Matthias Kuehle-Weidemeier (ed.)

WASTE-TO-RESOURCES 2019

VIII INTERNATIONAL SYMPOSIUM MBT, MRF AND RECYCLING

Resources and Energy from Waste

Proceedings

14th -16th of May 2019

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Ingenieurgesellschaft Prof. Czurda and Partner mbH is an independent and internationally recognized Engineering Consultancy based in Karlsruhe, Germany. ICP was founded in 1990 by Prof. Dr. Dr. Kurt Czurda and the managing directors Dr. Thomas Egloffstein and Gerd Burkhardt. Since then has grown in size with a staff of 25 at the head office in Karlsruhe and 50 based throughout Germany. Before 1995, ICP projects were predominately based in Germany, later ICP became increasingly engaged in international projects.

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- Preparation of solid waste plans, strategies, concepts, feasibility studies and economic analysis;
- Landfill technology (design and construction supervision of new landfills or landfill phased extensions, including sludge landfills);

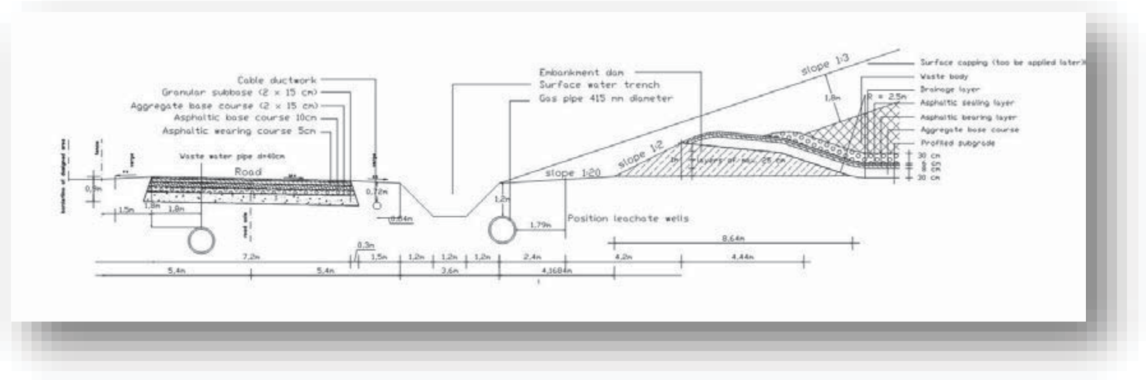
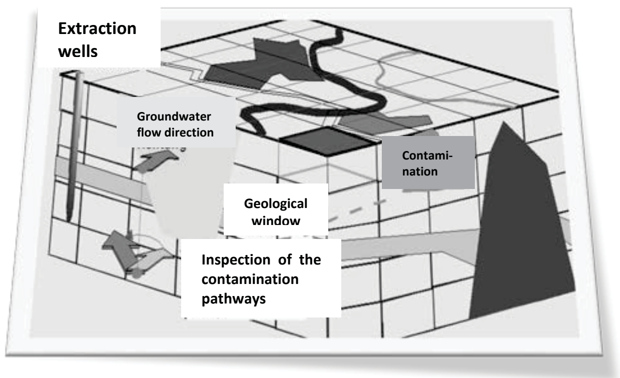


Figure 1: Example of a vertical section for a landfill in Muscat, Oman

- Landfill closure (landfill gas collection technology, leachate treatment, refurbishment of landfill drainage systems, site investigations and feasibility studies, monitoring etc.);
- Design and construction supervision of waste treatment plant (mechanical-biological pre-treatment, composting, fermentation, sorting and handling etc.); and
- Tender preparation and evaluation – technical and financial evaluation of offers submitted for solid waste management services, works and/ or supplies.

Contaminated site investigation and rehabilitation

- Contaminated site investigation (from historical records to technical sampling and ground water modelling);
- Clean up of contaminated sites (design and supervision of treatment methods such as Pump and Treat, Soil Vapor Extraction, Permeable Reactive Barrier, etc.);
- Securing of contaminated sites / stabilization of existing hazards (design and supervision of treatment measures such as surface sealing, slurry wall containment, etc.); and
- Monitoring systems.



Renewable Energies

- Waste to energy (Biogas plants and RDF production plants);
- Landfill gas utilization; and
- Solar plants.

Planning of building decommissioning and demolition

- Site investigation / Groundwater management;
- Stability of deep excavations also in densely built areas;
- Controlled demolition;
- Investigation of hazardous materials;
- Measurement of emissions and imissions; and
- Surveys of current condition / Conservation of evidence.

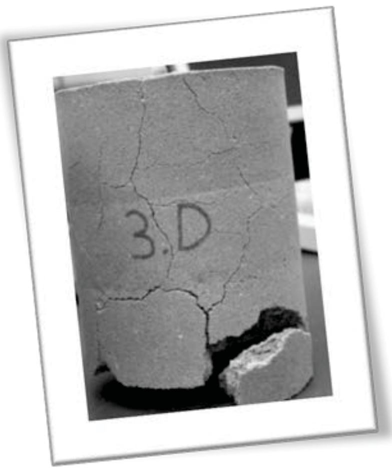
Plant and working safety

- Health and safety plans;
- Health and safety coordination;
- Work place health and safety; and
- Plant safety.

Environmental planning

- Environmental and social impact assessment;
- Risk assessment;
- Environmental expert advice; and
- Environmental damage assessment.

Geotechnical, soil mechanics and physical investigations



- Building assessment and foundation recommendations;
- Stability calculations;
- Settlement calculations;
- Execution of field tests and probing;
- Specification and supervision of boreholes;
- Disturbed and undisturbed sampling;
- Soil mechanical tests according to DIN ISO und ASTM;
- Soil physical tests according to DIN ISO und ASTM;
- Development of sealing materials from residues; and
- Testing of construction materials before being used as landfill sealing materials.

