Energy
National Research Programmes 70 and 71

Synthesis

wastEturn – Waste management to support the energy turnaround

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Joint synthesis

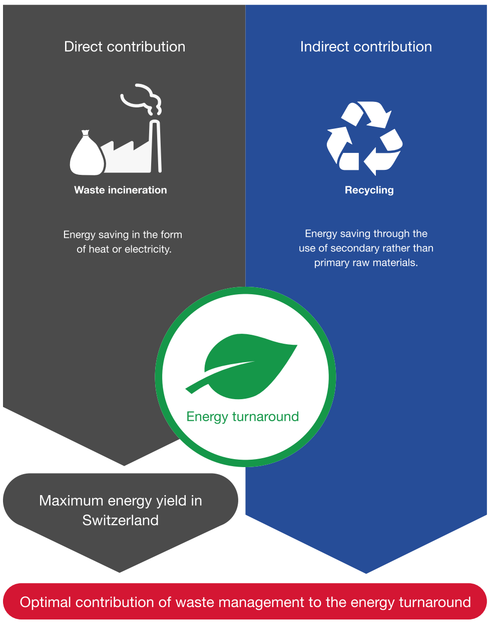
1. Waste management to support the energy turnaround

Synthesis of the NRP 70 joint project "Waste management to support the energy turnaround (wastEturn)"

1.1. Waste offers great additional energy potential

The joint project "Waste management to support the energy turnaround" investigated how and to what extent waste management can support the transformation of the Swiss energy system. This synthesis integrates the findings on municipal solid waste management in eight thematic areas and derives seven core statements as well as nine recommendations for action for the relevant stakeholders.

1.1.1. Summary



Direct and indirect contribution to the energy turnaround that should be optimised as a whole. *Source: Melanie Haupt, ETH Zürich*

A great deal of energy can be sourced both directly and indirectly from waste. For example, municipal waste with an energy content of around 60 petajoules is incinerated in Switzerland every year. The energy recovered directly from this waste covers around 4 % of the Swiss energy demand. However, the greatest potential offered by waste management lies in the recovery of secondary raw materials during the recycling process, thus indirectly avoiding the energy-intensive production of primary raw materials.

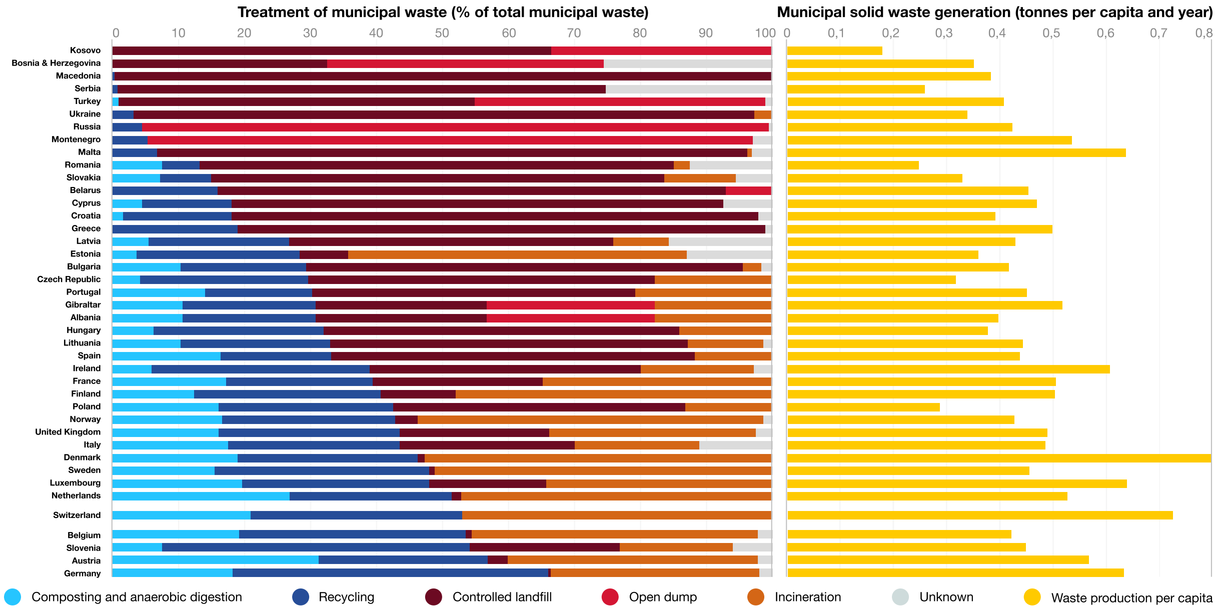
In order to optimise the contribution to the energy turnaround made by waste management, as a first step, improvements need to be made with respect to the transparent documentation of material and cash flows, in particular. On the basis of this, prioritisation according to the energy efficiency of various recycling and disposal channels is required. Paper and cardboard as well as plastic have been identified as the waste fractions with the greatest potential for improvement. In the case of paper and cardboard, the large quantities involved result in considerable impact. With the exception of PET drinks bottles, plastic waste is often not separately collected and therefore offers substantial improvement potential. Significant optimisation potential has also been identified with regard to the energy efficiency of incineration plants. To allow municipal solid waste incineration (MSWI) plants to use the heat they generate more effectively, however, consumers of the recovered steam and heat need to be located close by. A decisive success factor when transitioning towards an energy-efficient waste management system will be the cooperation between the many stakeholders of the federally organised sector. On the one hand, the sector needs to be increasingly organised along the value chains. On the other hand, however, there is also a need to utilise the freedom that comes with federal diversity in order to test different solutions.

1.2. Energy has only played a secondary role until now

This Swiss waste management system is characterised by large per capita volumes, high collection rates and its extremely federal organisational structure. A problematic issue, from an energy-policy perspective, is the minor importance of energy and secondary product sales for the business success of waste incineration plants.

Recyclable material # Recycling # Biomass # Households # Businesses

1.2.1. Large per capital volumes but high collection rates



Comparison of waste production and collection rates in Switzerland with various European countries, arranged according to the share of recovered waste (composting, anaerobic digestion and recycling). *Source: Data prepared in Pollak (2019) on the basis of data from Kaza et al. (2018).*

On the one hand, the waste management sector in Switzerland must ensure the safe disposal of all waste while minimising negative effects on the environment. On the other hand, the resource potential of waste should be utilised optimally by resource and energy recovery.

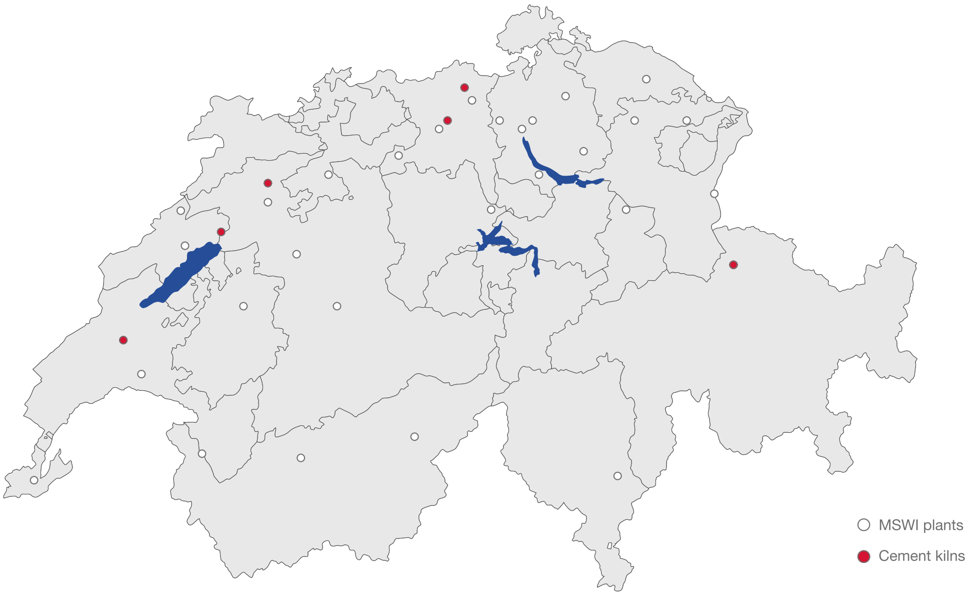
Every year, each person living in Switzerland produces an average of around 700 kg of municipal solid waste and thus significantly more than the residents of neighbouring European countries. At the same time, our country has a relatively well-developed waste management system. Around 50 % of all municipal solid waste is collected separately in more than ten different fractions of recyclables. In some cases, very high collection and recycling rates are achieved here. The largest fractions in terms of volume are paper, cardboard, green waste and glass. Waste bag fees are used as an incentive to encourage the separate collection of waste (following the “pay as you throw” principal). However, there are no nationwide deposit systems.

The use of the secondary materials gained from separately collected waste fractions is greatly dependent on their quality. In the case of green waste, for example, contamination can lead to plastics reaching fields and thus the environment. The colour of the material can also play an important role. While recycled blue and transparent PET bottles are used again for the production of bottles, green and brown bottles are currently only used in packaging materials or as PET fibres. The separation of waste glass according to colour enables the incorporation of the cullet in the production process for bottles of the relevant colour. In contrast, mixed-colour glass can only be used for the production of green glass, foam glass (insulation material) or glass sand.

Mixed municipal solid waste in Switzerland is fully recovered by means of thermal processing. As the first MSWI in Switzerland and the fourth in continental Europe, the MSWI plant at Josefstrasse in Zurich commenced operations back in 1904. There are now 30 MSWI plants in Switzerland. These incinerate between 36,000 and 240,000 tonnes of waste per year. An increasing share of the released energy is either being used directly as heat or for the production of electricity.

Market # Guidance # Public administration # Businesses # Politics (federal government, canton, municipality)

1.2.2. Federal organisation with many stakeholders



Switzerland's federal waste system: as the cantons and municipalities are responsible for waste disposal, the MSWI plants are also distributed accordingly (white dots). Cement kilns, which utilise waste as alternative fuel and raw materials in some cases, are also spread across Switzerland (red dots). *Source: Melanie Haupt, ETH Zürich*

In the Swiss Environmental Protection Act, the responsibility for the waste management system is assigned to the cantons. In some instances, this has then been transferred by the cantonal authorities to the municipalities. With respect to thermal waste recovery, this federal organisational structure has led to a situation in which municipalities and, in individual cases, cantons operate the incineration plants. In contrast, the recycling systems are currently primarily organised at a national level and are supported by various associations and the head organisation Swiss Recycling. Around 100 plants (MSWI plants, recycling companies, composting plants, etc.) have also joined forces as part of the Association of Plant Managers of Swiss Waste Treatment Installations (VBSA), which acts as the national umbrella organisation.

The fact that the numerous stakeholders in the area of municipal solid waste management are active at different levels has an impact on the system's ability to innovate and change. On the one hand, central strategic changes and national control mechanisms are difficult to implement within the federal organisational structure. The many mutual dependencies can also give rise to technical lock-ins which mean that it is not possible to introduce promising technologies or these can only be introduced slowly (e.g. overcapacity at a MSWI plants can hinder the development of recycling systems). On the other hand, however, individual municipalities and cantons in a federal system also have the opportunity to risk experimenting within the scope of nationwide legislation and try out new things. These innovations can then – should they work – be incorporated by other municipalities and cantons.

In order to successfully initiate and implement coordinated changes within the federal Swiss municipal solid waste management system, sound knowledge of the various stakeholders as well as their interests and objectives is essential. Here, stakeholders from authorities, industry and associations at both national and cantonal level need to be taken into account. As Switzerland combines diverse cultures with regional roots, it is also essential to analyse the socio-political context.

Recyclable material # Market # Price # Energy provision # Businesses

1.2.3. Energy production and recycling are currently of little economic relevance for MSWI plants

On balance, cost-coverage was achieved for the incineration of municipal solid waste at Swiss MSWI plants in 2012. However, the lion's share of the proceeds (around 70 %) comprises fees. These include waste bag fees, waste fees charged via the municipality as well as fees for the domestic waste delivered directly to the respective plants. The market proceeds generated from the sales of energy and secondary raw materials cover only around 30 % of the total costs.[1]

The fact that the income from the energy sold only makes a small contribution to financing the incineration of the waste has a major impact on the business models of MSWI plants. It is for this reason that they are not designed to maximise energy production, but rather to maximise the volume of the treated waste.

