Decision support tools in the waste management field.

Conceptual modeling of mixed municipal waste generation and treatment in the Czech Republic

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Introduction

Terminology:

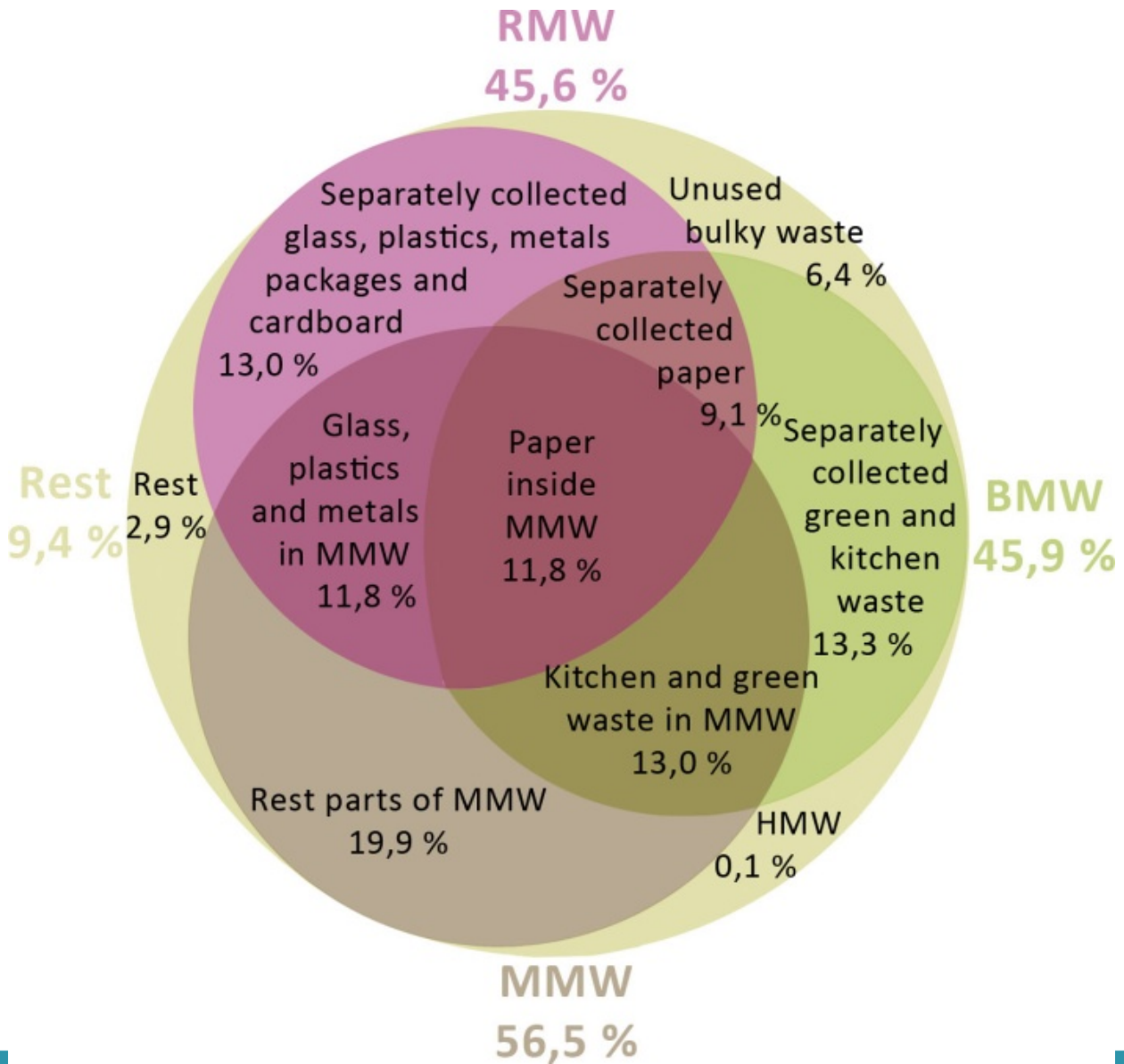
Municipal solid waste (MSW): the waste, generated in municipalities (prevalently in households)

Group 20 and subgroup 1510 in European waste catalogue

Let us consider waste streams in MSW:

