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A Road Map to the Circular Economy for Municipalities. Case Study of the Czech Republic

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Abstract
The Circular Economy (CE) is a current European phenomenon following the green economy. The recent EU Action Plan for the Circular Economy points out the necessity to move from a linear economy (take–make–consume–dispose), where resources are simply extracted, used and thrown away, to a CE where resources are put back in the loop. The objective of the paper is to propose a model of a road map to the CE for the municipalities of the Czech Republic. This model includes the following consecutive modelling steps: the identification of appropriate municipal waste streams using the waste codes of the European List of Waste and computational formulas to determine the amounts of material involved; the processing of historical annual municipal waste stream generation and treatment reports (2009–2014) produced by waste generators and facilities, and the analysis of their data sets; the determination of driving forces for municipal waste streams and the identification of the purpose of government intervention. We consider new challenges facing municipal waste management (MWM): how local authorities can implement their Municipal Waste Management Plans, improve those plans and recycle more chosen appropriate municipal waste streams. In addition, we discuss how authorities can decrease the amount needing to be spent in this sector via municipal budgets as a result of the lower expenditure associated with more efficient MWM.

Keywords
Circular economy, waste generation, municipal waste management, waste management plan.

Introduction

Over the last few years the Circular Economy (CE) has been receiving increasing attention worldwide as a way to move beyon the current production and consumption model based on continuous growth and increasing resource throughput. A circular economy makes best use of waste and resources, which is a high priority for local authorities as key delivery agents for municipal waste collection, reuse, recycling and disposal services in many European Union (EU) countries.

The recent EU Action Plan for the Circular Economy [1-2] points out the necessity to move from a linear economy where resources are simply extracted, used and thrown away to a CE where resources are put back in the loop. To this end, the European Commission (EC) intends to include new waste targets and indicators to monitor resource efficiency, new policies to boost recycling and prevent the loss of valuable materials, and new initiatives to create green jobs and support eco-entrepreneurs.

This Action Plan has ambition to transform Europe into a more competitive, resource-efficient economy, addressing a range of economic sectors, including the municipal waste management (MWM) sector. The revision of CE proposals provides the opportunity for local authorities to change the existing state of MWM. There are clear benefits from achieving the CE, including value obtained from existing resources in the economy. A more circular waste management approach would also offer increased employment potential and ensure greater resource efficiency.

Our research is focused on the MWM sector because municipal waste (MW) forms 15% of all generated waste in the Czech Republic, and constitutes a significant proportion of all generated wastes, in a lot of EU Member States (MS). Therefore, municipalities have to be the starting point for the transition to the CE. They are the first places where products are produced, consumed and discarded, and their population density and (in the case of big cities) industrial productivity mean that waste streams can be cost-effectively collected, transported and recycled.

In addition, in relation to the EU Action Plan for the Circular Economy [1-2], the common EU target is to recycle 65% of MW by 2030 and reduce landfilling to a maximum of 10% of all waste by that date. Reusing, repairing, refurbishing and recycling existing materials and products play a central role in turning what used to be regarded as waste into a resource. The aim is to look beyond waste with all resources being managed efficiently and sustainably throughout their life cycles. The transition to a CE requires fundamental systemic changes in many different areas of the current socio-economic system to occur simultaneously. Although a complex process that is difficult to predict, several crucial areas of change can be identified in the technical, economic and social domains, with a focus on the enabling factors guiding and accelerating the transition process. There are the major goals for municipalities. On the other hand, achieving these goals can help municipalities to decrease their MWM expenditure.

In the Czech Republic, municipal expenditure on MWM from 2010 to 2015 was more than 60 % of current municipal expenditure on environmental protection. The MWM area is an integral and indispensable part of municipal budgets and also a suitable area for measures aimed at saving public resources and seeking factors that influence them, also including the Circular Economy.

The objective of the paper is to propose a network model of a road map to the CE for municipalities with consideration of the ideas of the European Innovation Partnership on Smart Cities and Communities (EIP-SCC) [5]. This creates a new challenge: research needs to be conducted into how local authorities can implement their Waste Management Plans (WMP), improve municipal Waste Prevention Plans (WPP) and recycle more MW. Another subject needing investigation is how authorities can decrease the amount needing to be spent in this sector via municipal budgets as a result of the lower expenditure associated with more efficient MWM. We try to show this in the present case study of Czech municipalities regarding potential expenditure savings and legal conditions related to environmental protection and the MWM area.

The MWM segment was selected for the proposed research because CE proposals will naturally include elements of the EIP-SCC ideas that are focused on the materials collected from households as waste.