From a full-cost-account perspective, the data collected as part of the joint project also show that the thermal treatment of most waste is currently more cost-efficient than recycling. An increase in the share of separately collected and recycled material thus also increases the price of municipal solid waste management. The additional costs incurred due to rising collection and recycling rates can, however, be covered by the waste management system itself if the market price for energy and secondary materials rises in parallel. As things currently stand, fee and tax increases would be necessary.[2]

State regulation relating to the use of secondary materials can have a positive impact on the level of market revenues. For example, a regulation coming into force in 2025 as part of the EU's circular economy package is already leading to an increase in demand and a rise in the prices paid for recycled PET. Under this package, new plastic packaging must contain at least 25 % recycled material. It can be expected that corresponding regulations for other materials will also trigger similar effects.

Notes and References

1 Project "Economics of waste-to-energy systems"
2 Project "Economics of waste-to-energy systems"

Resources # Cold / heat # Heating # Energy provision # Businesses

1.2.4. Waste management as part of energy management

The heat recovered at the MSWI plant Hagenholz (right) covers a large share of the energy requirements of the district heating network around Zurich throughout the year. Between October and May, it is supported by the Aubrugg wood-fired power plant (left).
Source: Melanie Haupt, ETH Zürich

Both the incineration and recycling of waste can lead to energy savings in other areas through the provision of heat and electricity as well as the replacement of primary materials. Waste management can thus make an important contribution to the energy turnaround. In the case of thermal utilisation, waste is incinerated at a MSWI plant without the addition of fuel. This releases thermal energy that can either be used itself or for the production of steam and electricity. The secondary materials that are gained during the recycling procedure lead to a reduction in energy requirements in primary material production as they replace materials from primary resources that are generally produced as part of an energy-intensive process.

The direct contribution waste incineration makes to Swiss electricity production currently covers 3 % of Swiss energy requirements in terms of electricity.[1] The contribution to the heating supply for households and industry made via a MSWI plant's district heating systems or steam networks can be well above 80 % at a local level. Depending on the region, waste incineration thus substantially contributes to the supply of heat. In contrast to the recovered thermal energy, which is used in Switzerland, the indirect savings realised when substituting the production of primary materials usually takes place abroad.

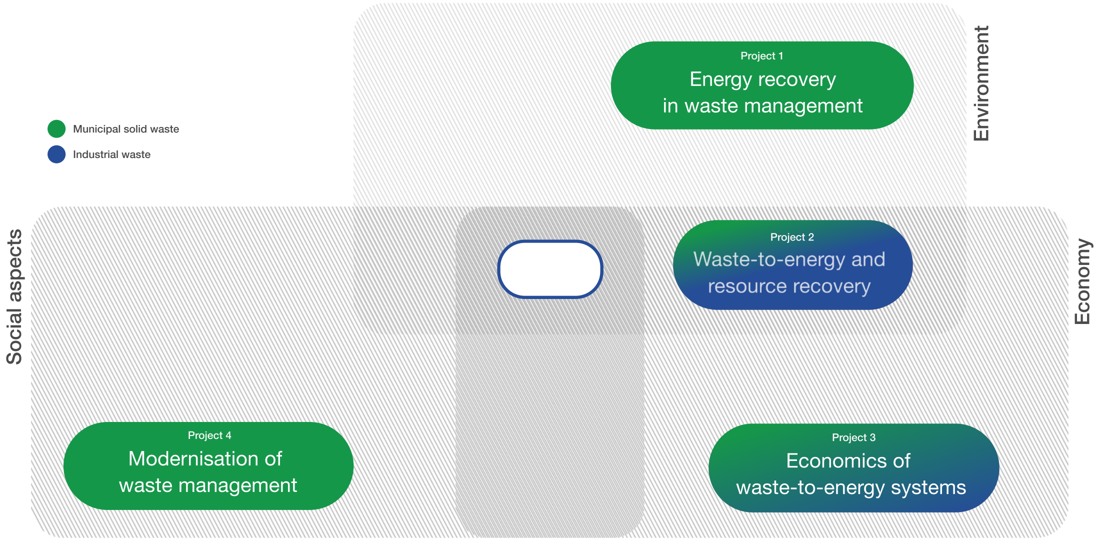
While this is not always true, it can often be the case that more energy can be saved through recycling than can be utilised through incineration when viewed over the entire life cycle. The balance is, however, dependent on many factors and has therefore been analysed in more detail for each waste fraction as part of the joint project “Waste management to support the energy turnaround” by means of a life cycle assessment.[2] Fundamentally, the most effective strategy for saving energy in the area of waste management is of course to avoid waste. This approach was not, however, investigated as part of this project. The objective of the joint project was to optimise the utilisation and treatment of waste occurring in Switzerland with respect to its contribution to the energy turnaround.

Notes and References

1 Swiss Federal Office of Energy (SFOE). 2018. 2017 results for energy consumption in industry and service sector. Swiss Federal Office of Energy (FSOE). Berne, Switzerland.
2 Haupt, M., T. Kägi, and S. Hellweg. 2018. Modular life cycle assessment of municipal solid waste management. Waste Management 79: 815–827.

Combustible / fuel # Sustainability # Energy provision # Businesses

1.2.5. Industrial waste offers additional potential



The joint project wastEturn covers all three pillars of sustainability. While all sub-projects (at least in part) addressed municipal waste (green), projects 2 and 3 also looked at chemical industrial waste (blue). This synthesis deals exclusively with municipal solid waste. *Source: Melanie Haupt, ETH Zürich*

The overarching objective of the joint project "Waste management to support the energy turnaround" was to optimise Swiss waste management from an environmental and economic perspective as well as to analyse socially accepted implementation strategies. It thus comprised the three fundamental pillars for sustainable development, namely the environment, the economy, and society. Four interdisciplinary research groups looked at both municipal and industrial waste.

This synthesis focuses on the findings of all sub-projects in the area of municipal solid waste. To this end, the results from the environmentally focussed "Energy recovery in waste management"[1], the economics-based project "Economics of waste-to-energy systems"[2] and the project "Modernising waste management"[3], which looked at implementation strategies, were summarised.

In addition to the work on municipal solid waste assessed in this synthesis, the joint project also investigated the possible contribution to the energy turnaround that could be made by chemical industrial waste. The energetic optimisation of the industrial waste management revealed that additional fuels could be substituted by solvents and mother liquors (+8 %). The increasing local thermal recovery of this waste also reduces the transport of hazardous chemicals. The maximum contribution that can be made by industrial waste management to the energy turnaround is, however, greatly dependent on future waste volumes and their composition.[4 5 6 7]

Notes and References

1 Project "Energy recovery in waste management"
2 Project "Economics of waste-to-energy systems"
3 Project "Modernising waste management"

4 Bolis, V., E. Capón-García, and K. Hungerbühler. 2016. Optimal Design of Industrial Waste-to-Energy Networks. Computer Aided Chemical Engineering. Vol. 38. Elsevier Masson SAS.
5 Bolis, V., E. Capón-García, and K. Hungerbühler. 2017. Optimal Design of Multi-Enterprise Industrial Waste-to-Energy Networks. Computer Aided Chemical Engineering. Vol. 40. Elsevier Masson SAS.
6 Bolis, V., E. Capon-Garcia, M. Roca-Puigros, A. Gazzola, and K. Hungerbuehler. 2019. Optimal design and management of industrial waste-to-energy systems. Industrial & Engineering Chemistry Research: acs.iecr.8b03129.
7 Bolis, V., E. Capón-García, O. Weder, and K. Hungerbühler. 2018. New classification of chemical hazardous liquid waste for the estimation of its energy recovery potential based on existing measurements. Journal of Cleaner Production 183: 1228-1240.

1.3. Analysis of waste flows and relationships reveals potential

In order to optimise the energetic effects of waste, a reliable data base must first be created. The greatest improvements are likely to come from large categories of waste, an improvement in the energy efficiency of MSWI plants and more effective cooperation between the various stakeholders.

Resources # Recycling # Guidance # Energy provision

1.3.1. Systematic recording of all quantity and energy flows

Energy flow analysis of the Swiss waste management system (2012).*Source: Melanie Haupt, ETH Zürich*

The systematic recording of all relevant indicators for Swiss municipal solid waste is a fundamental prerequisite for optimising the system. In the project "Energy recovery in waste management"[1], the material and energy flows of all fractions were mapped. The untapped energetic and material potential offered by paper, cardboard, glass, aluminium, sheet steel and PET bottles as well as the recycling process were investigated in more detail.

Important identified key figures:

- In 2012, a total of around 21 million tonnes of waste was produced in Switzerland.
- With around 13 million tonnes, construction and demolition waste was the largest waste fraction in terms of quantity (62 %) in 2012 but was less relevant from an energy perspective (24 %, see figure). It primarily comprises inert, mineral material that is recycled in concrete aggregates or mineral filling material.[2]
- At 5.5 million tonnes, municipal solid waste represents the second most important waste fraction in Switzerland in terms of quantity (26 %) and the most important from an energy perspective (52 %, see figure). In 2012, 52 % of municipal solid waste was collected separately and 48 % was treated in a MSWI plant.
- A substantial share of the fractions collected for recycling was exported (42 % of industrial separate collections, 65 % of hazardous waste and 27 % of separate collections from households).

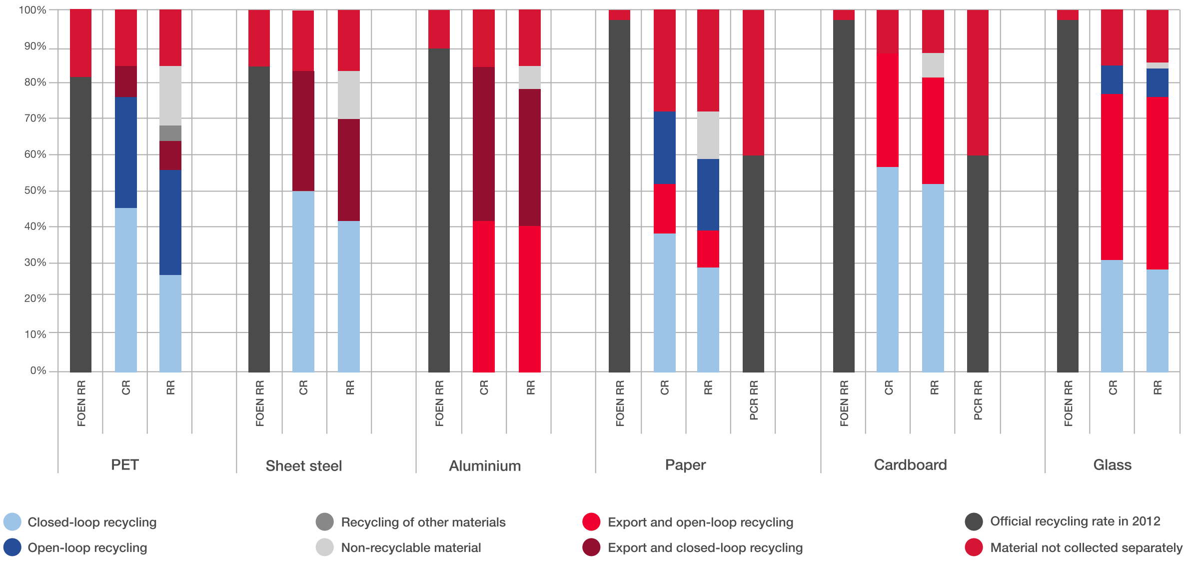
In 2012, Swiss waste management contributed a total of 61 petajoules (PJ, 10^{15} J) to the energy system, which equated to a calculated share of around 4 % of Switzerland's energy demand.[3] Of this figure, 16 PJ was recovered in MSWI plants as electricity or heat and 45 PJ was saved indirectly through recycling. Indirect savings are often not realised in Switzerland, but rather in the countries in which the primary materials replaced by recycled products would have been produced. In the area of electricity production, the contribution of MSWI plants amounts to 3 %.

Notes and References

1 Project "Energy recovery in waste management"
2 Dettli, R., R. Fasko, U. Frei, and F. Habermacher. 2014. Transformation der Abfallverwertung in der Schweiz für eine hohe und zeitlich optimierte Energieausnutzung [Transformation of waste management in Switzerland towards a high and time-wise optimal energy recovery]. Zurich, Switzerland.
3 Frischknecht, R., C. Nathani, S.B. Knöpfel, R. Itten, F. Wyss, and P. Hellmüller. 2014. Development of Switzerland's worldwide environmental impact. Technical report.