- **Biodegradable waste (BMW): remains of food and vegetables;**
- **Recyclable waste (RMW): paper, plastic, glass and metal containers, printed matter (newspapers, magazines, books etc.);**
- **Mixed municipal waste (MMW): household waste, i.e. destroyed products, ashes and rubbish, used or unwanted consumer goods, including shoes and clothing;**
- **Hazardous municipal wate: hazardous parts of MSW;**
- **Rest of waste which does not belong to BMW, RMW and MMW.**

Composition of MSW (100%) in the Czech Republic in 2012



Forecasting MSW generation in the Czech Republic [Mt] for 2015-2024

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
MSW	5,44	5,43	5,39	5,38	5,36	5,34	5,33	5,31	5,30	5,30
citizens	3,97	3,97	3,94	3,94	3,94	3,94	3,94	3,93	3,93	3,94
businesses	1,47	1,46	1,45	1,44	1,42	1,40	1,39	1,38	1,37	1,36

Development of forecasting models

Model M1 using multiple linear regression and nonlinear system of equations (2012 – 2014)

- Hřebíček, J., Kalina, J., & Soukopová, J. (2013) Developing forecasts of waste production and waste treatment in the Czech Republic in the period 2014-2024. Part1., Part 2. Masaryk University, Brno
- Kalina, J., Hřebíček, J., & Bulková, G. (2014) Case study: Prognostic model of Czech municipal waste production and treatment. iEMSS 2014

Model M2 – new approach with using non linear programming approach (2014 – 2015) based on

- Pires, A., Martinho, G., & Chang, N. (2011) Solid waste management in European countries: A review of system analysis techniques. Journal of Environmental Management, 92, 1033-1050

Model of waste treatment construction

Five principal waste streams (total MSW, MMW, BMW, RMW and hazardous substances in USW) from model of waste generation were considered. Waste streams are not distinct sets and their intersections change their sizes (see Fig. 1).

Therefore, **8 distinct waste sub-streams** were defined in the model of MSW treatment to enter the computation and entirely describe all the waste streams of interest:

1. Amount ***rmw*** of separated recyclable waste except paper (plastics, glass, metals etc.) in USW;
2. Amount ***bmw*** of separated BMW except for paper;
3. Amount ***brmw*** of separated paper and wood;
4. Amount ***bmmw*** of kitchen and garden waste in MMW;
5. Amount ***mrmw*** of recyclable wastes in MMW except for paper;
6. Amount ***bmrmw*** of paper in MMW;
7. Amount ***mmw*** of non-usable part of MMW (ashes, particulated matter, composites etc.);
8. Amount ***rest*** of the rest USW (bulky waste, some hazardous parts, electro waste, … etc.).

Comparison of two models based on different mathematical principles

Model 1

- introduced in 2013, based on a solution of an equation set (75 nonlinear equations for each year in the period 2015–2024) by Maple;
- the solution was fully determined;
- several estimates and uncertainties were made to fill all the gaps of our knowledge on the waste management system.

Model 2

- developed as an innovation of M1, strengthening its weaknesses;
- instead of 75 equations, M2 works with 58 equations and inequalities covering the issue of waste management;
- to find an optimal solution a method of non-linear programming (NLP) system of Maple was used.

Types of equations and inequalities to solve

1. Equations describing the logical structure of municipal waste management

Involves all relations of the mentioned 8 waste subflows and their 4 sums, which are apparent directly from the structure of the set.

$$msw = rmw + bmw + mmw - brmw - bmmw - mrmw + bmrmw + rest$$

$$bmw = bmw0 + brmw + bmmw - bmrmw$$

$$mmw = mmw0 + mrmw + brmw - bmrmw$$

$$rmw = rmw0 + bmrw + mrmw - bmrmw$$

Types of equations and inequalities to solve

2. Equations arising from technical and legislation demands

These inequalities describe minimal EU legislation and technical conditions: the demanded diverse of biowaste from landfills in 2020, 50% material recovery rate in the same year and the total expected capacity of necessary waste facilities.

Types of equations and inequalities to solve

Planned energy recovery plants

Table 1: Expected waste to energy facilities in the Czech Republic to be built between 2015 and 2024		
Locality	**Planned capacity [t/year]**	**Expected start of operation**
Plzeň Chotíkov	95 000	2015
Jihlava	150 000	2019
Přerov	150 000	2020
Most Komořany	150 000	2021
České Budějovice	100 000	2021
Brno (extension of operated WtE)	100 000	2021
KIC in Moravian-Silesian region	192 000	2023