Some aspects of current research (particularly in the MWM sector) are moving tentatively towards circularity, but not necessarily in a systematic or coordinated way. More information is needed to facilitate decision making concerning MWM, and Smart Cities ICT technologies can provide this and enable the combination of current ideas about the economic, environmental, social, legislative and technical effects of CE.

However, there is a lack of a comprehensive approach to the area of interest of this paper in the Czech Republic that is able to mirror the specificities of the Czech Republic. This paper is an attempt to fill this gap.

Material and Methods

Theoretical and legislative background

The Circular Economy [1-2] has most often been considered only as an approach to more appropriate waste management. However, such a limited point of view may lead the CE to fail, in that some recycling, reuse or recovery options may either not be appropriate in a given context while instead fitting other situations and, above and beyond that, some conversion options based on green chemistry and biotechnology may end up being much more expensive and impactful than the conventional technologies they are intended to supersede. This means that prevention is a better course of action than treatment.

All in all, the challenge ahead is not a "more of the same" approach, calling for increased implementation of "green" technologies, but instead requires a broader and much more comprehensive and interdisciplinary look at the design of radically alternative solutions.

If we were to ask ourselves the question: "*What's the role of local authorities and communities in a circular economy?*", we would have to answer: "*Local authorities and communities, along with businesses and NGOs, have a huge role to play in challenging and changing the way we think about municipal waste.*"

Czech local authorities are trying to continue to improve and develop their services based on what they can deliver locally, but there is a limit to what can be achieved by the collectors of waste alone. The most effective course of action, following the principles of the waste hierarchy, is to influence the amount and nature of material long before it reaches the waste stream and in some cases before it even exists at all.

Due to the fact that municipal expenditure on MWM from 2012 to 2014 was more than 60% of current expenditure on environmental protection, and accounts on average for 3% of total current municipal expenditure in the Czech Republic, it is obvious that the MWM area is an integral and indispensable part of municipal budgets, and also a suitable area for research aimed at saving public resources and seeking factors that influence them, which also include the CE.

The EU proposals should provide long term certainty about the role of all, not just publicly funded, participants in the CE. The focus should be on measures that encourage innovation in product design and the shaping of a stronger reuse and recycling market in order to support new, more efficient processes.

The Waste Management Plan (WMP) is the basic EU tool and framework reflecting the CE. It allows the assessment of the existing situation, the definition of the objectives that need to be met, the formulation of appropriate strategies, and the identification of the necessary means of implementation. The drawing up of WMPs is an obligation of the EU MS and is required by Article 28 of the Waste Framework Directive (WFD) [3]. In order to assist national, regional and local municipal authorities (MAs) in preparing WMPs in line with the requirements of the WFD, the European Commission (EC) has published a methodological Guidance Note [4] where it specifies the framework by which MA decision-makers can can move MWM towards circularity. In order to move up the waste hierarchy, the WFD requires MAs to establish Waste Prevention Programs (WPP) as a part of WMP. This is opening up a further area in which MaAs can pursue CE implementation.

Further activities which will be able to support CE implementation in municipalities are proposed in the first draft of the EIP-SCC Operational Implementation Plan (OIP) with its 3 Priority Areas concerning "Integrated Infrastructures" [5] focused on Waste for Energy and Intelligent Bins (Putting sensors on bins enables cities to communicate within the waste collection system, optimising truck routing, minimising energy consumption and congestion, and satisfying customers).

There is scope for the OIP proposals to combine increased resource efficiency and security with a reduction in the burden on tax payers. MWM regimes may be delineated according to Gille [20, p. 9] "through what economic, political and material dynamics waste is produced, how it is conceptualised, and how it is politicised". They vary enormously in all these respects, both comparatively and historically, including the ways consumers dispose of their waste.

Network model of a road map to the circular economy for municipalities

Our developed network model of a road map to the CE for municipalities includes the following consecutive modelling steps:

1. Identification of appropriate municipal waste streams using the waste codes of the European List of Waste (ELW) [6], and computational formulas to obtain the amounts of material involved.
2. The processing of historical annual municipal waste stream generation and treatment reports (2009–2014) produced by waste generators and facilities, and the analyzing of their data sets.

3. Determination of driving forces for municipal waste streams.
4. Identifying the purpose of government intervention.

Identification of appropriate municipal waste streams

The appropriate municipal waste streams which have been defined, and which we consider in our research, are presented in Table 1.
We have to consider Sludge and CDW generation together with MW streams because municipalities combine the MWM of their treatment in municipal ordinances. CDW is also huge potential source for the CE.
Note: We have also included in the biodegradable waste (BW) stream both MMW and Bulk waste, which contain biodegradable components, like the wastes with the codes 200110, 200111, 200302, 200303.