Recyclable material # Recycling # Guidance # Businesses

1.3.2. Clear and meaningful indicators for the assessment of recycling



Results from the study by Haupt et al. (2017): the collection and recycling rates (CR and RR) of Switzerland in 2012. FOEN RR = recycling rate as published by the FOEN, RPK RR = recycling rate of Association for Paper and Cardboard Recycling (RPK). *Source: Haupt et al. (2017)*

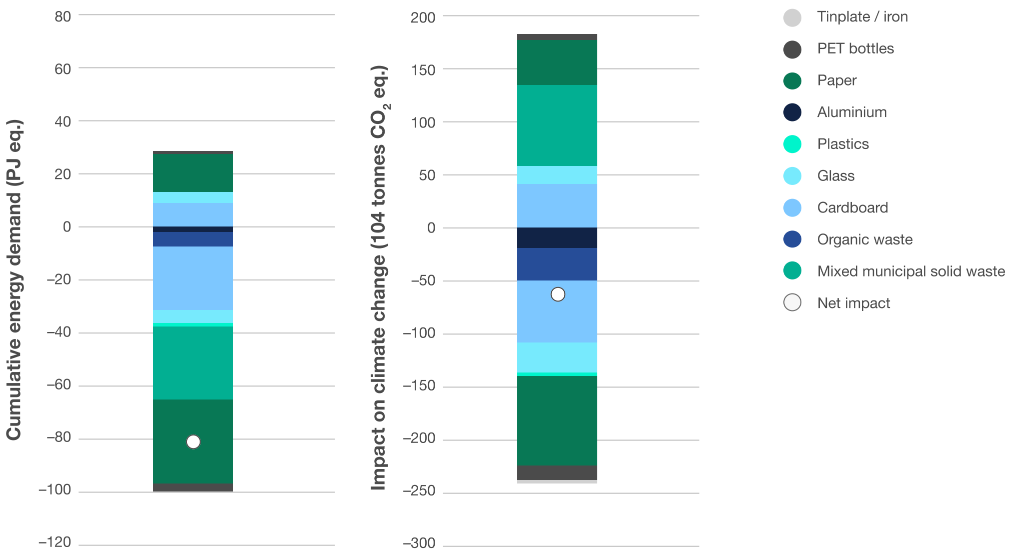
The performance of the municipal solid waste management in Switzerland – as all around the world – is primarily measured as recycling rates. This indicator is, however, not precisely defined. Neither the choice of system boundaries ("where are which flows measured?") nor the definition of contaminants ("including or excluding material flow impurities?") are explicitly specified although they have a major impact on the calculated rates. In order to obtain comparable data, it is necessary to establish clearly defined and consistent system boundaries for the calculation of recycling rates.. In the joint project "Waste management to support the energy turnaround", the actual material flows were recorded together with the relevant stakeholders and the optimal measurement points for the recycling rates were specified. Several different kinds of rates were quantified for Switzerland and compared with one another. In order to report the actual flows more accurately, some rates have in the meantime been revised by the respective recycling organisations. The systematic analyses show that it would be better to assess the overall system according to recycling rates and no longer use collection rates as performance measure. Using recycling rates is the only way to include the improvements in the recycling processes, as well as the impact of contaminants in recycling streams, in the performance assessment of the waste management system.[1]

Notes and References

1 Haupt, M., C. Vadenbo, and S. Hellweg. 2017. Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System. Journal of Industrial Ecology 21(3): 615–627.

Recycling # CO2 / greenhouse gases # Energy efficiency # Sustainability # Businesses

1.3.3. The biggest material fractions have the greatest environmental impact



Results of the life cycle assessment of the Swiss municipal solid waste management system. Left: cumulative energy demand, right: impact on climate change. Positive figures represent environmental impacts (e.g. emissions or energy requirements), negative figures represent environmental benefits (avoided emissions or gained energy). *Source: Haupt et al. (2018)*

The life cycle assessment of the Swiss municipal solid waste system is currently positive: overall, it reduces national greenhouse gas emissions by around 1 % and saves approximately 4 % with respect to Switzerland's cumulative energy demand.[1] As the biggest separately collected waste fractions in terms of quantity, paper and cardboard are responsible for a significant share of the environmental performance. Mixed municipal solid waste, which dominates from a quantitative perspective, currently has ambivalent environmental performance. While its thermal utilisation is beneficial with regard to the cumulative energy demand, it leads to substantial additional greenhouse gas emissions. These originate to a large extent from plastic, which in Switzerland is primarily deposited as part of the mixed municipal solid waste.

There is thus great potential for optimisation in the area of plastics. Although plastics only account for a small weight fraction of mixed municipal solid waste, they are responsible for 35 % of the calorific value at MSWI plants (or almost 60 % if composite packaging, which primarily comprises plastics, is also taken into account) and therefore make a considerable contribution to energy recovery at these facilities. The incineration of plastics is, however, also responsible for a large share of the CO_2 emissions generated by municipal solid waste incineration. From an environmental perspective, it is thus key that the energy from this CO_2-

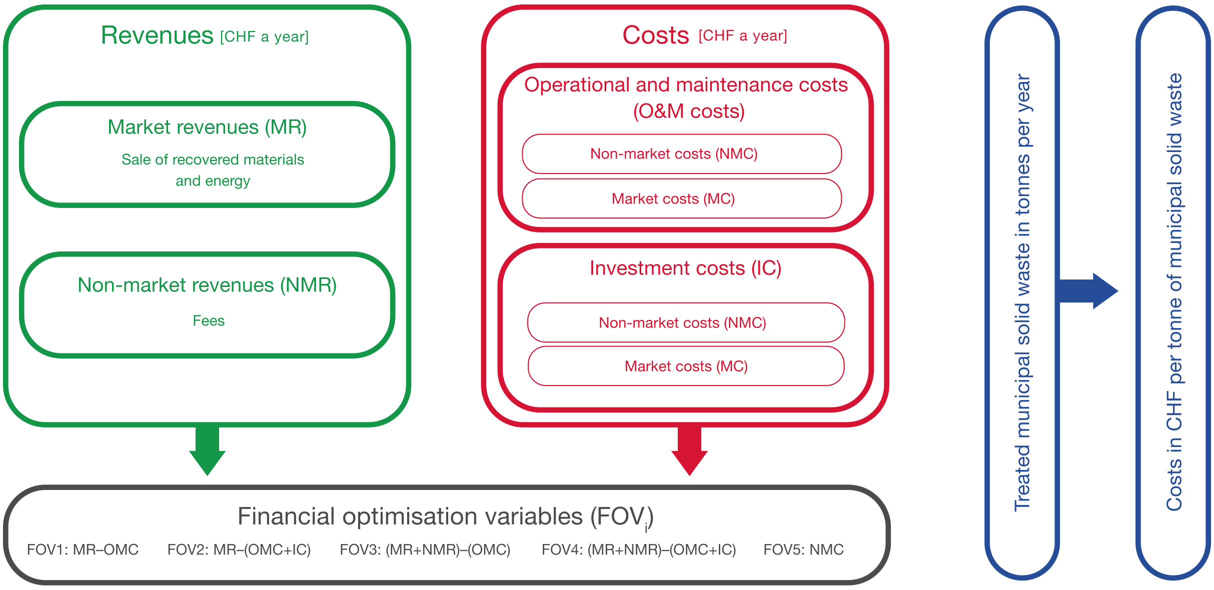
intensive material is recovered with as little losses as possible. Separate collections are required to this end. This enables plastics to be either recycled or used as a substitute for fossil fuels at cement kilns. Both uses are preferable to incineration in MSWI plants from an environmental viewpoint.

Notes and References

1 Frischknecht, R., C. Nathani, S.B. Knöpfel, R. Itten, F. Wyss, and P. Hellmüller. 2014. Development of Switzerland's worldwide environmental impact. Technical report.

Market # Acceptance # Guidance # Costs / benefits # Businesses # Politics (federal government, canton, municipality)

1.3.4. Life cycle costs of all material flows form the basis for optimisation



Methodology developed for the calculation of the life cycle costs of municipal solid waste. *Source: Christoph Hugi, FHNW*

Cost and income calculations are fundamental for the optimisation of the municipal solid waste management system. As part of the project “Economics of waste-to-energy systems”, the life cycle cost method was adapted to the waste system.[1] To this end, the financial data of all material flows, ranging from the cost of collection, sorting and processing to the sale of commodities and energy, was recorded and compared.

The analysis shows that the costs for most material flows exceed the income even if fees such as advanced recycling fees are included in the calculation. The result is surprising as most systems have already been operating for a long period and officially work on a break-even basis. Possible explanations for the difference include that the costs in the calculations may have been overestimated (e.g. assumed service life of investments is too short) or are compensated for in other ways (e.g. subsidised collection costs) or that the long-term income has been underestimated (only one year taken into account). In particular, the allocation of costs for the collection of different waste fractions can be difficult. The lack of cost transparency in many areas is of little help in this regard. Costs and income are often not publicly accessible and are treated as a business secret[2].

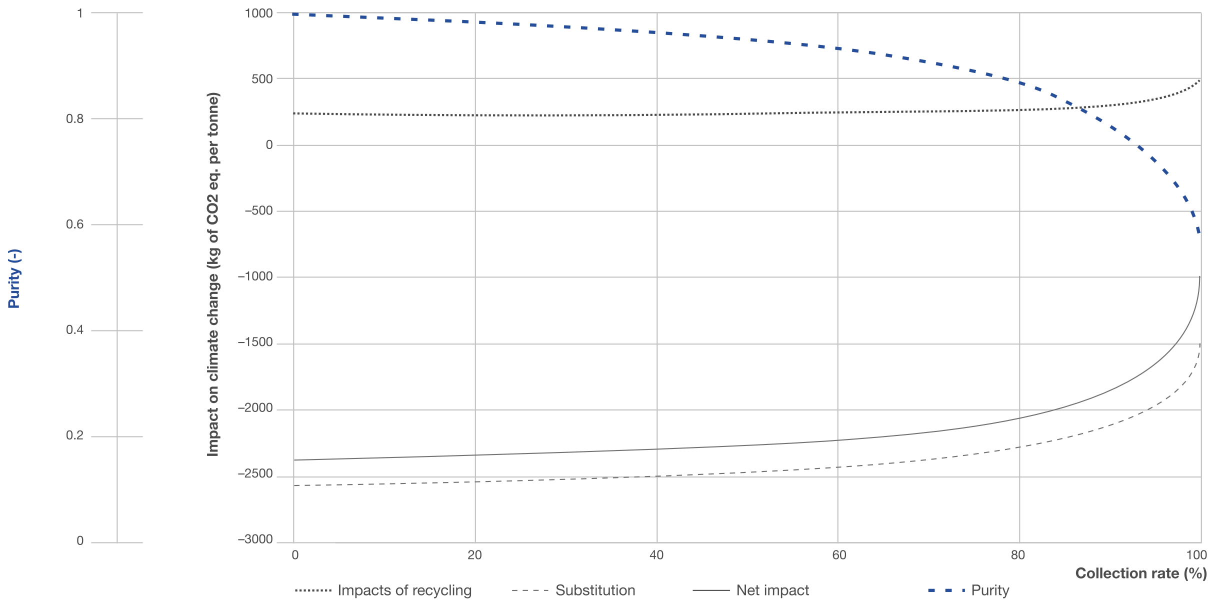
A further problematic area is the lack of transparency, especially with respect to the acceptance of measures aimed at increasing recycling rates, which would make sense from an environmental and energy perspective. As the calculations show, these are associated with considerable cost increases for the Swiss municipal solid waste management. As the synthesis on "Acceptance" of the National Research Programme "Energy" makes clear, transparency is a fundamental requirement for gaining trust in political measures among the population. This applies even if additional costs arise.

Notes and References

1 Project "Economics of waste-to-energy systems"
2 Project "Economics of waste-to-energy systems"

Recyclable material # Recycling # Price # Households # Businesses

1.3.5. Material quality has a considerable effect on environmental benefits



Correlation between the purity of the PET bottle collection and the PET bottle collection rate. The correlation between the collection rates and the impact on climate change is also shown. Positive figures represent environmental impacts (e.g. emissions or energy requirements), negative figures represent environmental benefits (avoided emissions or gained energy). *Source: Haupt et al. (2018)*

In two case studies, the impact of the collection behaviour on material quality and the effect of material quality on the life cycle assessment of recycling processes were investigated. To this end, the recycling of PET bottles and steel scrap from MSWI plants were investigated in more detail.