Geology und Hydrogeology

- Expert opinions;
- Ground water measurements;
- Drinking water protection areas;
- Execution of field tests and probing;
- Specification and supervision of boreholes; and
- Borehole probe, analysis and review.

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- Settlement monitoring; and
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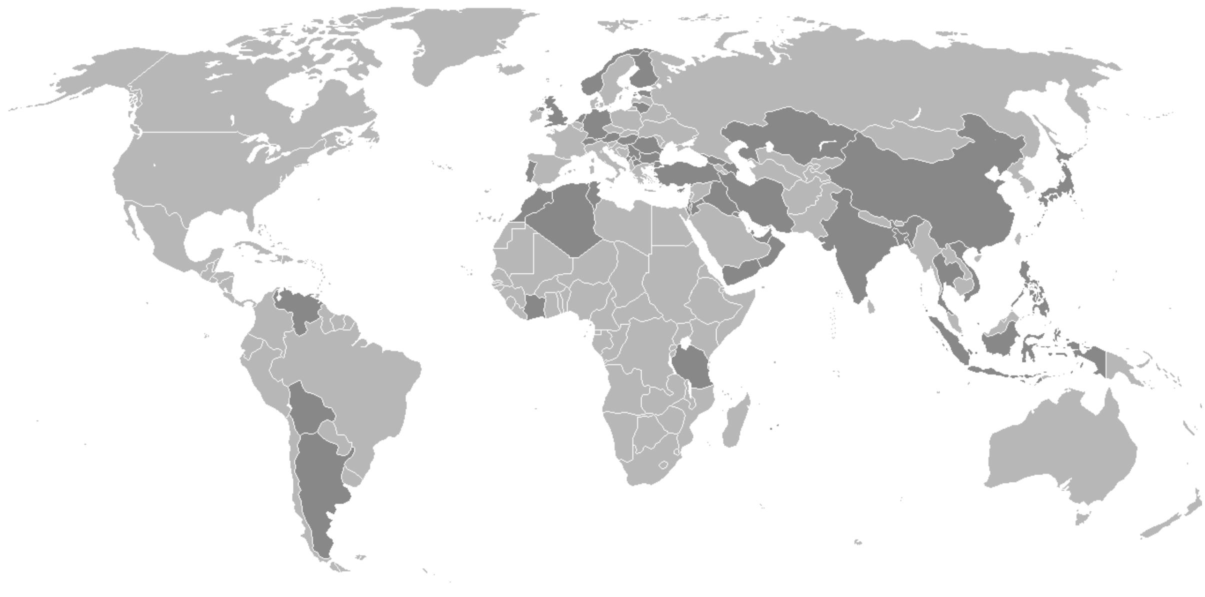

Figure 2: ICP’s experience in other countries

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Potential of waste management to achieve the recycling rates of the EU Waste Framework Directive

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Abstract

Future waste streams and corresponding recycling rates are projected by use of a forecast model for the context of Germany. The model produces a forecast for the municipal waste amount based on the past waste generation, material compositions of the waste streams, economic (growth rates) and demographic (population) developments. Each waste stream is defined by a respective material composition that allows stream modelling on the level of material categories (e.g. paper, glass, plastics, organic) in the waste stream (e.g. residual household waste) by defining growth rates for the amount of each material category. The contribution of each municipal waste stream to the new recycling targets is estimated by respective factors taken from DESTATIS data and own calculations. In the chosen baseline scenario, the new WFD recycling targets will not be achieved. For this reason, further scenarios are defined with higher collection rates of certain waste material categories in the main municipal waste streams. This follows the approach to “divert” recyclable material from such municipal waste streams that contribute low amounts to recycling according to the new WFD (e.g. residual household waste), towards those municipal waste streams that are related to high recycling contributions (e.g. separately collected paper, glass, organic). It is the objective to explicitly point out the great challenge to meet future recycling rates, to express the need of appropriate and validated data for reliable scenario definitions and to demonstrate the functionality of the model. This results into the question how to implement appropriate waste management strategies that will realize the necessary higher collection rates to reach the future recycling targets.

Keywords

WFD recycling targets, municipal waste streams, forecast model, collection rates, recycling rates, waste management strategy

1 Introduction

The European Commission has adopted changes to the Waste Framework Directive (WFD). This affects the existing reporting system in Germany and the methodology for determining recycling rates for municipal waste (EU, 2018).

At present, the determination of recycling rates in Germany is based on the measurement of material input into waste treatment plants. As a result of the revision of the Directive the measurement points for recycling will have to be changed in future. The Commission proposes to determine the recycled amount primarily on the basis of the input into final recycling plants or, under certain conditions, on the basis of the output of sorting plants. In addition, it is proposed to estimate recycling quantities by means of average waste specific loss rates.

The amendments to the WFD may have multiple and far-reaching consequences for the collection, processing and management of the statistical data and the legal framework. The municipal waste recycling target for 2020 remains unchanged at 50%, but will be gradually raised in the following years to 55% (2025), 60% (2030) and finally 65% (2035).

2 Modelling approach

2.1 Forecast of waste streams

2.1.1 Waste streams

For the forecast of the German recycling rates a projection of the amounts of the relevant municipal waste streams is necessary. For this purpose, the material-specific municipal waste streams are defined according to the municipal waste definition (EU, 2018) on the basis of the List-of-Waste (LoW) codes. The displayed amounts for the municipal waste streams correspond to the annual input into German waste treatment plants, reported under the respective LoW codes. This study focuses on five major municipal waste streams as material specific aggregates of the respective LoW codes:

- Residual Household & Business Waste (LoW: 20 03 01 00 - 02)
- Organic Waste (20 03 01 04, 20 02 01, 20 01 08, 20 03 02, 20 01 25)
- Paper & Cardboard Waste (15 01 01, 20 01 01)
- Mixed Packaging & Recyclables (15 01 06 00 - 02, 20 01 99 01, 15 01 05)
- Glass (20 01 02, 15 01 07)

It is important to note that the above mentioned waste streams are usually collected separately at source, directly. And so, the waste separation habits of the population have a major impact on the collection rates.