Table 1 A list of waste streams for which municipalities are responsible, and a list of the waste codes for each waste stream taken from the European List of Waste (ELW) [6]. The digits of the codes for hazardous waste end in *. Source: The authors, according to [6]

Waste stream	*Waste codes of the ELW*
Municipal waste other (MWO)	200101, 200102, 200108, 200110, 200111, 200125, 200128, 200130, 200134, 200136, , 200138, 200139, 200140, 200141, 200199, 200201, 200202, 200203, 200301, 200302, 200303, 200306, 200307, 200399, 150101, 150102, 150103, 150104, 150105, 150106, 150107, 150109
Municipal waste hazardous (MWH)	200113*, 200114*, 200115*, 200117*, 200119*, 200121*, 200123*, 200126*, 200127*, 200128, 200129*, 200130, 200131*, 200132*, 200133*, 200135*, 200137*, 150110*, 150111*
Mixed municipal waste (MMW)	200301
Biodegradable municipal wastes (BMW)	150101, 200101, 200108, 200110, 200111, 200138, 200201, 200301, 200302, 200303, 200307
Collected separated paper (Paper)	150101, 200101
Collected separated plastics (Plastics)	150102, 200139
Collected separated glass (Glass)	150107, 200102
Collected separated metal (Metal)	150104, 150111*, 200140
Bulk waste (Bulk)	200307
Packaging waste other (PWO)	150101, 150102, 150103, 150104, 150105, 150106, 150107, 150109,
Wastes from electrical and electronic equipment (WEEE)	200123*, 200135*, 200136, 200121*
Wastes from batteries and accumulators	200133*, 200134
Sludges from treatment of urban waste water	190805

Processing historical annual waste stream generation and treatment reports

The environmental legislation of the Czech Republic requires municipalities (i.e. environmental reporters) to provide *public administrations* (PAs) on a regional level with annual data and information on their MSW activities (waste reports). They add them them to the ISPOP - *Integrated System of Reporting* [7] operated by the Ministry of the Environment (MoE) according to the Czech waste legislation laid down in the prescribed annual standards [8].

The MoE's ISOH - *Waste management information system* [9] is a comprehensive environmental information system built according to the principles of service-oriented architecture (SOA). ISOH contains data on waste generation and treatment by generators and data on facilities for the treatment, recovery, and disposal of waste. It records more than 70,000 different generator's reports every year for all 6,500 municipalities of the Czech Republic, as well as more than 3,000 reports from facilities. The annual ISOH database contains more than 50,000 municipal waste generation records and 10,000 records concerning waste treatment [10]. We had access to these databases from the period 2009-2014 and the calculated waste streams from Table 1 for these years.

The following Table 2 and Table 3 show the amount of municipal solid waste generated in municipalities in tonnes and also in kilograms per capita during the period from 2009 – 2014.

Table 2 Generation of chosen MW streams from 2009 – 2014 in the Czech Republic. Source: The authors, according to ISOH [9]

Waste stream [tonnes]*year*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
MW total	5,728,292	5,688,095	5,574,194	5,303,801	5,323,382	5,523,641
MWO	5,715,317	5,678,664	5,565,109	5,293,582	5,312,898	5,513,419
MWH	12,975	9,43	9,084	10,219	10,484	10,221
MMW	3,236,263	3,090,805	3,015,468	2,889,040	2,822,834	2,911,765
BMW – MMW – Bulk	1,098,024	1,194,066	1,251,678	1,221,992	1,285,674	1,433,115
Paper	731,884	786,470	833,226	795,008	808,572	836,679
Plastics	208,731	226,643	222,045	220,761	225,349	242,280
Glass	206,420	223,184	180,814	157,728	154,619	154,702
Metal	67,503	78,848	69,087	60,298	63,368	61,728
Bulk	506,482	486,444	478,607	448,675	432,797	431,625
PWO total	933,627	1,003,542	989,095	913,293	906,795	944,185
WEEE	10,222	6,923	6,083	6,189	7,911	5,123
Sludges	168,866	162,723	163,739	162,039	154,627	161,278
CDW	16,295,728	16,753,890	15,532,864	15,385,084	16,297,051	17,477,568

Table 3 Generation of chosen MW streams per capita in the Czech Republic from 2009 – 2014. Source: The authors, according to ISOH [9]