The PET recycling case study clearly demonstrated that an increase in collection rates is associated with a decline in material purity. This subsequently leads to greater costs in the recycling system; the causes range from longer-distance transportation and greater sorting requirements to the disposal of additional residues. The linear models used until now, which assume that the same environmental benefits can be gained from each additional tonne of collected recyclables, are thus overly optimistic. However, the new dynamic model, which was developed on the basis of the study’s results, also shows that PET bottle recycling is environmentally beneficial even in the case of very high recycling rates when compared to incineration.[1]

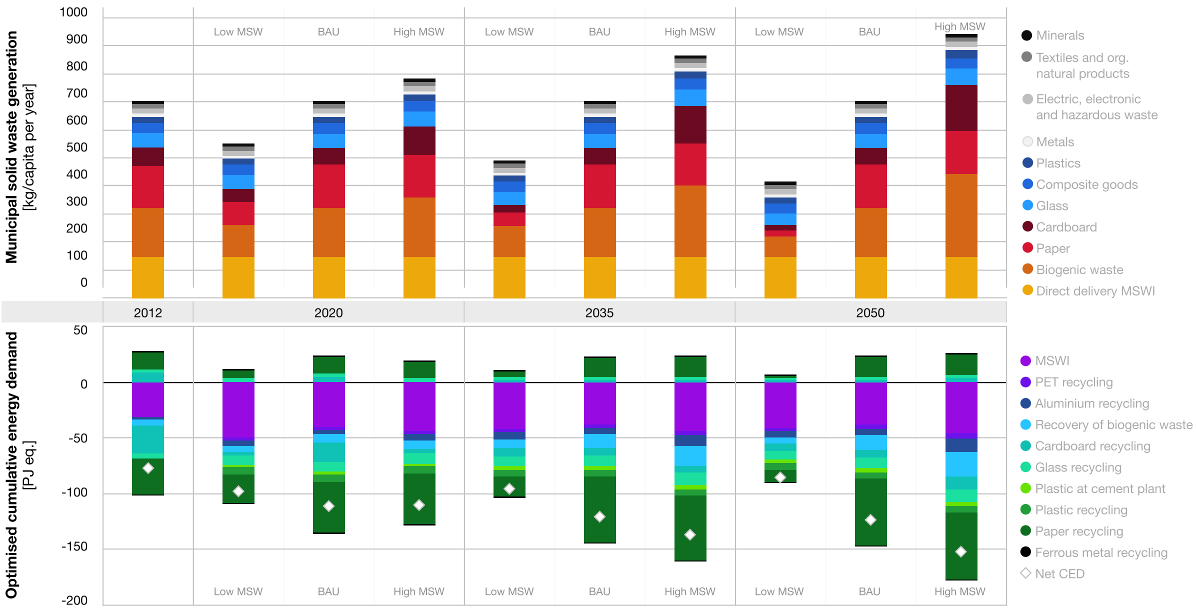
The purity of the materials has a major influence on the environmental impact. This also applies in the case of steel scrap. The production data of an industrial partner revealed that the electricity consumption for the recycling of contaminated steel scrap recovered from the municipal solid waste incineration bottom ash is 40 % higher than for medium-quality scrap collected separately. If the steel scrap is contaminated with other metals such as copper, the quality of the produced steel declines. This means that its utilisation options are also diminished, as copper can no longer be removed from the molten steel. The prior mechanical treatment of scrap recovered from MSWI bottom ash can reduce contaminants.

Notes and References

1 Haupt, M., E. Waser, J.-C. Würmli, and S. Hellweg. 2018. Is there an environmentally optimal separate collection rate? Waste Management.

Recyclable material # Combustible / fuel # Energy efficiency # Sufficiency # Businesses

1.3.6. The Swiss waste management system still has potential for improvement



Top: municipal solid waste production in the various scenarios (MSW = municipal solid waste, BAU = business-as-usual). Bottom: optimal contribution to the energy turnaround as cumulative energy demand for all scenarios (energy scenario: New Energy Policy, SFOE). The cumulative energy demand describes the total energy demand deemed to be accounted for by primary energy arising in connection with the production, use and disposal of a product. *Source: Melanie Haupt, ETH Zürich*

The environmental optimisation potential of the Swiss municipal solid waste management system is still a long way from being exhausted. This is the conclusion drawn by comprehensive modelling activities conducted as part of the joint project. Here, three waste and energy framework scenarios over three time horizons (2020, 2035 and 2050) were observed,[1] taking into account the following four environmental indicators: impact on climate change, cumulative energy demand, human toxicity and ecotoxicity.

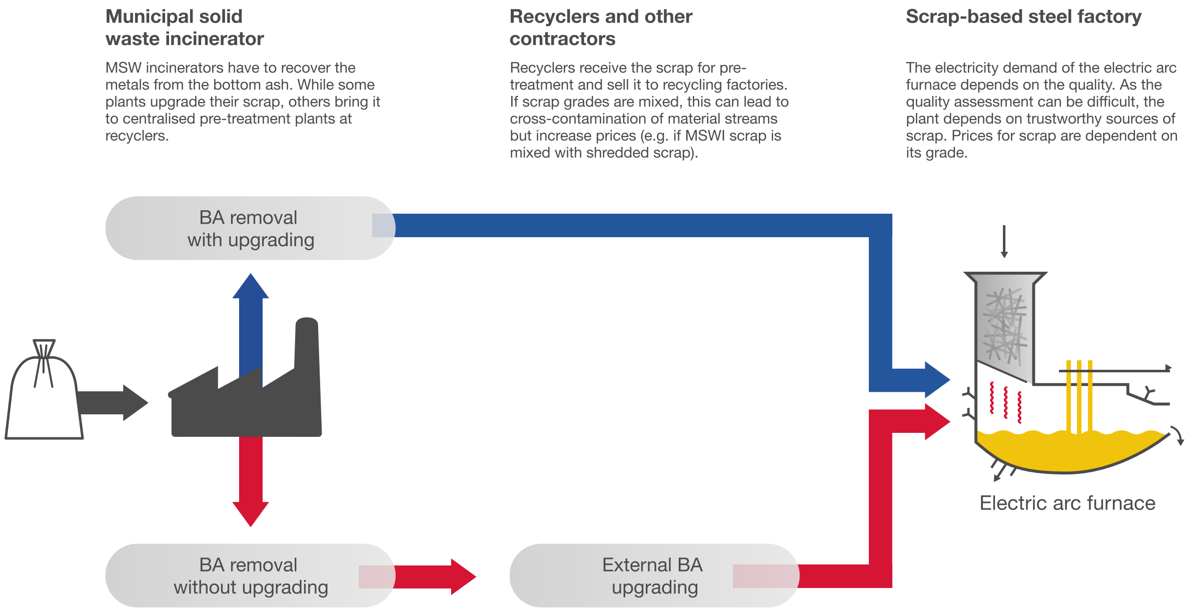
With high quantities of waste, the energy recovered both directly and indirectly can be more than doubled by 2050 irrespective of the energy mix. If a reduction of 40 % in waste quantities is assumed, 10 % more energy can still be recovered. Indirect energy benefits, which are achieved by substituting primary materials with secondary materials, are of great importance. However, this requires the fulfilment of two conditions: firstly, the recycling material must actually replace primary material and must not become a cheaper additional source that stimulates consumption. Secondly, the increase in recycling must not simply be the result of a greater volume of waste. From an environmental perspective, avoiding waste is always more beneficial than its subsequent recycling.

Notes and References

1 Meylan, G., M. Haupt, M. Duygan, S. Hellweg, and M. Stauffacher. 2018. Linking energy scenarios and waste storylines for prospective environmental assessment of waste management systems. Waste Management 81: 11-21.

Acceptance # Guidance # Sustainability # Decentralisation # Businesses # Politics (federal government, canton, municipality)

1.3.7. Stakeholder diversity represents both a barrier and an opportunity



Value chain based on the example of steel scrap recovered from MSWI bottom ash. MSWI plants, recyclers and processors exert a great influence on material quality. A steelworks, in contrast, is dependent on other stakeholders, as the electricity consumption and the resulting steel quality depends on the quality of the scrap.
Source: Melanie Haupt, ETH Zürich

In some instances, the various stakeholders in the Swiss waste management system understand sustainability differently. For example, economic and trade organisations primarily focus on the economic dimension. They thus question certain recycling practices when they believe there is no reliable market for the secondary products. There is also no agreement as to whether it would be better to assess environmental sustainability on the basis of waste hierarchies or life cycle assessments. The discourse analysis conducted as part of the project "Modernising waste management"[1] suggests that these differences are underpinned by the different core beliefs and pragmatic interests of stakeholders.

On the one hand, these fragmented interests may represent an opportunity as the various stakeholders can test different innovations, allowing for more experiences to be gained with new technologies and practices. On the other hand, a system change will require dialogue and intensive cooperation between the relevant stakeholders if the various activities are not to run contrary to one another. Just how important this can be for unlocking potential was demonstrated by the improvement in the value chain for steel scrap recovered from MSWI bottom ash. Together, it was possible to simultaneously reduce energy consumption and increase resource quality. For many recycling processes, the decisive measures have to be performed by a stakeholder that personally gains no benefit from the savings which are generated much later in the chain.

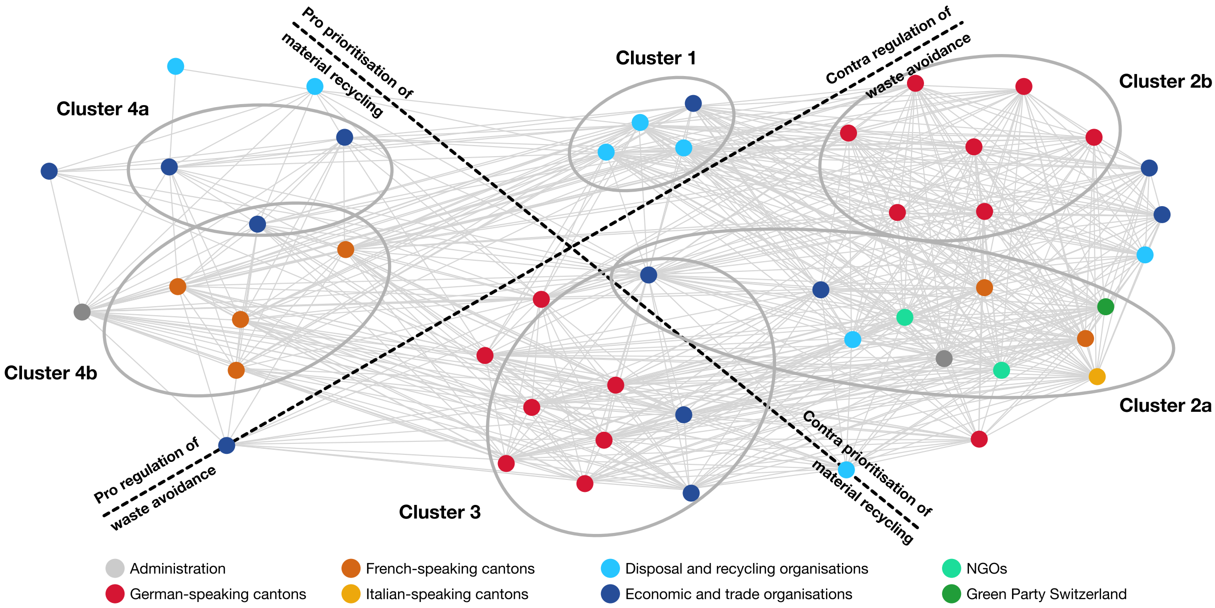
The social dimensions of sustainability, such as quality of life or intergenerational and intragenerational justice, are only a secondary issue for the stakeholders in the Swiss waste management system. The synthesis on “Acceptance” shows, however, that this can have a boomerang effect if the approval of the population is required, for example, for the relocation of a MSWI plant. The population attaches much greater importance in particular to quality of life and justice than to environmental aspects.