Further existing municipal waste streams are defined and modelled separately. But for reasons of readability and their quantitative importance (approx. 14% of the total municipal waste amount) they are aggregated here to one waste stream (Rest):

- Rest: bulky waste (20 30 07), wood (15 01 03, 20 01 38), plastic (15 01 02, 20 01 39), street cleaning (20 03 03), electronic equipment (20 01 23, 20 01 35, 20 01 36, 20 01 21), metal (15 01 04, 20 01 40, 15 01 11), textile (15 01 09, 20 01 10, 20 01 11), others (20 01 13-19, 20 01 26-34, 20 01 99 00, 20 03 99, 20 02 03, 15 01 10, 20 01 37, 20 01 41)

In comparison to the above mentioned major waste streams, the specific collection systems for these waste streams are usually not close to private households (except for bulky waste maybe). These collection systems are located closer to recycling centres, waste disposal companies or business actors. Waste separation habits of private consumers have less impact. It is assumed that collection rates are already high due to efficient waste separation practices in the non-private sector.

The Table 1 shows the corresponding amounts of municipal waste measured as input into German waste treatment plants with domestic origin (DESTATIS, 2011-2018). These inputs are considered as the past municipal waste potential. The future projection of these waste streams is the basis for the calculation of the respective recycling rates. Here, the latest available eight reporting years are used as period for trend analysis, and 2016 is considered as starting point for the forecast, so that 2017 will be the first forecast year.

Table 1 Reported municipal waste inputs into German waste treatment plants [Mio. t]

Waste stream / year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Res. Household & Business	17.9	18.0	18.1	17.7	17.7	17.6	17.5	17.8
Organic	9.3	9.6	9.9	10.0	9.8	10.8	11.0	11.5
Paper & Cardboard	8.1	8.0	8.1	8.1	7.6	8.0	8.1	7.8
Mix. Packaging & Recyclables	4.3	4.4	4.5	4.6	4.6	4.7	4.9	4.8
Glass	2.4	2.5	2.6	2.4	2.5	2.4	2.6	2.6
Rest	5.9	6.3	6.4	6.5	6.8	7.0	6.8	7.2
TOTAL	47.9	48.8	49.6	49.2	49.0	50.6	50.9	51.6

[DESTATIS, 2011-2018]

2.1.2 Composition of waste streams

Each projected municipal waste stream is defined by an average material composition. As validated average compositions for the domestic context are not yet available, the compositions are assumed, based on extensive experience from related projects and studies. However, the average domestic material composition will be determined as result of an on-going waste analysis of the domestic residual household waste stream. The following Table 2 shows the assumed average material compositions for the major waste streams (only on the main material level for better readability).

Table 2 Average waste stream compositions [mass %]

waste stream / material category	**Res. Household & Business Waste (stream)**	**Organic Waste (stream)**	**Paper Waste (stream)**	**Mix. Packaging/Rec. Waste (stream)**
Paper/cardboard	10.7%	0.0%	95.2%	7.4%
Glass	6.4%	0.0%	0.0%	3.2%
Plastic	7.2%	0.0%	1.9%	42.3%
Metal	2.0%	0.0%	2.9%	10.2%
Organic	47.0%	94.6%	0.0%	10.0%
Wood	1.0%	0.0%	0.0%	1.2%
Textile	3.6%	0.0%	0.0%	1.3%
Inert	2.0%	0.0%	0.0%	0.0%
Compound	6.9%	0.0%	0.0%	16.8%
Hazardous	0.5%	0.0%	0.0%	0.0%
Others	8.6%	5.4%	0.0%	0.3%
< 10 mm	4.2%	0.0%	0.0%	7.3%

[Example data from a municipality]

2.1.3 Growth rates of waste stream material categories

A further requirement for the forecast of municipal waste streams is the definition of the future development of the waste stream material categories. This is realized by definition of (constant or graded) growth rates that describe the expected change of mass per capita with reference to the previous year. In this case, constant annual growth rates are used.

Growth rates are defined on various levels. For a certain number of waste material categories, the future trends are projected based on an analysis of the net-domestic consumption, e.g. the annual net-domestic consumption of print paper per capita is associated to the generation of paper waste per capita (with certain time delay determined through average product use time). As further requirement of the forecast, the generated waste per capita at the beginning of the forecast period (2016) has to be defined. This data is obtained from the reported municipal waste amounts (Chapter 2.1.1), the waste stream compositions (Chapter 2.1.2) and the past population figures of the respective years (Chapter 2.1.4).

The Table 3 summarizes the starting values of generated waste per capita and the respective expected annual growth rates (constant) obtained from net-domestic consumption trends. These growth definitions are applied to all waste streams.

Table 3 Growth rates of waste stream material categories by analysis of net-domestic consumption

material category	Generated waste (2016) [kg per cap.]	Expected future annual growth [+/-% p.a.]
Paper packaging	28.3	2.3%
Print paper & others	91.3	-1.1%
Glass	45.2	-2.0%
Plastic packaging	27.4	2.5%
Other plastics	29.0	-1.1%
Ferrous metal packaging	6.1	-0.8%
Compound packaging	12.4	-1.0%
Electronic equipment	12.2	-1.0% *
*) modified value, based on net-domestic consumption trend		

[DESTATIS, UBA, VDP, BKV, EUROSTAT, MULTIPLE YEARS, modified]

In a similar way, per capita starting values (2016) and growth rates are defined for all the other material categories that form part of a waste stream (Chapter 2.1.2). As an example, the following growth rates are considered in the forecast:

- Ferrous metals, not packaging (+0.7% p.a.)
- Wood (+1.8% p.a.)
- Textiles (+6% p.a.)
- ...