Types of equations and inequalities to solve

3. Equations describing properties of individual waste flows

- **MMW** flow not materially recovered nor composted;
- **BMW**, not in **MMW** nor RMW, not burned or recovered;
- **RMW** flow not composted in any subflows (incl. paper);
- fraction of polluted (unusable) **RMW** will decrease from present 8% to final 2.6% in 2024;
- fraction of materially recovered **RMW** which is not in **MMW** or **BMW** will exceed 85% in 2024;
- fraction of materially recovered paper will reach 98%;
- amount of materially recovered **MSW**, which is not in **RMW** flow will remain constant (ca. 550,000 t/year);

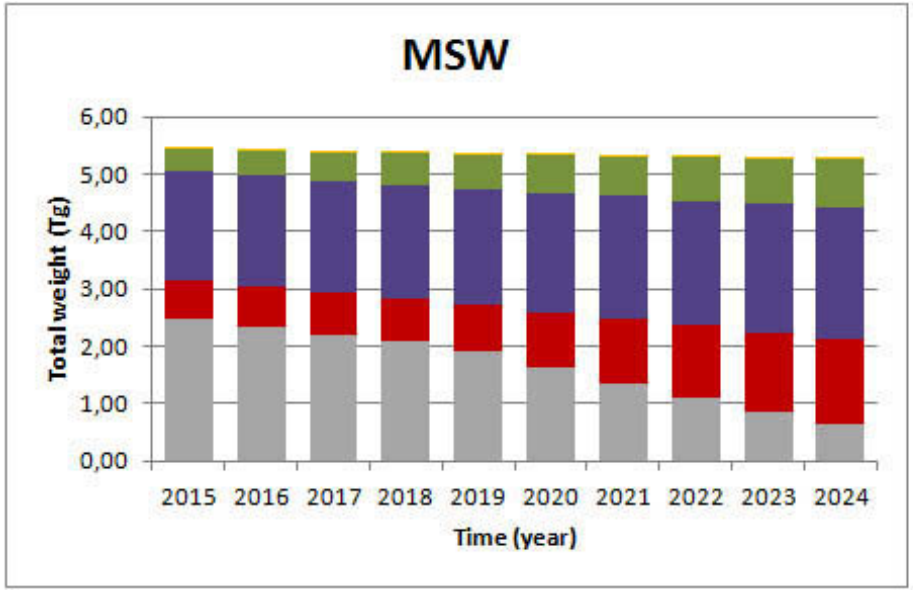
Non-linear programming optimization

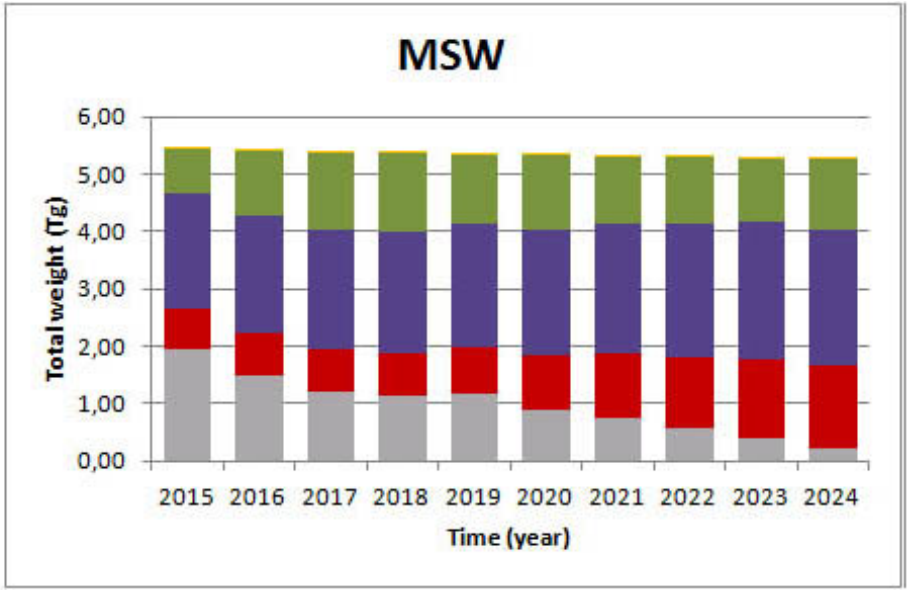
- NLP method was used to solve the set of 58 fundamental equations and inequalities;
- 15 equations were omitted compared to M1 (is not necessary to obtain the fully determined set);
- NLP in waste management material flow models was never used in the Czech Republic.

The optimization involves computing a minimum (or maximum) of a real-valued objective function, possibly subject to constraints.

