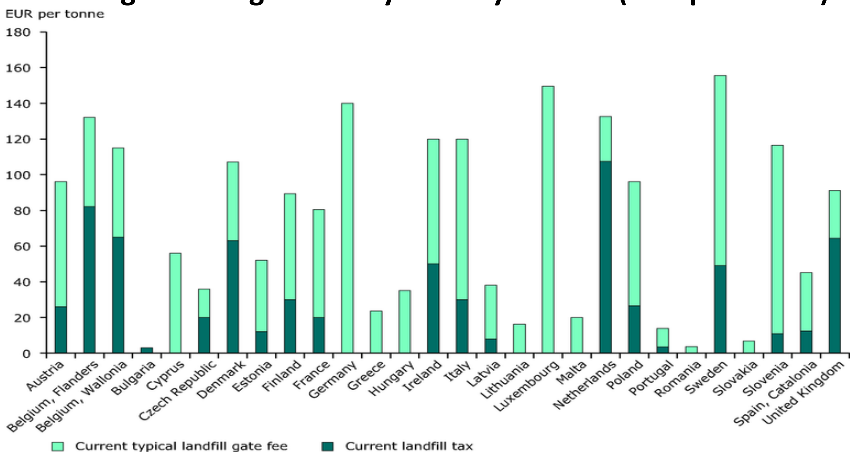
First condition and requirement for successful achievement of committed goals is to fully adopt the European regulation. There are multiple regulations which are currently not included in the regulation such as “Single Use Plastics Directive” which bans to sell 10 single-use plastic items most commonly found on European beaches such as straws, cotton swabs made from plastic, plastic plates and cutlery, plastic coffee stirrers and plastic balloon holders. (European Commission, 2019) Secondly, it should be fully adopted previously multiple times mentioned “Circular Economy Package”. Adoption would put into the Czech legislative many times mentioned *“…binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030*” and other supporting financial and operational instruments. It would also mean unification of measures and harmonization of previously mentioned classification of waste throughout all EU countries. There is no need to develop absolutely new regulation for waste just fully adopt above mentioned one to start the shift towards ecological model of waste management.

3.2.2. Both models – Local regulation

Secondly, the EU regulation has to be supported by local incentives and regulation. It means primarily increase the landfilling tax. In these days the landfilling tax and gate fee are below the European average what is suboptimal. If we look on the case studied countries all of them have above average the European Union Average. The data about current levels of Landfilling tax are in Figure 21. As long as the tax would be increase, from the financial perspective, it is less financially perspective for private companies and municipalities to change current model. However, in this area is necessary to gather support of Members of Parliament and gather enough support for new measures, which under current circumstances looks unlikely. Simultaneously, the money gathered from increased taxes can be used for subsidizing of new technologies implementation and supporting shift towards more ecological model. It is obvious that complex schemes for subsidizing of large-scale projects has to be developed. In this area would be interesting to evaluate possibilities of Public-Private-Projects (PPP).

Subsidy schemes should be developed in both cases in for waste to energy plants. Optimal for are there basic instruments (i) allocation of free allowances – free allowances can be allocated both for the producers of energy from GP and ADP to decrease the price of production. Free allowances can be allocated also for their customers, mainly companies which would use syngas for generation of energy. (ii) Feed-in tariffs – feed-in tariffs would set regulated price for energy generated from GP and ADP above the standard market price and thus increase profitability of businesses operating on the market. The instrument is used for subsidizing of generation of ecological energy by customers. (iii) Direct subsidies – subsidies provided by the government on operation and thanks to that decrease the cost of doing business. Other form could be state support for construction of new plants, state guarantees and other instruments which would ease life for construction of them. Volume of subsidies is probably going to be the key measure for influencing of final mix in the waste management in the Czech Republic.

Figure 22: Landfilling tax and gate fee by country in 2013 (EUR per tonne)



Source: European Environmental Agency

3.2.3. Economical model – how to achieve it

Economical model requires low involvement of general population and thus do not require large involvement of citizens in the implementation. Therefore, it would be significantly easier to implement it than ecological model. However, the key constraint is to gather enough resources, mainly financial, for construction of them.

Firstly, there should be identified optimal locations for large gasification plants and include them into the strategic energetic conception of the Czech Republic. Previously was outlined that the potential is probably in Stredocesky region and Vysocina region, however, detailed study should be performed. Key parameters for location study was population of region, waste generations volume in region and infrastructure in region.

Secondly, should be developed scheme for support of ADPs construction. Again, as it is decentralized source of energy it should be identified where they should be constructed. What might be evaluated as potential from perspective of state if they would be owned by municipalities to secure energy for street lighting and other public goods in a city.

The most important would be ensure financial resources for construction. There are multiple options how the money could be obtained (i) European Funds – similarly as Slovenia was able to gather multi billion Euros from European Funds for improvement of its waste management system Czech Republic should set as priority to get as much as financial resources from the Union. (ii) PPP – in Czech Republic not that common way of financing, yet, but very popular in Western countries. This approach was selected in Finland and helped them to in relatively short time, approximately 5 years, to construct majority of their modern waste to energy facilities. (iii) Direct financing and local money

– last option is to finance it from the local resources. It would probably combination of 3 major streams – increase of fees for waste collection and local municipal waste fees, increase of landfilling taxes, ecological tax, and other sources endorsing the change, and also changes in the state budgets and governmental expenditures.

3.2.4. Ecological model – how to achieve it

Ecological model must focus on people. Without people it is impossible to achieve the goal. Therefore, it is probably less feasible for the Czech Republic because there would not be political will to support such significant change.

For ecological model it would be optimal to adopt stricter regulation and focus on two basic areas. Significantly increase direct separation before the collection. It could be achieved via implementation of fines and penalties for not sorting similarly like it is done in Germany or Slovenia. Each citizen or company could receive fine if they do not sort waste and in the beginning after adoption promote zero-tolerance policy. From the regulatory perspective it would have to be adopted compulsory sorting of organic waste, too.

Sorting of organic waste during collection would require developing new infrastructure in terms of containers (about 50 thousand new containers), collection vehicles and hire new staff. Only thanks to the sorting it would be possible to easily process the waste in composting facilities. Without it the composting is less economically efficient, and the capacity of facilities might not be fully utilized.

However, what would be crucial, is clear communication of government and companies towards citizens why such change is happening. Government and municipalities would have to spend money for awareness campaigns and communication plans. That because the biggest constraint in the beginning would be change behavior patterns of citizens. Czechs are not used to put organic waste into separate bins and as long as they would fully understand the reasons why they must, and eventually are penalized if they do not comply, that would create general resistance in the population.

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