The respective trend analysis is not based on net-domestic consumption but on the reported municipal waste amounts, the waste stream compositions and the population figures. These growth rates are applied to all municipal waste streams, apart from the

Residual Household & Business Waste. In the case of the Residual Household & Business Waste, the material category growth rates result from specific waste analyses from several years.

2.1.4 Demography

Population figures from the past and the expected population size within the forecast period are necessary in order to normalize the municipal waste amounts, and to calculate the absolute waste amounts, respectively.

The official population data from the past and a certain population forecast scenario are integrated into the model. The Table 4 shows population figures for the starting year 2016 (DESTATIS, 2018a) and for selected years from the chosen future demographic scenario ("BEV-VARIANTE-05", DESTATIS, 2018b).

Table 4 Population scenario (selected years)

Year	***2016 (start)***	***2017***	**2018**	**2020**	**2025**	**2030**	**2035**
Population [Mio.]	*82.5*	*82.8*	81.7	81.6	81.1	80.2	79.0

As a remark, it should be noted that there is a major gap of approx. 1 million persons due to the shift from the past to the future time series between the years 2017 (past) and 2018 (scenario). This circumstance will have an effect on the absolute waste amounts in form of a discontinuity around these years.

For this study it is assumed that half of the population lives in (rural) conditions that lead to typically "rural" waste compositions, while the other half lives in (urban) conditions generating typical "urban" waste. This is especially relevant in terms of organic garden and kitchen waste generation.

2.2 Waste stream specific recycling factors

In future, the overall recycling rate has to be determined based on the output of waste treatment plants, or based on the input into recycling plants (Chapter 1). The recycling targets mentioned in Chapter 1 refer to this modification of the measurement points.

In a previous (not yet published) study, waste stream specific "recycling factors" were determined for each municipal waste stream that express the relation between the reported municipal waste input into the waste treatment plants and the expected output that can be considered recycled after the complete waste treatment process. Table 5 shows first rough approximations for the average recycling factors, based on the previous study results (for reference year 2015) and used in this forecast.

Table 5 Waste stream specific recycling factors (reference year 2015)

Waste stream	Recycling factors (2015)
Res. Household & Business	5%
Organic	70%
Paper & Cardboard	95%
Mix. Packaging & Recyclables	40%
Glass	90%
Rest	35%

Such factors are used to determine the future recycling amounts of each municipal waste stream by multiplication of the forecasted municipal waste amounts with the respective factors, i.e.

Municipal Waste Stream [t] x Recycling Factor [%] ≈ Recycled Amount [t]

This means for example, that only 5% of the residual household waste is recycled, while other municipal waste streams collected separately close to households show far higher recycling factors.

The recycling factors are also employed under the assumption that they will increase in future (see Chapter 2.3.3). This can be understood in the way that the existing waste treatment plant technology and the corresponding recycling efficiency will improve during the forecast period.

2.3 Scenario definition

2.3.1 Baseline

The baseline scenario describes the situation that the municipal waste streams are projected under the constraints mentioned in the previous chapters. Upon this base, the (constant) recycling factors (Table 5) are applied in order to calculate the respective overall recycling rate, i.e. without consideration of measures that aim to raise collection rates.

2.3.2 Scenario A: Higher collection rates in collection systems close to private households

This scenario is defined by far higher collection rates of certain material categories in the main municipal waste streams than in the baseline scenario. This follows the approach to “divert” recyclable material from such municipal waste streams that contribute low amounts to recycling according to the new WFD (e.g. residual household waste), towards those municipal waste streams that are related to high recycling contributions (e.g. separately collected paper, glass, organic). Recycling factors in this scenario are the same as mentioned in Table 5 (constant over time).

For this scenario the collection rates defined in Table 6 are used. For example, the actual collection rate of paper packaging in the Paper & Cardboard Waste Stream is about 64%, i.e. this share of the total paper packaging potential in the municipal waste can be expected in this waste stream at the beginning of the forecast period (2016). It is targeted to raise the collection rates linearly to 90% in 2025 and then to 95% in 2035.

Table 6 Collection rates of Scenario A

Collection rate		**actual**	target	target
OF material category:	IN waste stream:	**2016**	2025	2035
Paper packaging	Paper & Cardboard	**64%**	90%	95%
Print paper & others	Paper & Cardboard	**80%**	90%	95%
Glass	Glass	**65%**	90%	93%
Plastic packaging	Mix. Packaging & Rec.	**53%**	70%	85%
Compound packaging	Mix. Packaging & Rec.	**49%**	50%	55%
Ferrous metal pack.	Mix. Packaging & Rec.	**62%**	80%	85%
Other ferrous metals	Mix. Packaging & Rec.	**25%**	40%	40%
Other plastics	Mix. Packaging & Rec.	**32%**	40%	45%
Garden Waste	Organic (urban collection)	**91%**	95%	95%
Kitchen Waste	Organic (urban collection)	**34%**	65%	70%
Garden Waste	Organic (rural collection)	**86%**	95%	95%
Kitchen Waste	Organic (rural collection)	**9%**	65%	70%

All collection rates are determined with the aim to divert the necessary mass for reaching the targeted collection rates from the Residual Household & Business Waste. The limited presence of the necessary material mass to be shifted is a limitation for the definition of the collection rates. In principle, the masses could be taken from other waste streams, too.

2.3.3 Scenario B: Higher recycling factors of selected waste streams and higher collection rates in collection systems close to private households

This scenario setting is similar to the one in Scenario A, with the difference that the recycling factors of selected waste streams are raised linearly over time until reaching +10% in 2035 (with reference to the starting values in 2015 mentioned in Table 5). As recycling factors of the waste streams Glass and Paper & Cardboard are already on a high level, the increase in recycling efficiency is only expected for the waste streams Residual Household & Business, Organic, Mixed Packaging & Recyclables and Rest (see Table 7).