Notes and References

1 Project “Modernising waste management”

Market # Consensus # Guidance # Public administration # Businesses # Politics (federal government, canton, municipality)

1.3.8. Network analyses reveal the impact of individual stakeholders and their links



Discourse network in the debate on the waste hierarchy. The grey links shows the number of waste hierarchy policy statements shared by the stakeholders. Six clusters on the issue were identified. *Source: Duygan et al. (2018)*

Socio-technical systems such as the municipal solid waste management system are characterised by the fact that various systems and technologies are linked to one another and are thus also dependent on each other. There are also various mutual dependencies between the economic, political and social stakeholders and organisations involved. Many written and unwritten rules apply in the interplay between the different players. Those who want to influence the system should therefore know the stakeholders and their interests as precisely as possible. This applies, in particular, in cases in which fundamental changes are to be initiated, such as those required for the environmental optimisation of Swiss municipal solid waste management system.

The project “Modernising waste management” recorded and analysed the networks in the municipal waste management system.[1] The more similar the opinions and interests that they represent, the closer together the stakeholders are placed in the network (see figure above). Among others, stakeholders who belong to several different interest groups were identified during the recording of the network. As bridge-builders, these could help to lead discussions and promote cooperation between two different groups.[2] Furthermore, individual stakeholders who have until now had a major impact on political affairs such as the revision of the technical Waste Ordinance were determined.

Excessive barriers to the optimisation of the waste management system are likely to lead to the resistance to change typically observed for socio-technical systems. The established stakeholders generally have an interest in ensuring that the system remains as it is with respect to its technical and institutional characteristics.

Notes and References

1 Project "Modernising waste management"
2 Duygan, M., Stauffacher, M., & Meylan, G. (2018). Discourse coalitions in Swiss waste management: gridlock or winds of change? Waste Management, 72, 25–44. https://doi.org/10.1016/J.WASMAN.2017.11.006

1.4. Optimise the worthwhile elements and the system as a whole

Plastic, paper and cardboard as well as the energy efficiency of MSWI plants are among those elements of the Swiss waste management system that offer the greatest potential for improvement. It is important to always consider the entire life cycle and the system as a whole when assessing improvement potentials and proposing future developments.

Recycling # Price # Costs / benefits # Politics (federal government, canton, municipality)

1.4.1. Quality makes a major difference - for waste too!

The quality of plastic varies greatly depending on the collection system. Mixed plastics from households comprise various polymers which have to be sorted with great effort. Low-quality products such as cable conduits are usually produced from mixed plastics. In contrast, colour-sorted PET bottles (visible in the middle of the picture above) can be recycled into PET bottles. *Source: Maja Wiprächtiger, ETH Zürich*

The environmental and energy optimisation of the municipal solid waste management system has shown that increased recycling allows for more energy to be saved than can be recovered through incineration. Nevertheless, it is not only the quantity of waste recycled that plays a role here, but rather also the quality of the recycling. Only if the quality of the secondary materials generated from the recycling process meets the demand of customers, high-quality primary materials can be replaced and the environmental impact be optimised.

An increase in collection rates may potentially reduce quality.[1] For example, if the collection rate of materials is increased by recyclables collected from public and unsupervised spaces, the danger of contamination is much greater than in the case of collection points with retailers or at central collections points such as waste disposal and recycling centres. Where waste is incorrectly sorted, for example when it is mixed with composite materials, the sorting process is made more difficult or even impossible. It is therefore essential that awareness levels among the population are improved.

However, even if a high collection quality is achieved, secondary material is often only used if it is cheaper than primary material or if its application is legally required. In order to increase sales of secondary materials, corresponding political framework conditions or financial incentive systems are therefore necessary. For example, regulations requiring green procurement in the public sector could have a major impact.

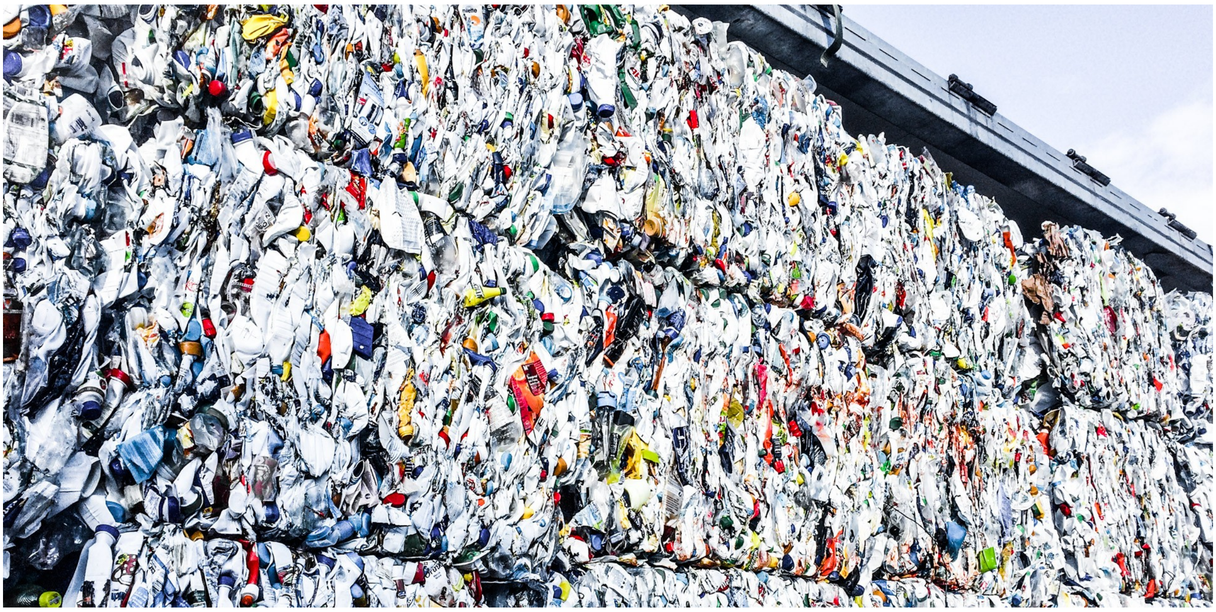
In this context, however, it must also be taken into account that a closed cycle does not necessarily represent a better solution than further use in another product (e.g. the use of packaging glass for foam glass insulation). The optimum recycling approach from an environmental and energy perspective should therefore be determined for all materials and applications on the basis of a life cycle assessment that incorporates and evaluates the material's entire life cycle.[2]

Notes and References

1 Haupt, M., E. Waser, J.-C. Würmli, and S. Hellweg. 2018. Is there an environmentally optimal separate collection rate? Waste Management.
2 Haupt, M., T. Kägi, and S. Hellweg. 2018. Modular life cycle assessment of municipal solid waste management. Waste Management 79: 815–827.

Recycling # Energy efficiency # Costs / benefits # Public administration # Businesses # Politics (federal government, canton, municipality)

1.4.2. Plastics offer significant recycling potential that is yet to be tapped



Plastics recycling – collected hollow vessels. *Source: Maja Wiprächtiger, ETH Zürich*

Until now, plastics have primarily been collected as part of mixed municipal solid waste and are, therefore, subsequently disposed of at municipal solid waste incineration plants. This situation is slowly changing, as in addition to the system for PET bottle recycling, which will soon celebrate its 30th birthday, collection systems for other polymers such as polyethylenes and polypropylenes have been under development for a number of years. So-called monomaterials, i.e. products that comprise only one polymer or those that can easily be separated into individual polymers, are especially attractive from an environmental perspective. At present, the material qualities of the collected waste usually only permit use in low-quality applications. As the supply of secondary polymers is still currently very small, they can nevertheless be sold and replace primary materials. In the event of a marked increase in recycling rates, this will only continue to be possible if, in parallel to this development, a greater focus is placed on separate collection (as individual polymer types) and if the markets for secondary materials are developed in a targeted manner.

The financing of plastic recycling systems also needs to be clarified as current findings suggest that the revenues generated do not cover the associated costs.[1] At present, the still very small systems are either financed through pay-per-bag fees or cross-subsidisation. For PET bottle recycling, an advanced recycling fee has been charged per bottle upon purchase for a number of years. Whether such structures are also appropriate for other plastics needs to be examined.

For low-quality plastics and many composite materials, thermal utilisation is the most suitable utilisation form from an environmental and energy perspective.[2] Wherever possible, this should take place at a cement kiln where plastics usually replace CO_2-intensive coal as a fuel. In a MSWI plant, on the other hand, a less CO_2-intensive mix comprising non-renewable and renewable energy sources such as gas, wood and crude oil is substituted. What is important for the co-incineration of plastics at cement kilns is that the material does not contain any inorganic pollutants or halogens as in the case, for example, of PVC.

Notes and References

1 Project "Economics of waste-to-energy systems"
2 Haupt, M., T. Kägi, and S. Hellweg. 2018. Modular life cycle assessment of municipal solid waste management. Waste Management 79: 815–827.

Recycling # Energy efficiency # Costs / benefits # Public administration # Businesses # Politics (federal government, canton, municipality)

1.4.3. Paper and cardboard: large quantities mean considerable savings

Left: fibre from paper recycling before and after deinking. Right: storage facility with mixed waste paper and cardboard at the former Utzenstorf AG paper factory. *Source: Melanie Haupt, ETH Zürich*

Paper and cardboard recycling offers great potential for improvement, especially as the actual recovery rates are lower than previously assumed. For example, recycling rates have been overestimated because of the strong growth in packaging imports related to e-commerce not being taken into account in calculations of recycling rates.[1] In order to prevent a situation in which paper and cardboard quality declines due to the increase in collection rates, however, new collection or sorting mechanisms are required.

Viewed from an energy-efficiency perspective, both paper and cardboard should be recycled in Switzerland. An exception is the incineration of cardboard in a very energy-efficient MSWI plant which makes optimal use of the released heat. The saved greenhouse gas emissions can in this case be greater than those achieved through recycling. The difference in environmental impacts are small, however, and an improvement in the efficiency of cardboard recycling would shift the balance once more in favour of material utilisation.[2]

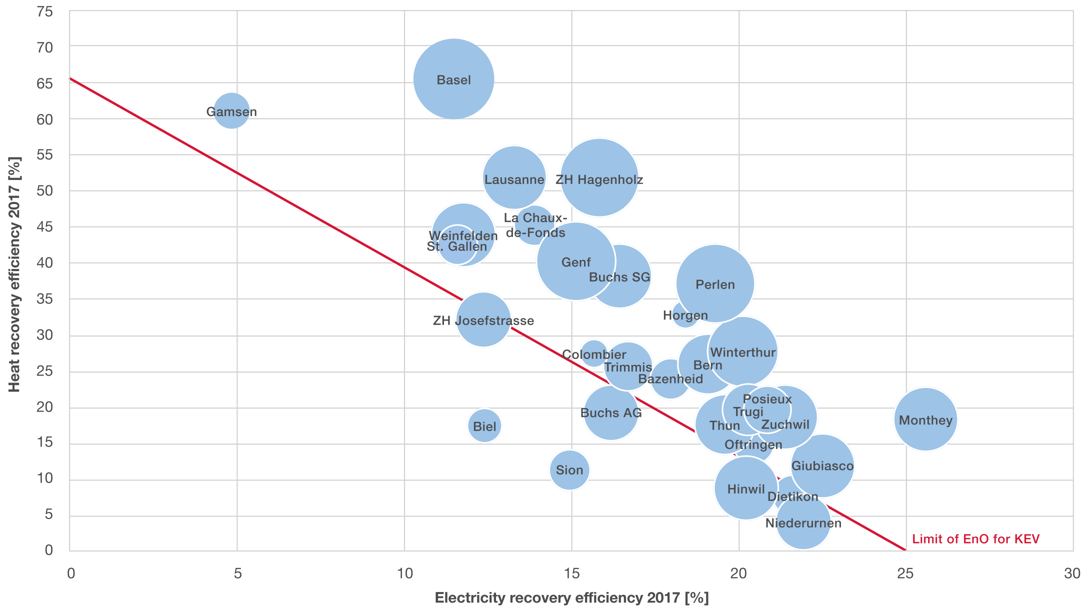
Notes and References

1 Haupt, M., C. Vadenbo, and S. Hellweg. 2017. Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System. Journal of Industrial Ecology 21(3): 615–627.

2 Haupt, M., T. Kägi, and S. Hellweg. 2018. Modular life cycle assessment of municipal solid waste management. Waste Management 79: 815–827.