Waste stream [kg/capita]*year*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
MW total	545.99	540.83	531.04	504.68	506.47	524.82
MWO	544.76	539.94	530.18	503.71	505.47	523.85
MWH	1.24	0.09	0.87	0.97	1.00	0.97
MMW	308.47	293.88	287.28	274.90	268.57	276.66
BMW – MMW – Bulk	104.66	113.53	119.26	116.28	122.32	136.17
Paper	69.76	74.80	79.38	75.65	76.93	79.50
Plastics	19.90	21.55	21.15	21.01	21.44	23.02
Glass	19.70	21.22	17.23	15.01	14.71	14.70
Metal	6.43	7.50	6.58	5.74	6.03	5.87
Bulk	48.28	46.25	45.60	42.69	41.18	41.01
PWO total	88.99	95.42	94.23	86.90	86.27	89.71
WEEE	0.97	0.66	0.58	0.59	0.75	0.49
Sludges	16.10	15.47	15.60	15.42	14.71	15.32
CDW	1,553.23	1,592.99	1,479.79	1,463.95	1550.52	1,660.61

We can see that the average total generated amount of MW was 5,523 million tonnes and 525.64 kg per capita in the period from 2009-2014.
The following Table 4 shows basic types of waste treatment with the total MW amount in tonnes and percentages for 2009-2014.

We can see that 48% of generated MW was landfilled, 35 % underwent material recycling and 12% were sent for energy recovery in 2014. At the current level of around 5.5 million tonnes of MW generated per year, there is still large amount of room to increase the capacity of facilities for MW material recycling and energy recovery, and to focus on the transition of municipalities to the CE.

Table 4 Basic treatment of MW: totals for 2009 – 2014 in the Czech Republic. Source: The authors, according to ISOH [9]

Treatment \year		*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Material recycling	[tonnes]	1,206,436	1,302,476	1,661,703	1,576,519	1,561,729	1,849,864
	[%]	22.7	24.3	30.8	30.4	30.2	34.7
Energy recovery	[tonnes]	319,284	475,576	583,614	610,367	614,502	627,234
	[%]	6.0	8.9	10.8	11.8	11.9	11.8
Disposal in landfills	[tonnes]	3,409,772	3,188,722	2,982,745	2,785,555	2,698,737	2,569,965
	[%]	64.0	59.5	55.4	53.6	52.2	48.3
Disposal via incineration	[tonnes]	2,057	2,333	2,246	2,109	2,837	3,949
	[%]	0.04	0.04	0.04	0.04	0.05	0.07

There is huge potential for achieving circularity in municipalities through reducing the disposal of MMW via landfilling and increasing its sorting in order to gain separated material components of MW streams (paper, plastics, glass, metal, etc.); see Table 5. This approach must be taken because MMW energy recovery facilities are only available in the cities Prague, Brno and Liberec.

Table 5 Basic treatment (energy recovery and landfilling) of MMW for 2009 – 2014 in the Czech Republic. Source: The authors, according to ISOH [9]

Treatment \year		*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Energy recovery	[tonnes]	292,229	436,197	541,286	572,605	580,383	583,053
	[%]	9.0	14.1	18.0	19.8	20.6	20.0
Disposal in landfills	[tonnes]	2,755,477	2,577,277	2,418,431	2,285,662	2,200,784	2,132,085
	[%]	85.1	83.4	80.2	79.1	78.0	73.2

We can see that 73% of generated MMW was landfilled and 20% was disposed of via energy recovery in 2014. These numbers show the large potential for sorting MMW at the household level or at the new generation of MBT (mechanical biological treatment) facilities.
Let us take a look at the development of the material recycling of chosen MW streams (paper, plastics, glass, metals) from 2009 – 2014 in the Czech Republic (Table 6).

Table 6 Material recycling of MW streams (paper, plastics, glass, metals) for 2009 – 2014 in the Czech Republic. Source: The authors, according to ISOH [9]

Material recycling	*year*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Paper	[tonnes]	317,034	330,507	339,056	326,121	349,568	363,906
	[%]	43.3	42.0	40.7	41.0	43.2	43.5
Plastics	[tonnes]	109,595	113,161	119,433	123,206	128,324	127,338
	[%]	52.5	49.9	53.8	55.8	56.9	52.6
Glass	[tonnes]	133,902	128,886	139,193	157,246	148,331	135,697
	[%]	64.9	57.7	77.0	99.7	95.9	87.7
Metals	[tonnes]	23,663	31,826	34,850	37,576	35,022	38,583
	[%]	35.1	40.4	50.4	62.3	55.3	62.5

We can see that the material recycling of paper (43%) and plastics (52%) from households has remained practically stable, while the proportion of glass and metal recycling is increasing. This is also an area with large potencial for movement towards the CE via the installation of recycling facilities.