Table 7 Expected recycling factors (2020 to 2035)

Waste stream	Recycling factors (2015)	2020	2025	2030	2035
Res. Household & Business	5%	5%	5%	5%	6%
Organic	70%	72%	74%	75%	77%
Paper & Cardboard	95%	95%	95%	95%	95%
Mix. Packaging & Recyclables	40%	41%	42%	43%	44%
Glass	90%	90%	90%	90%	90%
Rest	35%	36%	37%	38%	39%

The recycling factors are increased in order to observe the impact on the overall recycling rate if these waste streams would be recycled with higher efficiency. If recycling targets are met or even surpassed then certain collection rates could be decreased perhaps (compared to Scenario A).

3 Forecast results

3.1 Waste stream potential

As a next step, the total expected municipal waste amount is projected on the level of material categories. The forecast results for the municipal waste streams of Scenarios Baseline, A and B are given in Table 8.

Table 8 Expected municipal waste amount for Scenarios Baseline, A and B [Mio. t]

year / waste stream	2020 Base	2020 A/B	2025 Base	2025 A/B	2030 Base	2030 A/B	2035 Base	2035 A/B
Res. Household & Business	17.3	13.0	17.0	7.2	16.7	6.0	16.4	4.8
Organic	11.4	14.4	11.3	18.0	11.2	18.2	11.1	18.4
Paper & Cardboard	7.8	8.4	7.6	9.0	7.5	9.1	7.4	9.3
Mix. Packaging & Recyclables	4.7	5.1	4.8	5.7	5.0	6.2	5.1	6.7
Glass	2.3	2.7	2.1	2.9	1.9	2.6	1.7	2.4
Rest	7.1	7.1	7.4	7.4	7.8	7.8	8.2	8.2
TOTAL	**50.6**	**50.6**	**50.3**	**50.3**	**50.0**	**50.0**	**49.8**	**49.8**

For the baseline scenario in general, it can be expected that the major municipal waste streams will stay on a constant level, however with slightly falling tendency.

The huge impact of the specified collection rates (Chapter 2.3.2) on the waste stream amounts (and thus on the composition of the municipal waste stream) can be observed (Scenario A and B). For example, the total amount of Residual Household & Business Waste is strongly decreased during the whole forecast period. By 2025, approx. 10 Million t of this waste stream would be shifted to other waste streams (mainly towards Organic, i.e. +7 Million t), as a consequence of the defined challenging collection rates and because the residual household waste stream acts as the “source” for other waste streams. All other waste streams are increasing compared to the baseline (except waste stream Rest that is excluded from modifications by collection rates, see Chapter 2.1.1).

3.2 Overall recycling rate

Which overall recycling rate can be expected based on the municipal waste stream forecast of Chapter 3.1? The specific recycling factors for each projected municipal waste stream (Chapter 2.2) reveal that the new recycling targets will not be met in the baseline scenario (see Table 9). The expected overall recycling rate is always below the targets defined in the WFD.

Table 9 Expected contributions to recycling from each municipal waste stream, Scenarios Baseline, A and B [Mio. t]

year waste stream	**2020** **Base**	**2020** **A** **B**	**2025** **Base**	**2025** **A** **B**	**2030** **Base**	**2030** **A** **B**	**2035** **Base**	**2035** **A** **B**
Res. Household & Business	0.9	0.7 0.7	0.9	0.5 0.5	0.8	0.4 0.4	0.8	0.4 0.4
Organic	7.9	9.4 9.7	7.9	11.2 11.8	7.8	11.3 12.1	7.7	11.3 12.4
Paper & Card-board	7.4	8.0 8.0	7.2	8.6 8.6	7.1	8.7 8.7	7.0	8.8 8.8
Mix. Packaging & Recyclables	1.9	2.0 2.1	1.9	2.3 2.4	2.0	2.5 2.6	2.0	2.7 3.0
Glass	2.1	2.4 2.4	1.9	2.6 2.6	1.7	2.3 2.3	1.5	2.1 2.1
Rest	2.5	2.5 2.6	2.6	2.6 2.7	2.7	2.7 2.9	2.9	2.9 3.2
TOTAL RECYCLING	22.6	25.0 25.4	22.4	27.7 28.5	22.2	27.9 29.2	22.0	28.2 29.9
Expected municipal waste potential	50.6	50.6	50.3	50.3	50.0	50.0	49.8	49.8
Expected overall recycling rate	**44.7%**	**49.4%** **50.2%**	**44.5%**	**55.1%** **56.7%**	**44.3%**	**55.9%** **58.4%**	**44.1%**	**56.6%** **60.1%**
Targeted overall recycling rate	50%	50%	55%	55%	60%	60%	65%	65%

For 2020 and 2025, the collection rates of scenario A would lead to overall recycling rates (49.4% and 55.1%) that are in the range of the defined targets (50% and 55%). However, they would only be reached very tightly, without any “reserve”. In more distant years, recycling targets would not be met, while the gap seems to become even wider in the future.

For scenario B, it can be observed that the increase of the recycling factors might lead to sufficient overall recycling rates (50.2% and 56.7%) in 2020 and 2025. However, again there is not much reserve to expect, so that there is no reason to decrease the defined collection rates. For 2030 and following years, even more effort in improvement of recycling and collection seems necessary.

4 Discussion

The forecast of waste streams for municipal solid waste was based on data from 2009 to 2016 published by DESTATIS according to LoW categorization. These waste streams have been broken down to material categories using the composition of each waste stream. The currently used estimation of the waste composition for each waste stream can be significantly improved as soon as the nationwide analysis results (material composition of Household and Bulky Waste) for Germany will be available (expected by end of 2019).