Combustible / fuel # Energy efficiency # Energy provision # Public administration # Politics (federal government, canton, municipality)

1.4.4. The energy efficiency of MSWI plants can be greatly increased



Net heat and electricity recovery efficiencies of Swiss MSWI plants in 2017. EnO = Swiss Energy Ordinance, KEV = Compensatory feed-in remuneration. Data from Rytec (2018). *Source: Rytec (2018), angepasst von Melanie Haupt, ETH Zürich*

Swiss municipal solid waste incineration plants are a long way from achieving the currently feasible energy recovery efficiency rates. There are various reasons for this. On the one hand, a number of facilities are relatively old. On the other hand, insufficient account was taken in the past of energy-efficiency considerations when planning the respective locations as focus was placed on safe disposal. At the current locations the heat demand is often too small as only few consumers are located close enough for the heat and steam to be transported to them. The MSWI plants in Gamsen, Lausanne, Perlen and Basel (see figure) show in an exemplary manner how proximity to industry can be used to achieve a very high energy efficiency.

The potential offered by a national location strategy is highlighted by calculations conducted as part of the joint project. In the extreme scenario, a reduction to five plants across Switzerland was assumed.[1] These plants could be placed at strategic locations at which delivery distances can be minimised and the energy yield can be maximised. The results show that the potential for improvement offered by making adjustments to Switzerland's MSWI plants is greatly dependent on both the waste and energy scenario.

- Scenarios with few MSWI plants (reduction to five plants by 2050) and less municipal waste: the thermal capacity of the MSWI plants is fully utilised by mixed municipal waste and direct deliveries. A reduction in the number of plants and thus the incinerated waste combined with an increase in efficiency rates leads to a similar level of energy recovery to that seen in 2012.

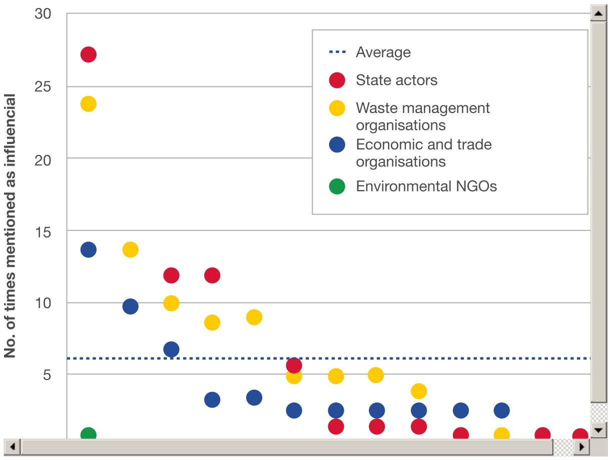
- Scenarios with 27 to 29 MSWI plants and 700 kg to 900 kg of municipal solid waste per person and year: the optimisation of the contribution of the waste management system towards the energy turnaround leads to higher recycling rates, which in turn means that in 2050 only around two-thirds of the MSWI capacity would be utilised.
- Greenpeace energy scenarios (fully renewable energy in 2050): since the recovered heat replaces renewable energy, the environmental credits are correspondingly small. Less waste is therefore taken to the MSWI plants, meaning that less energy is also recovered. It must, however, be noted that in return more indirect energy is saved through the recycling of materials.

Notes and References

1 Meylan, G., M. Haupt, M. Duygan, S. Hellweg, and M. Stauffacher. 2018. Linking energy scenarios and waste storylines for prospective environmental assessment of waste management systems. Waste Management 81: 11–21.

Acceptance # Energy efficiency # Guidance # Costs / benefits # Population # Politics (federal government, canton, municipality)

1.4.5. Transparency is essential for optimisation



Influence of individual stakeholders on the decision-making process. *Source: Mert Duygan, ETH Zürich*

A great deal of new data had to be collected for this study. In order to optimise the system in the long term and review its progress on an ongoing basis, the systematic collection of data on waste flow quantities and money flows will be required. Decision-making processes should likewise be structured and reported on transparently.[1 2]

At a material level, transparency is needed in order to close material cycles and convert the various waste flows once more into marketable secondary products. Cleanly separated collection is a prerequisite for the closing of material cycles and the substitution of high-quality materials. To this end, it must be known what a material comprises and which fractions have been mixed in the collection. Labels may help with the identification of materials.

In the area of finance, transparency is essential in order to allow for informed policy decisions to be made and corresponding objectives to be developed further. However, with respect to the assessment of costs and income, obvious gaps have been identified in the communication of financial data. The stakeholders in the waste management system should therefore be required to present transparent financial information. This could also be done via the respective associations, which could then aggregate the data and communicate it on an anonymous basis.

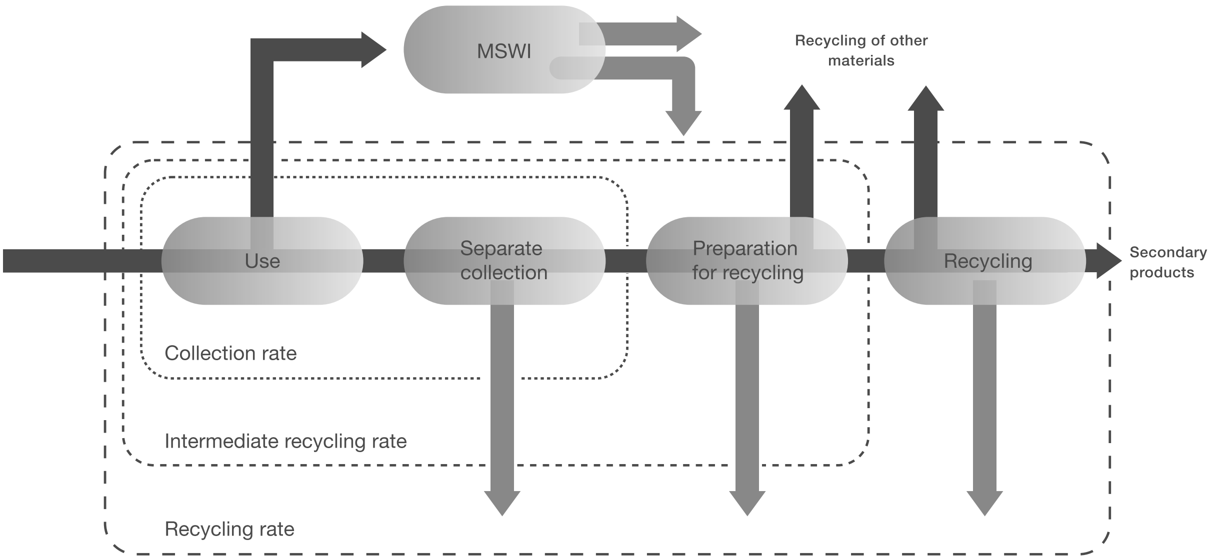
Greater transparency in the decision-making process is necessary for the acceptance of new strategies among the population. Current political processes in the area of waste management are prone to lobbying and this undermines the confidence of the population and industry in politicians. With transparent and analytical processes, the excessive influence of individual stakeholders could be minimised.[3]

Notes and References

1 Haupt, M., C. Vadenbo, and S. Hellweg. 2017. Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System. Journal of Industrial Ecology 21(3): 615–627.
2 Project "Economics of waste-to-energy systems"
3 Duygan, M., M. Stauffacher, and G. Meylan. Determinants of strong agency in socio-technical transitions: A study of Swiss waste management. In Preparation.

Recyclable material # CO2 / greenhouse gases # Guidance # Sustainability # Energy provision # Businesses # Politics (federal government, canton, municipality)

1.4.6. The sustainability of the Swiss waste management system must be measurable



Measurement points of previous indicators of the Swiss waste management system.
Source: Haupt et al. (2017)

Only things that are measured can be controlled. This principle of course also applies to the Swiss waste management system. It urgently requires objective systems that support sustainable development. The current monitoring of waste management systems is primarily based on collection rates; a measurable yet purely quantity-based parameter that does not take into account the effects on people and the environment. The project “Energy recovery in waste management”[1] revealed that quantity-based objectives are neither good indicators for closed resource cycles nor provide information on the environmental friendliness of the system.[2] [3] The current control mechanisms and objectives at the level of collection rates therefore neither cover the political goals of sustainable waste management nor correctly highlight the existing improvement potential.

In order to measure the sustainability of material recycling, it is essential not only to know the collection rates, but also the processes applied following collection as well as their losses and energy consumption. The only quantity-based statistic that takes account of all losses and thus provides a basis for a comprehensive sustainability assessment is the recycling rate. To allow for further utilisation to also be assessed from an environmental and economic perspective, additional details about the subsequent processes and the use of recycled materials need to be collected. For example, it needs to be ascertained whether materials are circulated in a closed loop or in an open loop (i.e. in a cascade). Based on a comprehensive quantity-based recycling rate statistic of this kind, a meaningful assessment of the environment impacts and life cycle costs can subsequently be conducted.

Notes and References

1 Project "Energy recovery in waste management"
2 Haupt, M., C. Vadenbo, and S. Hellweg. 2017. Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System. Journal of Industrial Ecology 21(3): 615–627.
3 Haupt, M., T. Kägi, and S. Hellweg. 2018. Modular life cycle assessment of municipal solid waste management. Waste Management 79: 815–827.

Knowledge and technology transfer # Just distribution # Consensus # Guidance # Public administration # Businesses

1.4.7. A system change necessitates a common implementation strategy

System change not climate change. Young protesters demand a system change.
Source: Flickr (Joe Brusky)

The comprehensive analyses performed as part of the joint project show that all dimensions of sustainability need to be taken into account when transitioning to an environmentally optimal waste management system. The project's findings thus provide a basis upon which the discussions initiated in the area of waste management concerning resource efficiency, the environmental benefits of recycling and other value-preservation processes, can be continued in the direction of practical implementation.

The discussions with, as well as between, industrial and state stakeholders are already yielding initial results. The circular economy, which is being promoted at an international level and also being met with political approval in Switzerland, has strengthened this dialogue. Aspects related to energy-efficiency and the environment are increasingly being incorporated in a wide range of planning activities. The knowledge that recovery paths should not only be assessed from a quantity-based perspective means that waste management is increasingly viewed as a system. The advisory board members and other industrial partners have opened many doors that will enable the knowledge to be transferred to the industrial sector.

A major barrier to the proposed system change are so-called technological lock-ins. Waste management infrastructure generally has a long service life over which it must be amortised. This prevents the introduction of new technologies and processes and thus also the implementation of new strategies. For example, the separate collection of plastics runs contrary to the self-interests of MSWI plant operators, who have designed their plants considering plastics as a fuel. The technological link can thus lead to resistance to structural changes.

1.5. Nine recommendations for more energy-efficient waste management

The findings from the joint project “Waste management to support the energy turnaround” have been brought together to make concrete recommendations for action that are specifically geared towards the relevant stakeholders in the Swiss municipal waste system.

Guidance # Sustainability # Associations and NGOs # Businesses # Politics (federal government, canton, municipality)

1.5.1. Steer waste management based on sustainability criteria rather than quantities!

Integrated waste management can make a significant contribution to the achievement of the Sustainable Development Goals (SDGs). The figure shows how the SDGs have been addressed in the optimisation of the Swiss municipal solid waste management system. *Source: Melanie Haupt, ETH Zürich*

The ability to control waste management necessitates measurable and meaningful indicators. Only if these reflect sustainability criteria will it be possible to optimise waste management in line with the Energy Strategy 2050.

The current indicators of the Swiss waste management system primarily aim to increase the quantities collected for recycling.[1] Areas of potential that, for example, relate to the quality of recycling have been neglected until now. Indicators are required that assess waste management with respect to their social, environmental and economic impact and cover the entire waste management system from the sorting of waste in households to the utilisation of secondary resources. The indicators should also be defined more broadly so that they are not only applicable to individual products (e.g. aluminium cans), but also entire material flows (entire aluminium fraction).

More comprehensive and detailed sustainability criteria create the basis for holistic optimisation:

- Indirect energy use: a sound collection infrastructure serves to strengthen the population's awareness and promotes the collection of high-quality fractions (environmental dimension).

However, this leads to additional costs (economic dimension).

- Direct energy use: the incorporation of local heating requirements in the selection of MSWI plant locations or the creation of local heating demand (e.g. placement of greenhouses or industry next to the MSWI plant or expansion of district heating networks) increases their energy efficiency (environmental dimension). The consideration of acceptance levels among the population and the bringing together of stakeholders helps to ensure the success of projects. An intensified dialogue between municipalities and cantons makes it easier to pursue coordinated strategies (social dimension). The consideration of financial factors such as transport distances and energy-efficiency or support contributions such as compensatory feed-in tariffs enables the optimisation of income and costs and is important for allowing economic incentives to be set (economic dimension).