The basic treatment of packaging waste is shown in Table 7. We can see a continuously increasing proportion of material recycling for the PWO type of MW; however, improvements can still be made in progress towards the CE by municipalites via the reduction of landfilling.

Table 7 Basic treatment of PWO for 2009 – 2014 in the Czech Republic. Source: The authors, according to ISOH [9]

Treatment \year		*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Material recycling	[tonnes]	615,614	646,014	659,175	672,538	703,357	744,280
	[%]	68.8	70.0	69.7	69.9	69.9	73.0
Energy recovery	[tonnes]	62,556	73,068	52,049	35,888	48,272	56,927
	[%]	7.0	7.9	5.5	3.7	4.8	5.6
Disposal in landfills	[tonnes]	216,183	203,644	234,092	253,919	254,120	218,598
	[%]	24.2	22.1	24.8	26.4	25.3	21.4

Table 8 displays data for the BMW type of MW stream - we do not include the MMW and Bulk streams in the BMW stream.

Table 8 Basic treatment of BMW without MMW and Bulk waste for 2009 – 2014 in the Czech Republic. Source: The authors, according to ISOH [9]

Treatment \year		*2009*	*2010*	*2011*	*2012*	*2013*	*2014*
Energy recovery	[tonnes]	23,916	29,627	30,638	29,729	20,981	30,083
	[%]	2.18	2.48	2.45	2.43	1.63	2.10
Disposal in landfills	[tonnes]	66,917	59,083	52,327	41,524	40,588	44,833
	[%]	6.09	4.95	4.18	3.40	3.16	3.13
Composting	[tonnes]	119,413	136,347	151,416	149,354	199,747	297,165
	[%]	10.88	11.42	12.10	12.22	15.54	20.74

We can see from Table 2 and 8 that over 1.2 million tonnes of BMW (not including MMW and Bulk waste) was generated between 2009-2014. However, only a small percentage of this was disposed of via energy recovery, or landfilled. The most commonly used waste disposal technique was composting, and composted BMW continuously increased during 2009-2014.

We will not present the treatment data for all MW streams from Table 1, as that would exceed the scope of this article.

The current state of several sources of national, regional and municipal environmental, socio-demographic, economic, financial data needed for CE analyses based on eGovernment implementation in the Czech Republic was presented by Soukopová et al. [10]. The related linked open data for CE analyses is often even available on PA web sites, such as those operated by the MoE, CENIA, the Ministry of Finance, the Ministry of Regional Development, and the Czech Statistical Office.

Construction of driving forces for municipal waste streams

The basic *driving force* of all MW streams is *population*. The development of the population, together with the relocation of residents with higher purchasing power to cities and agglomerations, also reduces the waste treatment options open to it (e.g. composting) and creates demand for the faster replacement of goods, which affects *household consumption*. The number of *pensioners* and the level of *unemployment* are also driving forces for the amounts of material involved in all MW streams, as families with small children, as well as some students, pensioners and the unemployed, tend to remain near their residence throughout the day where their activities generate waste (Hrebicek et al. [11]).
Our newest finding [12] was that demographic characteristics represent significant determinants that can influence waste generation. Results obtained by Soukopová and al. [12] show a trend of gradually rising municipal solid waste management expenditure per capita with increasing age up to the 60-64 age group, where the expenditure reaches what is by far its maximum value. Based on this finding we propose that understanding the interdependencies between socio-demographic variables and the decisions made by householders regarding the production and management of waste can help

municipal representatives to affect and manage municipal waste management expenditure and influence certain groups of inhabitants in relation to the prevention of waste creation, or the sorting of waste.
Workers and children in kindergartens and schools and some students carry out their daily activities at their place of employment or school, where they generate MW, etc. A major driving force behind this MSW production is also *consumer behaviour*, including packaging methods, which are driven by consumer demand and legal regulations, e.g. hygiene and health protection requirements [11]. The generation of all MW streams is also driven by *municipal expenditure* and the waste disposal fee paid by citizens. We are able to download data concerning these driving forces from sources of linked open government data for the Czech Republic [10].
Municipal expenditure and citizen's waste disposal fees are other driving forces for all MW streams that may motivate residents to produce less waste, especially in smaller communities where the fee is determined directly by the owner of the house when they purchase a garbage collection container. In larger settlements, this effect is suppressed due to the greater numbers of residents using a single collection site. Fundamental pressure can be applied on waste generators through the way the collection systems for all MW streams are set up. When they are set up effectively, it can motivate residents to minimize their generation of all MW streams and achieve lower MW stream treatment costs. MW treatment and disposal places pressure on natural resources. The availability of collection centers or waste assembly points reduces the amount of illegal waste dumps and lowers necessary removal costs