Further assumptions for the forecast are validated data for population published by DESTATIS, and net domestic consumption data from Federal Environment Agency, industry associations and others. Current recycling rates were calculated from the waste streams according to an output (from waste treatment plants) based calculation model developed by ARGUS. Future recycling rates were simulated in order to meet the defined recycling rates of the WFD.

The results show that huge efforts will be necessary to increase the separate collection systems and to improve the current residual waste treatment system towards material recycling instead of incineration or energy recovery. Furthermore, the model does not consider potential waste streams which are so far not collected and fed into waste treatment plants such as garden waste treated by home composting.

Assuming the recycling rates for currently separate collected material categories (ref. to table 5) will stay unchanged in the future and Residual Household & Business Waste is the main source to increase recycling rates by separate collection, it will be impossible to meet the European targets for 2030 and 2035 by increasing the collection rates only. This means, that additional efforts are necessary to improve the whole recycling process at each stage from separate collection until the final recycling facility.

5 Literature

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Recycling Region Harz – The Education Offensive

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Abstract

The Harz region has a long and diverse tradition when it comes to primary raw materials and is therefore severely affected by structural change. Under the leadership of the University of Applied Sciences in Nordhausen, four university partners from the federal states of Thuringia, Saxony-Anhalt and Lower Saxony are working on issues related to recycling recyclable materials as well as their quality assurance and appropriate treatment technologies. The results are intended to advance companies based in the Harz region and further boost the use of secondary raw materials. The main focus is on consumers taking back small electrical appliances. This group of substances is often incorrectly disposed of by the public and lost from the recycling loop. An educational campaign is to be carried out to make children and young people, in particular, aware of these problems in an interactive way.

1 Introduction

The collection and take-back of waste and the extraction of the recyclable materials it contains are essential to future raw material supply and environmental protection. Just like the green energy revolution already under way in Germany, a recycling material revolution is an indispensable foundation for growth and employment in society.

Nowadays, raising awareness and informing people about how to deal with increasingly scarce raw materials are especially important in the light of these primarily anthropogenic waste streams. The launch of a recyclable material revolution can only be successful if public understanding of the problem of ‘waste’ is created and fostered. Our task is to inform people and encourage citizens to become active participants. An educational campaign aims to make children and young people, in particular, aware of these issues in an interactive way, thereby laying the foundation for a sustainable and resource-efficient recyclable material revolution as early as school age.

Relevant questions can be answered by providing and sharing information on all issues relating to terms such as:

- Recyclable materials
- Take-back
- Processing
- Recovery.

Everybody can play their part in the recyclable material revolution. People can save raw materials, for instance, by sorting waste properly at home or only buying something new if they really need it. Public outreach work must identify risks to the environment caused by everyday behaviour. We are moving one step closer to the recyclable material revolution by offering practical suggestions for change and opportunities to get actively involved.

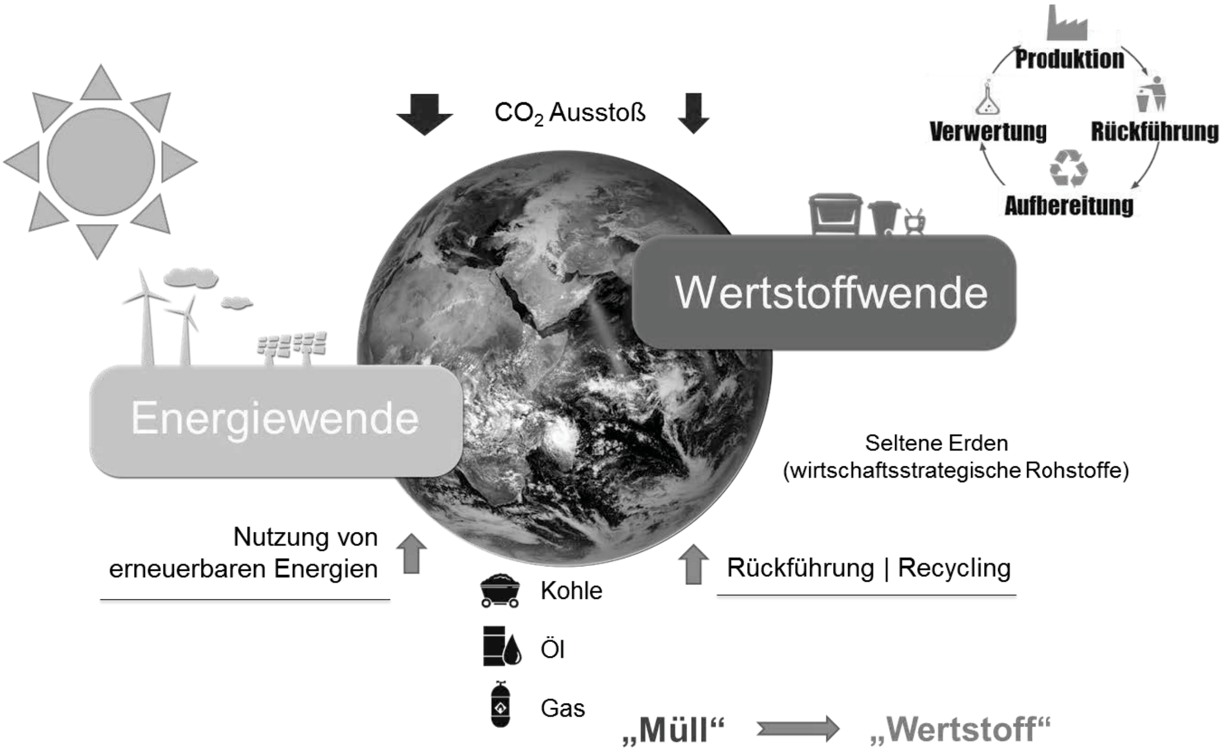

Figure 1: Interplay between the energy revolution and recyclable material revolution