Objective function was considered as amount of landfiled BMW in 2020.

Forecasting of waste streams treatment by model M1 and model M2



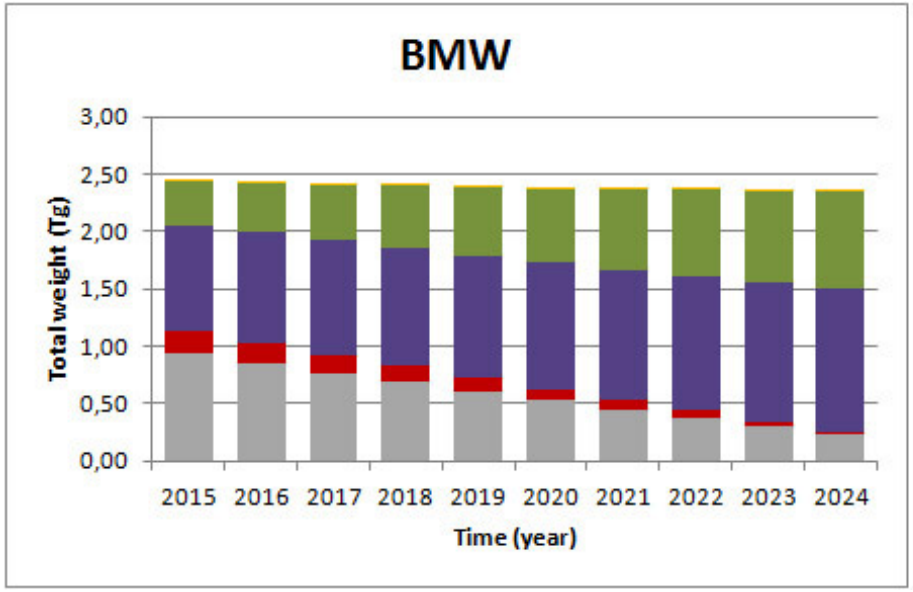


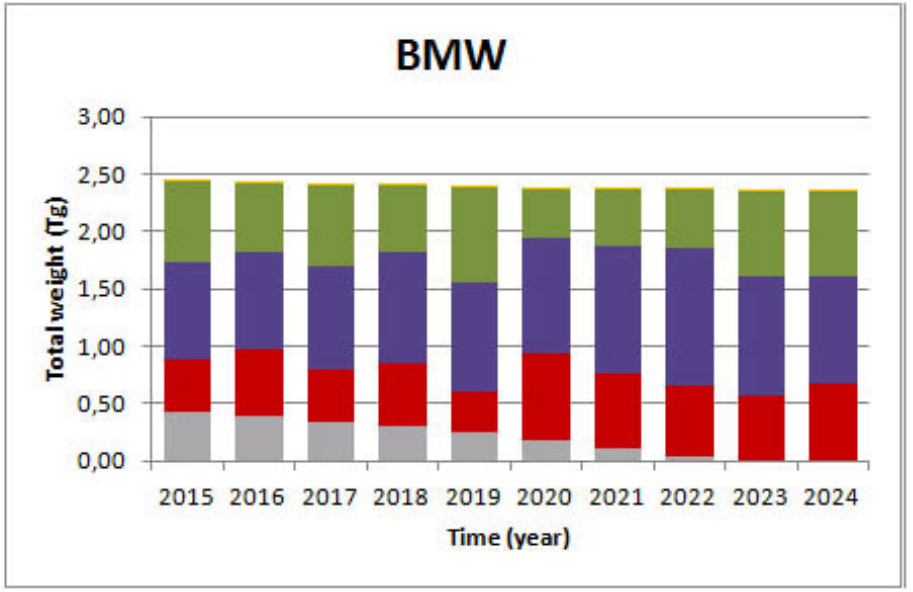
Municipal solid waste (complete flow)

- greater emphasis on composting,
- approx. equal material recovery,
- completely equal combustion,
- faster decline of landfilling.