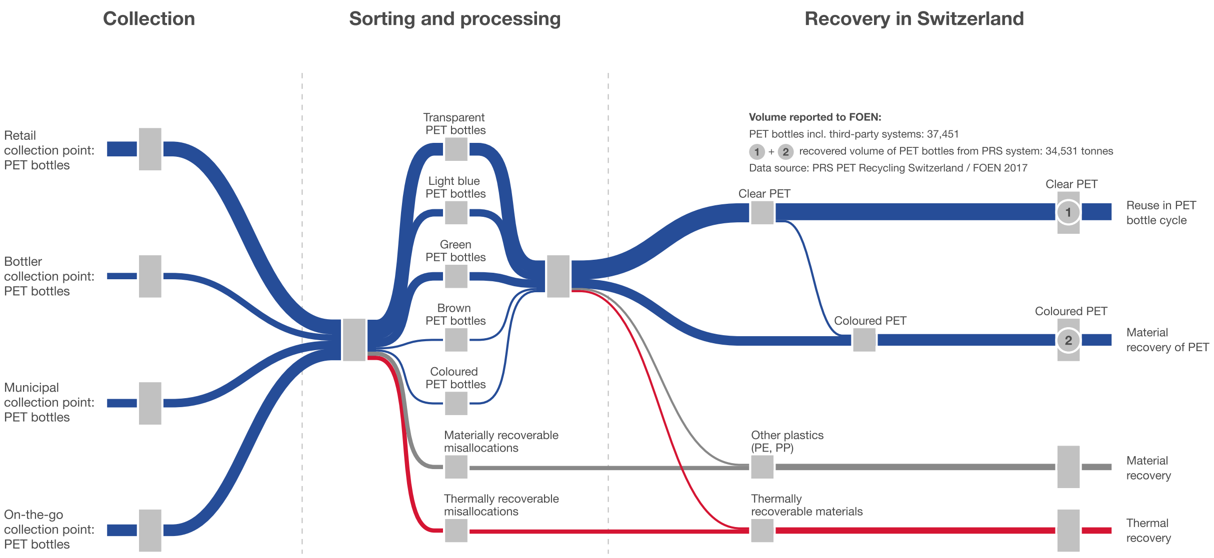
The definition of such criteria at a national level and for all material flows is the responsibility of the federal government. Nevertheless, associations can assume a pioneering role for individual systems, as it is currently being observed in the area of municipal waste.[2]

Notes and References

1 Haupt, M., C. Vadenbo, and S. Hellweg. 2017. Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System. Journal of Industrial Ecology 21(3): 615–627.
2 Development of Target System 2030 by Swiss Recycling and experts. Further information can be found at https://www.circular-economy.swiss/schwerpunkte/indikatoren/

Digitalisation # Guidance # Costs / benefits # Associations and NGOs # Businesses # Politics (federal government, canton, municipality)

1.5.2. Create complete transparency with respect to costs, material flows and decisions!



New transparency in the Swiss municipal waste system: excerpt from the Swiss Recycling 2019 Performance Report (Leistungsbericht 2019). *Source: Swiss Recycling*

Transparency is essential in order to understand the overall Swiss waste management system and improve it in a targeted fashion. However, the large number of stakeholders and the federal organisational structure make gaining and maintaining an overview more difficult.

The recording of material flows in Switzerland works perfectly for some clearly defined waste fractions such as the separately collected PET bottles. In contrast, however, only very rough estimates of the original use of metals, for example, are made. The measurement of the separately collected quantities thus hardly allows for conclusions to be drawn about collection and recycling rates. In order to identify improvement potentials, transparency needs to be created or increased in the following areas:

- Waste recyclers should make data available on the treated waste streams. While this is now governed in the Waste Ordinance (VVEA), there is currently no requirement to declare the origin of the waste.
- The recycling sector and its associations are called upon to provide data on the recycling processes (efficiency of the sorting and recycling processes, removed contaminants, secondary utilisation of recovered materials).
- The MSWI plants should record the origin and composition of waste more precisely and make this information available (significant data gaps exist in particular for direct

deliveries).

- Additional data on the consumption of primary products can only be collected and analysed if there is cooperation between the manufacturing industry (product sales) and the authorities (details on the population's consumption behaviour).
- Knowledge of the exact product composition is required for high-quality recycling and closed cycles. As much transparency as possible is therefore needed with respect to the contents of all products. This could be achieved either by means of product labelling or through the standardisation of the material composition. Digitalisation provides interesting opportunities for the tracking of material flows and the labelling of products with information on their contents.

It is equally important that the greatest possible level of transparency is ensured for consultation procedures and all other important political decision-making processes. This applies both to the different positions of politicians, associations, etc. and opinions as well as to the decisions derived on this basis.

Recyclable material # Recycling # Public administration # Households # Businesses # Politics (federal government, canton, municipality)

1.5.3. Cleanly separate waste fractions at the source and then keep them clean!

Waste collection is a lifestyle – at least at this separate collection point in Singapore.
Source: Melanie Haupt, ETH Zürich

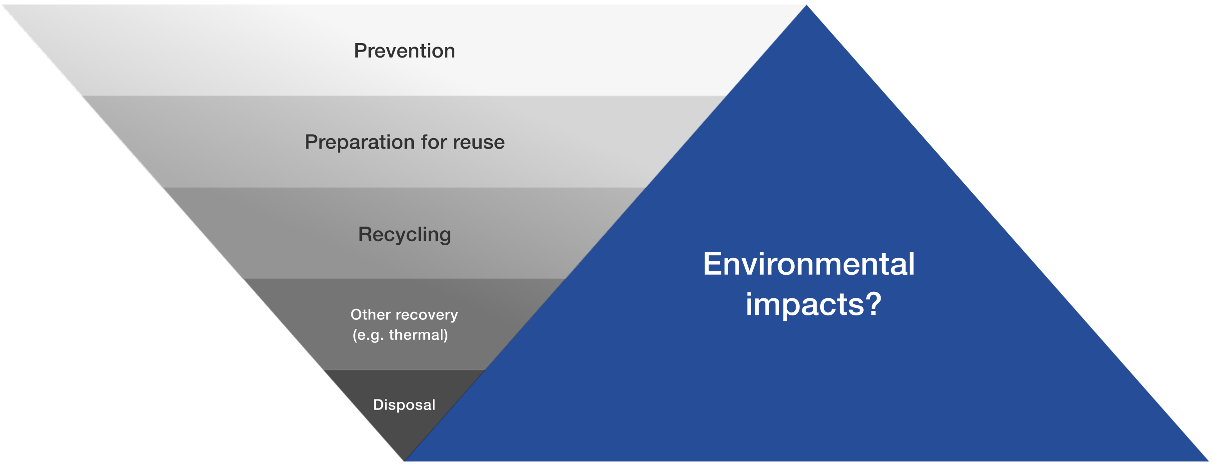
The separate collection of waste by consumers forms the basis for the efficient processing of waste into marketable resources. This applies, in particular, to materials that subsequently can no longer be sorted.

The municipalities play a key role in ensuring separate collection. On the one hand, they are responsible for the collection points and with this infrastructure provide the foundation for the clean separation of different waste fractions. On the other hand, they also play a decisive role, together with their waste disposal organisations, in communicating with the public and can raise awareness among residents concerning the importance of the clean separation of waste upon collection.

Waste that has been collected as monomaterials, i.e. not mixed with other material fractions, must also remain cleanly separated during subsequent processing. It is therefore key that recycling businesses are informed about all aspects of the quality of secondary resources. At present, often only the economic consequences of contaminants are known. The environmental benefits of clean material fractions, however, are often unknown or disregarded. In order to optimise recycling as a whole, objectives for all dimensions of sustainability (economic, environmental, social) and defined goals (e.g. with respect to the share of foreign bodies in collections) are essential.

Knowledge and technology transfer # Recycling # Information / communication # Sufficiency # Businesses

1.5.4. Avoid waste – but only if this makes sense!



Waste prevention is the top priority of the waste hierarchy and is usually beneficial from an environmental perspective. To generate real environmental added value, however, a number of things need to be taken into account here. *Source: Melanie Haupt, ETH Zürich*

From an environmental and economic perspective, it is in many cases best if the formation of waste is avoided. However, neither the manufacturing industry nor recycling businesses feel an obligation with regard to this issue.

In 2017, the Swiss population produced 720 kg of municipal waste per person. In the joint project, municipal waste quantities of between 400 kg and 850 kg per person and year were assumed. A reduction to 400 kg per person would require, among other changes, a reduction in the consumption of paper and cardboard as well as less food waste.[1]

The prevention of waste does, however, not always lead to a reduction in environmental impacts. For example, it makes no sense to purchase a tablet exclusively for reading newspapers even if this leads to a considerable decline in paper consumption. To enable a detailed examination of the consequences of waste prevention, the industrial sector will need to cooperate with research institutions and product developers. As purchase decisions ultimately lie with consumers, they also need to be informed and provided with recommendations for action.

Facts on waste prevention in Switzerland:

- It rarely makes sense to replace non-recyclable plastic packaging that is properly disposed of with recyclable disposable glass. The latter entails significantly greater production expenditure and the recycling process is also less beneficial from an energy-efficiency perspective due to the high melting temperatures.

- A large amount of consumer product packaging could be reduced. For example, cosmetics products are often double packed (e.g. a glass container in a cardboard box), with the external packaging commonly only being used for marketing purposes. In many cases, waste can thus be prevented in a simple manner.
- Packaging protects products and contributes to the avoidance of food waste by extending a product's shelf life. As the food itself is usually far more relevant from an environmental perspective than its packaging, it must be ensured in cases where packaging is avoided that the actual product does not spoil nevertheless.
- If plastic is replaced by materials made from renewable raw materials, the products are usually more durable. From an environmental viewpoint, however, they are only environmentally favourable if they are also in use for a long period. Cotton bags, for example, must be used many times before they can be deemed more environmentally friendly than plastic bags.

Notes and References

1 Meylan, G., M. Haupt, M. Duygan, S. Hellweg, and M. Stauffacher. 2018. Linking energy scenarios and waste storylines for prospective environmental assessment of waste management systems. Waste Management 81: 11–21.

Cold / heat # Energy provision # Decentralisation # Businesses # Politics (federal government, canton, municipality)

1.5.5. MSWI plants need heat and steam consumers in close proximity!

MSWI plants as power stations: at the KEZO disposal and recycling plant in Hinwil, two large greenhouses are connected that use the heat from the municipal solid waste incineration. Electricity is also produced at this MSWI plant. *Source: Christian Merz*

To enable the utilisation of heat and electricity recovered from MSWI plants, consumers must either be situated in the proximity of the MSWI plants or the MSWI plants need to be relocated to be based near consumers.

Historical developments and federal politics have led to Switzerland now having a large number of MSWI plants. However, only a few of these plants are located at sites that are optimal for heat recovery. Generally speaking, the linking with or the local settlement of heat consumers should be evaluated. Prior to modernisation measures being undertaken, the relocation of plants to a location with greater heating requirements should also be examined. The fact that income from the sale of energy currently contributes little to a MSWI plant's revenues is problematic.[1] There is thus a lack of financial incentives for an energetic optimisation. In order to increase efficiency levels, the implementation of the requirement for MSWI plants to achieve net energy-efficiency of 55 % by the end of 2025[2] must therefore be accelerated.

A wide range of stakeholders must contribute to the optimisation of heat utilisation:

- Modelling of future heating demand, especially in residential areas (energy suppliers, research): ever improving building insulation is leading to declining heating requirements per square metre of living space. District heating networks, however, are infrastructures with a long service life and present significant investment requirements, meaning that information about the development of future heating needs is essential for their economic viability.

- Examination of reduction in the number of MSWI plants (cantons, federal government): focussing energy production at locations with a high heating demand such as industrial zones or cities must be analysed. A reduction in the number of plants must, however, go hand in hand with investigations regarding the safe disposal of waste and the long-term development of local heating demand.
- Identification of potential offered by low temperature or residual heat utilisation (businesses, associations): this heat must be used locally and is suitable for greenhouses, for example.