Identifying the purpose to governmental intervention

The EU Action Plan for the Circular Economy [1-2] has provided revised legislative proposals regarding waste and set clear targets for the reduction of municipal waste. It has established an ambitious and credible long-term path for MWM and recycling. Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of total MW by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of MW by 2030;
- A ban on the landfilling of separately collected waste;
- Promotion of economic instruments that discourage landfilling;
- Simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;
- Specific measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;
- Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

We have a look at the above key elements of the CE from the view of the MWM strategy of the Czech Republic. The basic tools of governmental intervention are the *Waste management plan of the Czech Republic for the period 2015 - 2024* (WMP CZ) [14], a prepared update for Act No. 185/2001 Coll., on waste, (the "Waste Act"), a prepared law on selected end-of-life products which amends related laws (the "Act on selected products with expired service life"), and Act No. 477/2001 Coll., on packaging (the "Act on packaging"). These laws will influence the road map of MWM towards the CE.

Discussion and results

The MWM strategy of the Czech Republic for the next ten-year period is reflected in the government document *Waste management plan of the Czech Republic for the period 2015 - 2024* (WMP CZ) [14]. The WMP CZ acts in accordance with the principles of sustainable development to establish objectives, policies, and measures for waste management in the Czech Republic, and reflects the EU Action Plan for the Circular Economy.
The WMP CZ is the reference document for the mandatory development of *Regional waste management plans* (RWMP) for all regions of the Czech Republic and *Municipal waste management plans* (MWMP) mandatory for all municipalities of the Czech Republic which generate more than 1000 tonnes of other waste or 10 tonnes of hazardous waste. The binding part of the WMP CZ constitutes the mandatory basis for the decision-making and other activities of the relevant administrative authorities, RWMPs, and MWMPs in the area of waste management for the period 2015 - 2024. Each WMP (national, regional and local) will be changed immediately following any fundamental change in the conditions under which it has been drawn up (e.g. new legislation on waste management, which will

fundamentally affect the waste management strategy, including the establishment of new objectives or the redefinition of existing objectives, policies, and measures).
We will now present the MWMP in more detail.

A basic tool for Circular Economy implementation: The Municipal Waste Management Plan for the period 2016 - 2024

The MWMP is the basic municipal government tool supporting the road map to the CE in municipalities in the Czech Republic. It consists of analytical, binding and directive parts.
The *analytical part* of the MWMP contains an evaluation of the status of MWM, which includes:

a) the area of the prevention of MW streams;
b) the assessment of generated MW streams and their resources;
c) the evaluation of existing municipal collection systems and MWM in the given municipality at least for total MW, MWO, MWH, MMW, BMW, paper, plastic, glass, metals, and packaging waste, and their compliance with the mandatory parts of the RWMP;
d) an assessment of the necessary amendments and additions to the municipal system of MW and MWM collection.

The *binding part* of the MWMP contains measures for waste prevention in accordance with the RWMP and lays down objectives and the means of achieving them within the framework of the MWM and the system of indicators for the evaluation of the fulfilment of the objectives of the MWMP for:

a) the management of MW streams (total MW, MWO, MWH, MMW, BMW, PWO, etc.);
b) CDW, if the MWM includes the management of construction waste;
c) the management of end-of-life products in the case that the municipality operates collection sites for these products within the framework of cooperation with required persons;
d) preparation of the reuse, recycling, recovery and disposal of MW streams to minimize their negative impact on the environment;
e) reducing the amount of waste going to landfill, in particular BMW;
f) reducing the biodegradable components in MMW.

The *directive part* of MWMP contains:

a) proposals for improving the MWM system;
b) criteria for the evaluation of changes to the conditions under which the MWMP was prepared.

Objectives of MWMP
In order to meet the objectives of the WMP CZ, every MWMP should meet the following defined objectives and targets:

a) Keep at least the collection of MW consisting of paper, plastics, glass and metals separate.
b) By the year 2020, increase the amount of waste that is prepared for reuse and recycling to at least 50% by weight, at least in the case of MW that consists of materials such as paper, plastic, metal, and glass originating from households, and possibly wastes of other origin, if such waste streams are similar to waste from households.
c) Use MMW (after the sorting of materially recoverable components, hazardous substances and biodegradable waste) especially for energy recovery in facilities designed for this purpose in accordance with effective legislation.
d) Reduce the maximum quantity of BMW deposited at landfills in such a way that the share of this component in the year 2020 will be a maximum of 35% by weight of the total quantity of biodegradable municipal waste produced in 1995.