2 Harz recycling region

Four universities from three German federal states have joined forces and created the ‘Harz recycling region’ as part of the German Federal Ministry for Education and Research’s Twenty20 – Partnership for Innovation. The University of Applied Sciences in Nordhausen (HSN), the Technical University of Clausthal, the Magdeburg-Stendal University of Applied Sciences and Otto-von-Guericke University in Magdeburg have set themselves the goal of harnessing the previously untapped raw material potential contained in waste and landfills in a project under the leadership of Professor Jürgen Poerschke from HSN. Using waste electrical and electronic equipment (WEEE) as an example, the project aims to identify possible ways to optimise recovery operations, starting with take-back, and develop and test new potential solutions. An interactive educational campaign should be designed to raise awareness of this issue among children and young people, in particular. This project’s main focus is putting in place the conditions for a sustainable and resource-efficient recyclable material revolution.

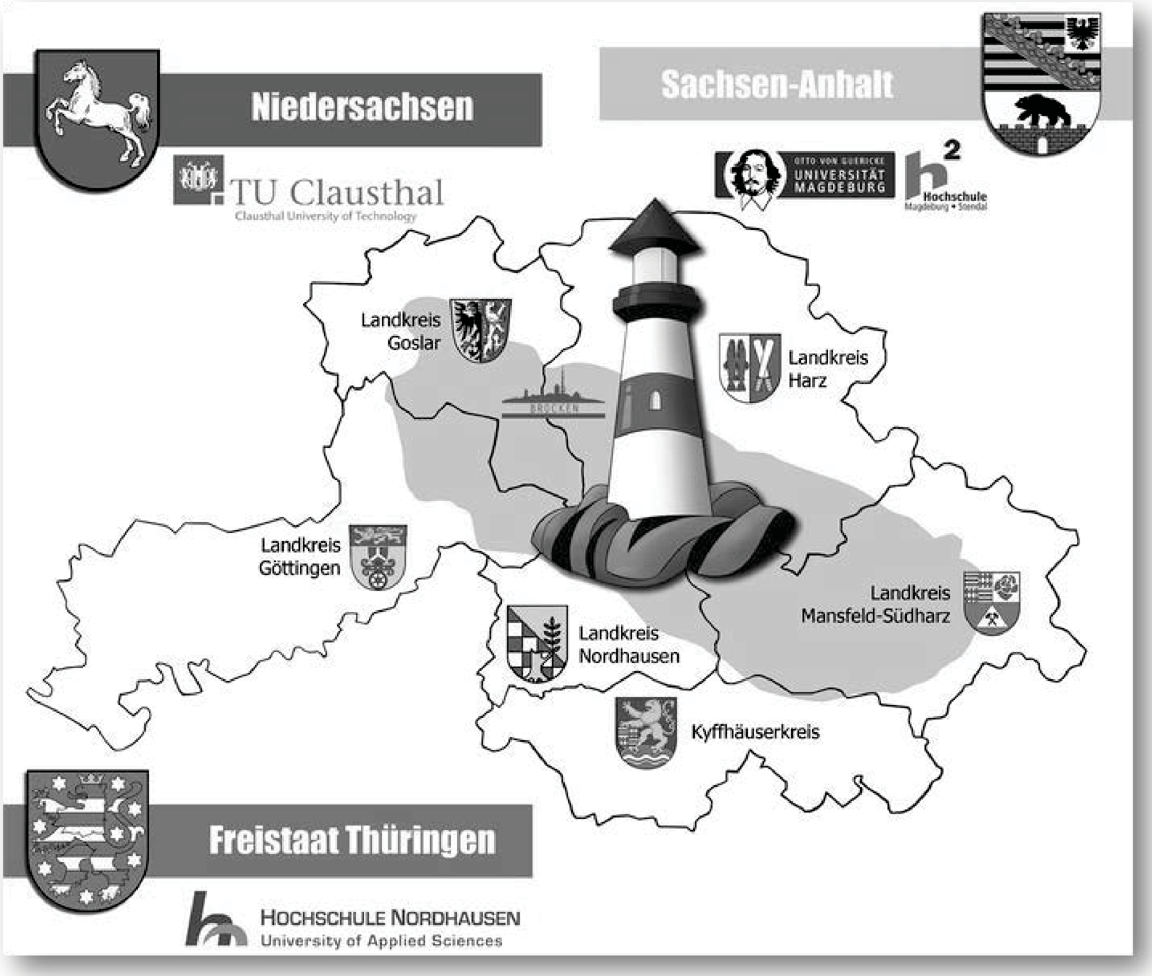

Figure 2: Project network for establishing and expanding the Harz recycling region

Simple take-back systems in touch with the people are the first pre-requisite for recycling WEEE. Short pathways and convenient take-back opportunities for all citizens may mean that WEEE does not end up in the bin or being littered. ‘Simple’ and ‘in touch with the people’ also means that the needs of shift workers, people who work far away from where they live, older residents and people with different levels of education are taken into consideration.

3 Education campaign

Many citizens are not interested in or motivated to discard their ‘waste’ in a way that makes it available as a source of secondary raw materials. A lack of information about the importance of taking back waste and/or about the benefits of ‘waste’ as a recyclable material is often behind this wrongdoing. Consequently, it is important to bring about a shift in public behaviour and a change in a material’s image from waste to recyclable. Children are a vital interface to create the necessary social pressure. Integrating this issue into school curricula is an important tool here. This information has to be easy for children and young people to experience and grasp. For instance, children can experience the concept of 'returning resources' in a playful way in primary schools. Children often share experiences that they are excited about immediately with their social circles. In the process, they become a 'supervisory body' for their parents, and parents want to be role models for their children, which gets the ball rolling. One way to get young people – whose lives are closely connected to communication using mobile phones or tablets – on board would be to develop an app showing how to sort recyclable materials.