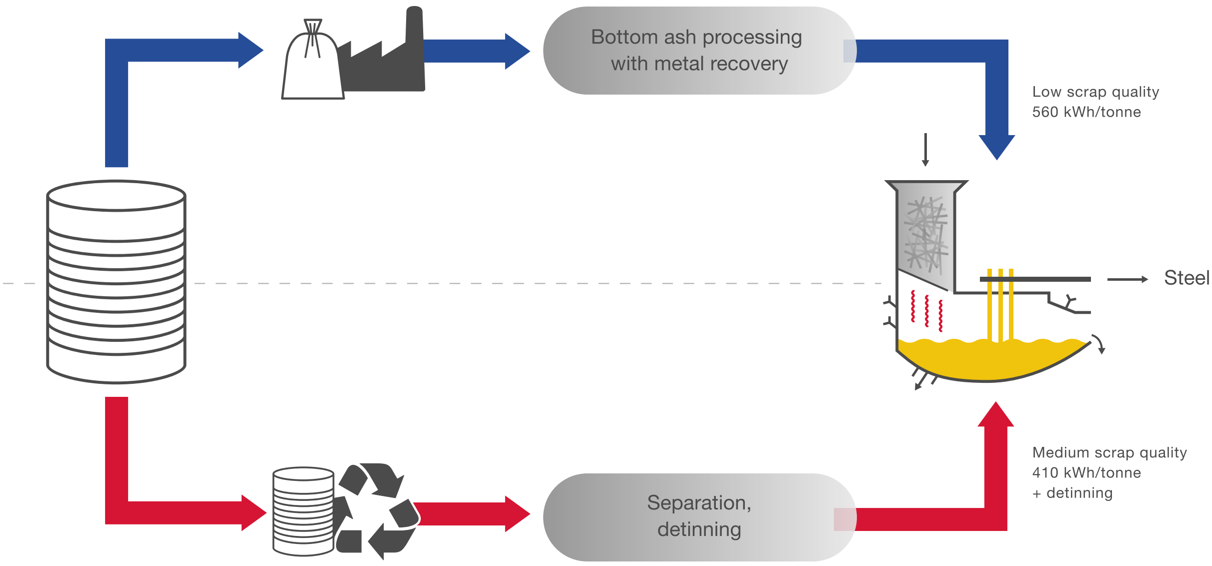
State bodies such as the Federal Office for the Environment are best placed to implement the essential coordination of the various activities.

Notes and References

1 Project "Economics of waste-to-energy systems"
2 ADWO. 2016. Ordinance on the Avoidance and the Disposal of Waste (Waste Ordinance, VVEA) Berne, Switzerland.

Recyclable material # Recycling # Steering / promotion # Associations and NGOs # Businesses # Politics (federal government, canton, municipality)

1.5.6. Define quality standards and compulsory use provisions for recycled materials!



The influence of quality for tinplate recycling. While separate collection results in average scrap grades, the scrap from MSWI plants (without subsequent processing) is of a low quality. This has a major impact on electricity consumption in the recycling sector. *Source: Melanie Haupt, ETH Zürich (basierend auf Haupt et al. (2017),*

On the one hand, the industrial sector should be required to use a minimum share of recycled materials in certain products. On the other, the secondary materials must also meet clearly defined, market-compliant quality standards.

The secondary production of materials from waste through recycling often requires much less energy than production from primary raw materials. To enable high-quality secondary materials to be produced, however, everyone involved is called upon to contribute. Waste needs to be collected as cleanly as possible and the collected materials must be processed into marketable secondary materials at the sorting and recycling centres, taking account of the respective quality requirements.

But this is not the end of the chain. To allow recycling to exploit fully its indirect energy-saving potential, it must also be ensured that the secondary materials in manufacturing industry replace raw materials of the highest possible quality. In order to facilitate this, recycling companies should create common quality standards for their secondary products which make marketability easier and transform the image of recycled products. In addition, however, political assistance is also required to promote the use of secondary materials. One example here is the EU regulation under which the content of new plastic packaging must comprise at least 25 % recycled material by 2025.

The following measures can help to increase the use of high-quality secondary raw materials:

- “Green” procurement in the public sector
- Targeted guidelines aimed at ensuring green procurement in individual industries
- Specification of a minimum share of secondary materials in certain products and construction materials

Information / communication # Acceptance # Sufficiency # Associations and NGOs # Population # Politics (federal government, canton, municipality)

1.5.7. Raise awareness of waste separation and prevention!

Image from the "Brings zurück" ("Bring it back") awareness-raising campaign of Swiss Recycling. *Source: Swiss Recycling*

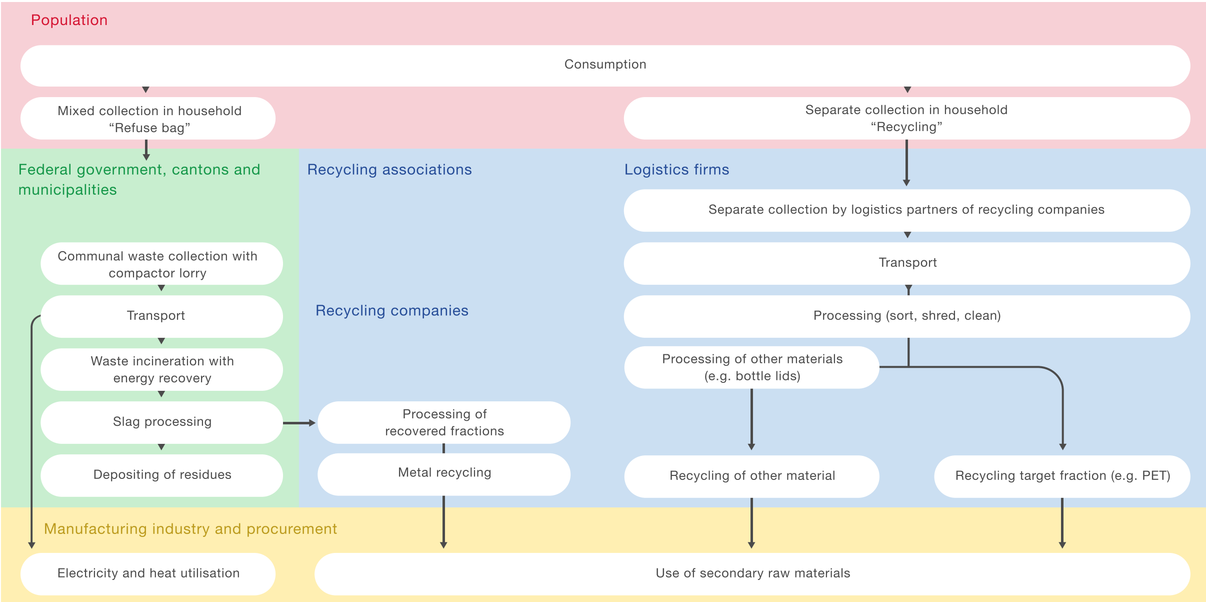
The population has a decisive impact on waste quantities and the quality of collections with its consumption and waste-collection behaviour – and bears a large part of the costs through the payment of fees. A great deal can therefore be achieved with awareness-raising campaigns.

Waste is produced in all households. The population makes an important contribution to recycling by separately collecting and pre-sorting waste. The better they do so, the more sustainable all of the subsequent processes can be. It is therefore important to provide the population with comprehensive information and raise awareness levels. Experience shows, however, that it is difficult to reach all of a society's members. There are thus many myths circulating about waste and its recycling such as "glass is required for waste incineration" and "fuel is required to incinerate waste at MSWI plants". In order to set right such misconceptions, persistent communication is required via municipalities and associations.

A key element for which the population requires repeated training is the clean sorting of recycling fractions following the "what belongs where" scheme. For each person, it should be clear which contaminants are acceptable in a collection (envelopes with windows belong in the waste paper collection!) and which have fatal consequences for the cycle (broken drinking glasses do not belong in the household glass collection!). The communication of environmentally appropriate waste prevention strategies such as "take your own shopping bag to the supermarket" and "buy loose vegetables without plastic bags" are just as important. The need for communication is not confined to waste, however. For example, building owners should also be informed about the benefits of connecting to a district heating network.

Guidance # Cooperation # Associations and NGOs # Businesses # Politics (federal government, canton, municipality)

1.5.8. Create partnerships along value chains!



The value chain in the Swiss municipal solid waste management system and the affected stakeholders. It is important to establish cooperation along the value chain in order to optimise the system. *Source: Melanie Haupt, ETH Zürich*

The change towards a more energy-efficient waste management system will only succeed if the many stakeholders at the different levels – ranging from consumers, manufacturers, municipalities, MSWI plants and recycling organisations to the consumers of energy and secondary materials – pull together in the same direction.

The implementation of new strategies in the area of Swiss municipal solid waste management will require close cooperation between the affected stakeholders due to the federal and multifaceted organisational structure. A common understanding of the issues at hand and the associated objectives must first be created in order for joint solutions to be subsequently developed. Due to the different responsibilities, the type of collaboration networks required for separate collections and for waste incineration differs significantly.

The thermal waste treatment is currently primarily ensured by the municipalities and individual cantons to which the federal government has ceded the monopoly concerning waste management. Although some activities are coordinated at a national level by the Association of Plant Managers of Swiss Waste Treatment Installations (VBSA) as the umbrella organisation, there is no nationwide planning with respect to the MSWI plants and the recovery of energy from waste. This has a negative effect on the efficiency of the system as a whole. In order to implement planning at a national level, all of the key stakeholders such as collection services, incineration plants and energy consumers as well as bottom ash and fly ash processors need to be involved.

While in the area of separate collections there are major differences between the individual material flows, the relevant recycling associations such as PET Recycling Switzerland, IGORA and Biomasse Suisse play a central role in all of them. However, the associations primarily cover the processing side of waste that has already been generated, i.e. the recycling process. In contrast, waste prevention by consumers as well as stakeholders dedicated to recycling and repair and the industries that use the secondary material produced during the recycling process are hardly taken into account. In order for an optimal contribution to the energy turnaround to be made, all relevant perspectives must be taken into account and cooperation must be more comprehensive.

Guidance # Steering / promotion # Decentralisation # Associations and NGOs # Politics (federal government, canton, municipality)

1.5.9. Experiment and support experimentation!

The recycling of beverage cartons was started and subsequently stopped as it was too successful: the quantities collected were too large for the small collection system.
Source: Maja Wiprächtiger, ETH Zurich

The federal organisation of the Swiss waste management system should be used to test various solutions and continuously try out new things. Everyone benefits from the results of such trials. Politicians need to create the required framework conditions.

Cantons and municipalities have great freedom in the area of waste management, for example with respect to the design of infrastructure, logistics or institutional constructs. There is thus also a great difference, for example, between the waste management system of the city of Geneva and that of a Graubünden municipality. This federal structure makes nationwide coordination difficult. In return, however, the individual municipalities and cantons have the opportunity to risk experimenting within the scope of nationwide legislation and try out new things. In order to make effective use of this freedom, openness is required from the responsible authorities with respect to new strategies, always under the condition that safe disposal is assured.[1 2]

Ultimately, everyone benefits from this diversity as they can adopt well-functioning innovations and learn from failures. In terms of time, experiments should initially be limited to around five years. This permits sufficient data to be analysed so that a fact-based decision can be made on the continuation of a measure and its possible expansion to other areas or materials. In order to increase the likelihood of success, it is in many cases also advisable to involve the population in the planning of the experiment. On the one hand, the people of Switzerland often play an important role as households, consumers or customers of recycling and disposal centres. On the other hand, the transparent involvement of the population as early as possible is one of the key elements for the acceptance of projects and measures.

The federal government should play a coordinating role. It finds itself at the heart of many waste management networks and enjoys legitimacy across the country. It should encourage experiments and, in particular, ensure that they are assessed on a systematic basis. Other organisations that could provide support are Cercle Déchets (the association of experts for waste and resources at a federal and cantonal level) and Kommunale Infrastruktur (competence centre for infrastructure management in cities and municipalities).

Notes and References

1 Duygan, M., M. Stauffacher, and G. Meylan. Determinants of strong agency in socio-technical transitions: A study of Swiss waste management. 1–40.
2 Duygan, M., M. Stauffacher, and G. Meylan. 2019. A heuristic for conceptualizing and uncovering the determinants of agency in socio-technical transitions. Environmental Innovation and Societal Transitions (February): 1–17.