For target b) the establishment of intermediate values has been proposed for the specified years 2016, 2018 and 2020 to reach 46%, 48% and 50%, respectively, in every municipality of the Czech Republic.

The *basic MWMP principles* of CE implementation for municipalities are the following:

a) Maintain, support and develop an independent collection system for each separate MW stream (paper, plastic, glass, metal, drink cartons) with respect to the targets set for each material, due to the higher quality of the waste streams collected in this manner.
b) Maintain and develop the availability of separate collection systems for recoverable waste in municipalities.
c) Ensure (establish) the obligatory separate (sorted) collection of recoverable components of MW streams (at least of paper, plastics, glass, and metals) in municipalities.
d) The system of collecting MW streams in the community is established by each municipality with regard to their requirements and the availability of technical waste processing. The collection system is established by the municipality under independent competence by a generally binding regulation.

e) The scope and method of the separate collection of components of MW streams in the community is defined by the municipality with regard to technical, environmental, economic, and regional possibilities, and the existing conditions for the further processing of waste; the arrangements for separate collection must be sufficient to ensure the objectives of the MWMP for municipal waste are met.
f) Reduce the production of MMW via the introduction or extension of separate collection systems for recoverable components of municipal waste, including biodegradable waste.
g) Prioritize environmentally beneficial, economically and socially sustainable MW stream treatment technologies.
h) Establish a mandatory system for the separate collection of BMW and its waste management, at least for biodegradable waste of plant origin within communities.
i) Before changing the system of collection and MWM, always perform a thorough analysis that includes environmental, economic, and social aspects, and subject it to a comprehensive discussion involving all parties concerned.
j) The processing of MMW by sorting may be supported as a complementary waste processing technique prior to material and energy recovery. This processing does not replace the separate collection of recoverable components of MW streams.

The following *measures for the implementation of CE* by municipalities exist:
a) Enact the obligation and conditions of the separate collection of MW streams in municipalities.
b) Consistently monitor how the separate collection of recoverable components of MW streams functions, at least for paper, plastics, glass, and metals.
c) Consistently monitor compliance with the hierarchy of waste management.
d) Continuously evaluate MWM and its performance, and propose measures for its improvement.
e) Classify sorted MW streams which are collected separately in municipalities.
f) At the community level, annually inform citizens and other participants in MWM regarding the manner and extent of the separate collection of municipal waste, the recovery and disposal of MW streams, and the waste management of other waste in the municipal system. This should also include information about how to prevent and minimize the generation of MW streams. The quantified results of MWM are to be published at least once a year.

Transition municipalities to the Circular Economy

If we investigate the challenges posed by the transition municipalilitie to the CE we have to consider the current and past attributes and structure of MW streams generated by households in municipalities in the Czech Republic, where:

- 73% of MMW was disposed of in landfills in 2014 (Table 5);
- 48% of all MW was landfilled in 2014 (Table 4);
- more than 30% of MMW consist of recyclable components [15];
- more than 30% of BW is in MMW [15];
- the motivation of people to sort MW and MMW is limited [16];
- the collection of recyclable waste is of low efficiency from the perspective of the income of the municipality [17];
- collection, sorting, material recycling and energy recovery technologies suffer from low availability and efficiency;
- MMW is stored in landfills without further treatment.

The road map to the CE for municipalities in the Czech Republic must issue from the MWMP for the period 2016-2024 and deal with the following issues:

- Reducing the amount of MMW and the treatment of residual MMW;
- Increasing the amount of sorted secondary raw materials from MMW;
- BW sorting of MMW;
- Improving the separate collection of paper, plastics, glass and metals;
- Motivation of people to reduce the amount of MMW, maintain addressable records of waste production and follow the ideas of sustainable production and consumption;
- A conception for technology and logistics in the region – cooperation between regions;
- Increasing revenue for municipalities for graded secondary materials.

Figure 1 shows a prototype of an appropriate MWM system where CE ideas are accepted. It shows basic MW streams and their management. On the left hand side of Figure 1 are the main MW streams

(MMW, Bulk, BW, MWO, MWH, wood and secondary materials – SECMAT, i.e. metals, glasses, plastics, papers, etc.). The arrows show the material flows of components of WM streams to appropriate innovative technologies fulfilling BREF documents (A mechanical biological treatment facility (MBT), an Energy Recovery facility, which supplies heat and electrical energy from waste, a composting or anaerobic digestion facility, and a landfill for the disposal of the unusable part of MW). We suppose that usable MWO, wood and SECAM will go to a sorting facility and, after sorting, will move on to material recovery, thus closing the CE cycle.