Moreover, converting Germany's waste management sector into a circular and resource economy – a task that will require new skilled workers and their continuing education in the long term - poses challenges not only for managing complex material streams and for technical development of efficient waste treatment technologies. It is also conceivable that new career opportunities will emerge in a circular economy model based on resource recovery.

3.1 Target groups

The target groups comprise primary and secondary school pupils, university students, unemployed people undergoing vocational retraining, apprentices and employees in the recycling industry, people working in businesses and citizens in their role as consumers.

Teaching materials, exhibitions and exhibits should facilitate age-appropriate knowledge transfer. All activities should focus on how interested parties interact with one another so that knowledge is absorbed in society and people can share what they have learned with one another. This promotes collective learning and strengthens a sense of community.

Events should be designed with the target group in mind and announced through a website, which has yet to be created. Additional parameters for target groups include:

- Use of these materials in the classroom, tailored to a variety of different schools, e.g. primary school – inclusion in science and local studies classes – adaptation of the visual aids to be used.
- School trips to WEEE manufacturers or processors, for instance (e.g. Nordthüringer Werkstätten – preliminary dismantling of WEEE).
- Drawing up flyers for WEEE or creating a brochure about the recyclable material revolution for all citizens.
- For apprentices – training on how to become a resource scout – learning to go through premises with open eyes, identify and dispose of waste. By doing so, they will encourage other employees to use resources more carefully (Source: IHK Erfurt, 2014, "Apprentices as Energy Scouts project").

3.2 Education on sustainable development

Sustainability in everyday teaching means creating ways of giving more space to this topic during regular lessons. Standard subjects could thus be incorporated into curricula, allowing sustainable thinking to be shared.

<u>Curricula in Thuringia</u>

Primary school – e.g. inclusion in science and local studies classes

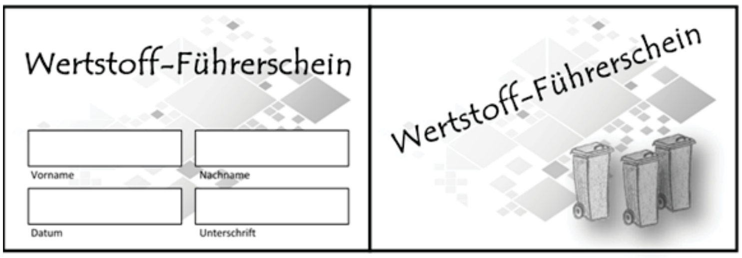

Figure 3: Recyclable materials licence for children

Secondary schools – e.g. inclusion in chemistry and geography classes

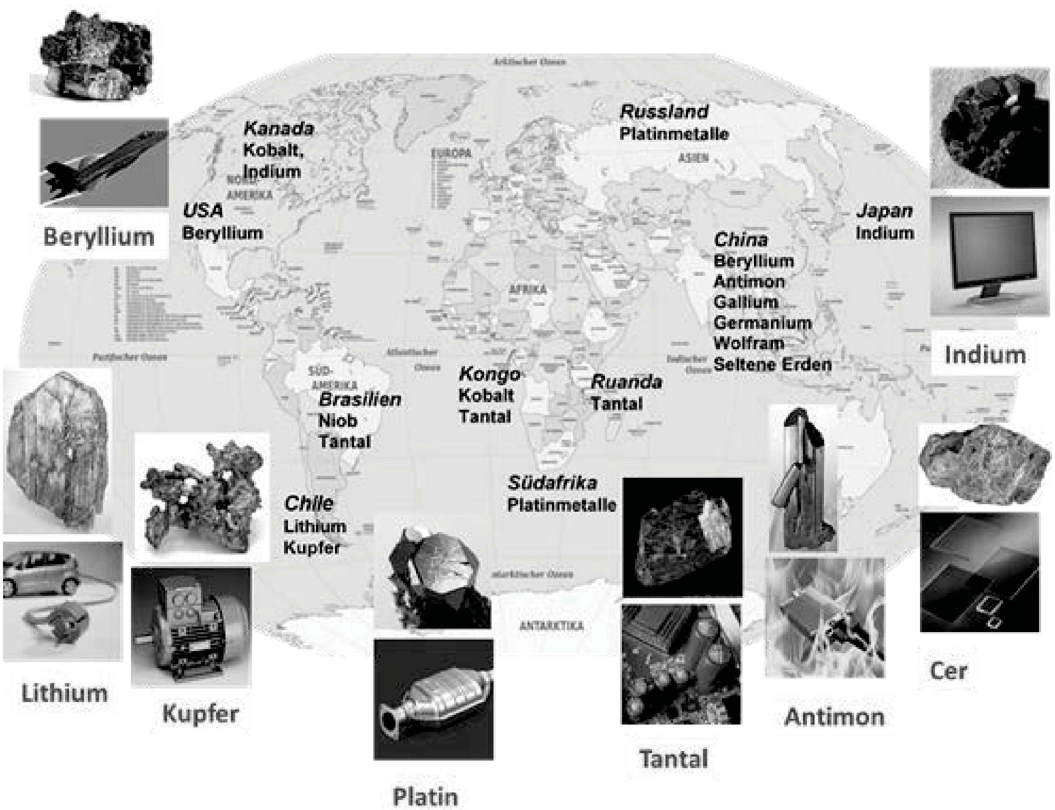

Figure 4: Key elements and their deposits (DERA, Nov. 2017, Britta Bookhagen)

This creates ways for students to use the knowledge they have gained directly in schools and/or their personal surroundings. Taking part in competitions may be a helpful tool to deal with the issue of the environment and sustainability and to understand the complexity of this issue.