combustion
composting and AD
material recovery
energy recovery
landfilling

Forecasting of waste streams treatment by model M1 and model M2



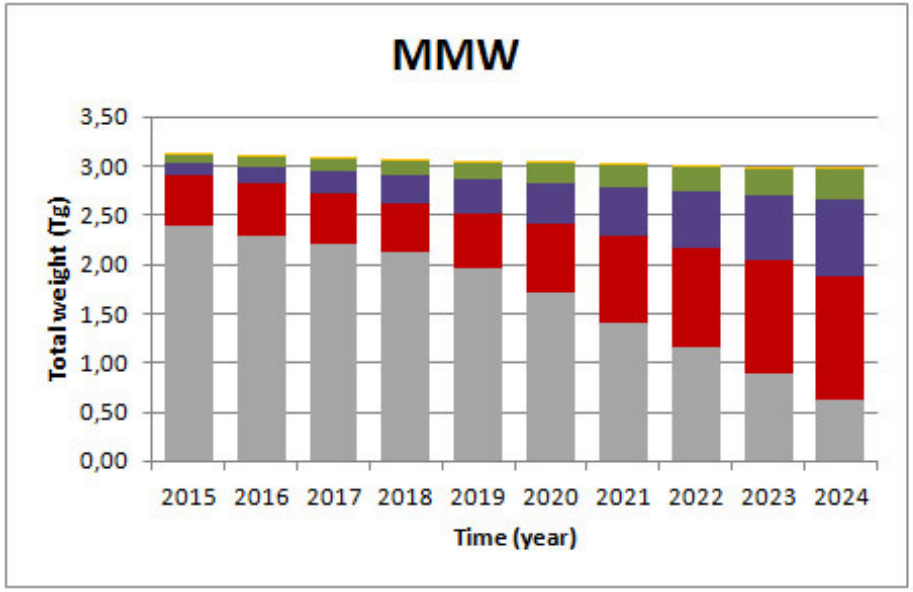


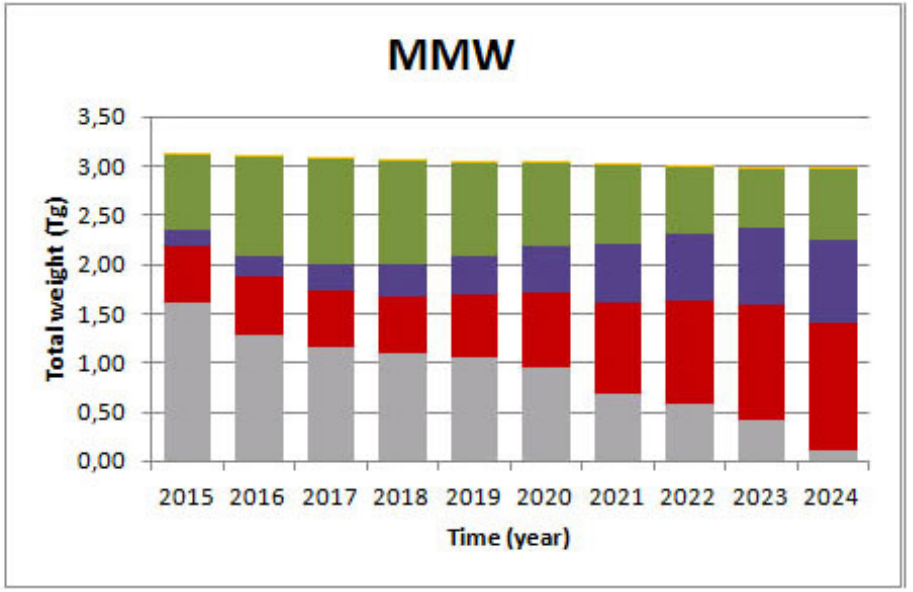
Biodegradable municipal waste flow

- more influenced by a capacity of energy recovery plants,
- approx. equal composting,
- faster decline of landfilling,
- very intense energy recovery (unseparated part of MMW, wood, paper).

combustion
composting and AD
material recovery
energy recovery
landfilling

Forecasting of waste streams treatment by model M1 and model M2





Mixed municipal waste flow (including separated part)

- focus on fast diversion of BMW part to composting,
- approx. equal material recovery,
- completely equal combustion,
- faster decline of landfilling.

combustion
composting and AD
material recovery
energy recovery
landfilling

Conclusions

- The model M2 using nonlinear programming (NLP) was developed and used for modelling MSW treatment forecasting (2015-2024) in the Czech Republic.
- It was implemented in the form of waste flows optimization consisting of a set of 58 (in)equalities.
- The model M2 was based on the same set of input data and assumptions on MSW future development as the past developed model M1 (Hřebíček, Kalina, Soukopová), which predicted MSW generation and treatment for the purposes of the Ministry of Environment of the Czech Republic in the national Waste Management Plan in 2014.
- The both models M1 and M2 give comparable results in the same period (2015–2024).
- New research will continue to explain differences

Thank you for your attention
Questions?

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