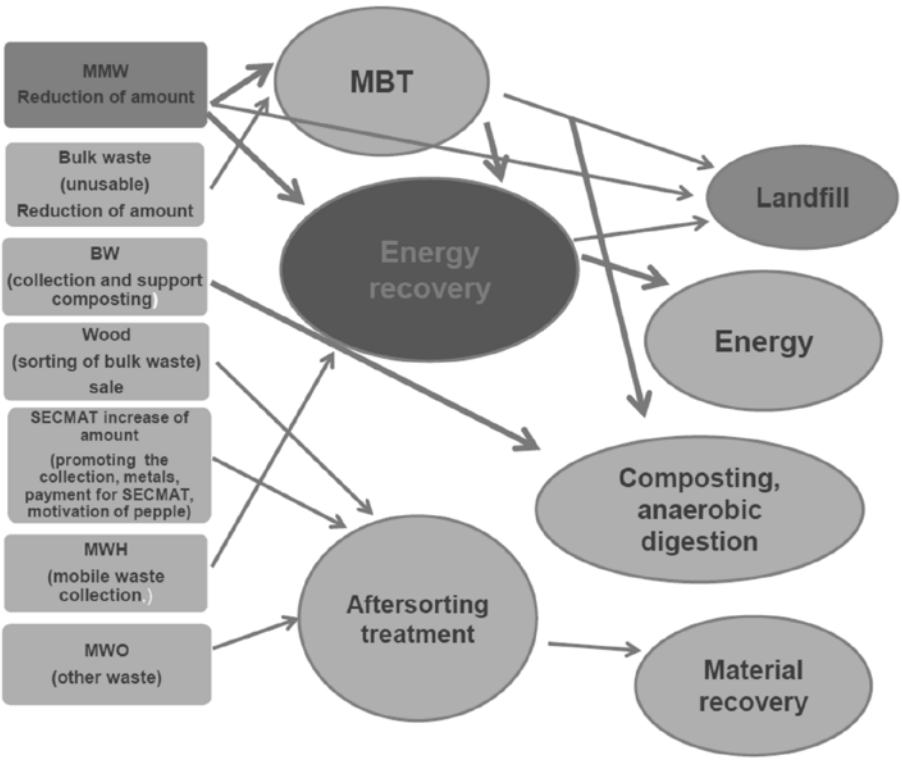

Figure 1 Prototype of an appropriate MWM system incorporating CE ideas for municipalities. Source: Authors

The basic MWMP principles a) - h) for the implementation of the CE for municipalities will enable them to choose economic efficient collection systems for MW streams. Soukopová and Ficek [18] have shown that the most powerful factors that influence the selection of waste collection companies in municipalities in the Czech Republic are the price and the quality of services. The level of significance of individual factors is directly proportional to the strength of the competitive environment. Figure 2 shows the basic principles by which a waste collection company may support the transition municipalities to the CE.

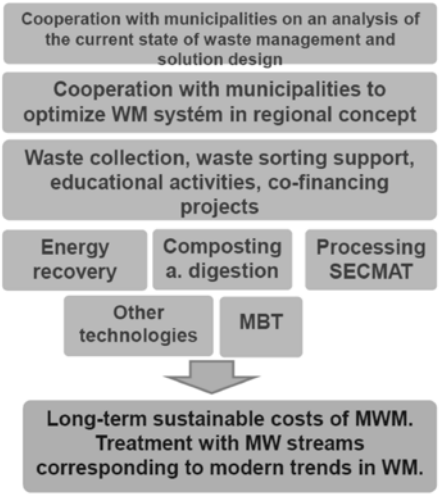

Figure 2 Cooperation with municipalities to optimise their WM systems according to the regional conception. Source: Authors

Conclusion

The Circular Economy will move the world towards the sustainable use of natural resources, and in some cases exceeds planetary boundaries, see Steffen et al. [19]. Similarly, the Circular Economy makes the best use of MW streams and resources, which is a high priority for Czech local municipal authorities as key delivery agents for municipal waste collection, reuse, recycling and disposal services. In essence, the combination of the CE with the use of MWMP and Smart Cities and Communities (EIP-SCC) ideas [5] represents a fundamental alternative to the take-make-consume-dispose economic model that currently predominates. The presented model of a road map to the CE for municipalities in the Czech Republic is based on the assumption that resources in MW streams are available, abundant, easy to access and cheap to recycle, but it is not sustainable without changing MWM in every municipality of the Czech Republic.

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