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Resource savings and CO_2 reduction potentials in waste management in Europe and the possible contribution to the CO_2 reduction target in 2020

Summary

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Study

Resource savings and CO_2 reduction potentials in waste management in Europe and the possible contribution to the CO_2 reduction target in 2020

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BDSV: Bundesvereinigung Deutscher Stahlrecycling- und Entsorgungsunternehmen e.V

BRB: Bundesvereinigung Recycling Baustoffe

BRBS: Dutch Construction and Demolition Waste Association

BVSE: Bundesverband Sekundärrohstoffe und Entsorgung e.V

CEWEP: Confederation of European Waste-to-Energy Plants

ERFO: European Recovered Fuel Association

ETRMA: European Tyre & Rubber Manufacturers' Association

FIR: Fédération Internationale du Recyclage

MRF: Dutch Steel Recycling Association

tecpol – Technologieentwicklungs GmbH für ökoeffiziente Polymerverwertung

VA: Dutch Waste Management Association, working together with European Composting Network on biowaste and IVAM/University of Amsterdam

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1. Project Objectives

Historically, waste is considered something bad - dirty, smelly, causing environmental and public health problems. This view, at least in part, still lingers.

While the industry has recognized the potential of waste for some time, policy-makers have only recently started to recognize the other - positive - side of waste as a valuable resource and energy supplier. EU waste policy has gradually addressed the environmental impact of material waste streams within the life cycle and, as a result, attempted to link waste policy with product and resource policy. Nevertheless, current discussions show that this integrated approach, connecting waste management with energy policy, environmental policy and the economy, will not be easy.

In order to successfully follow such an approach, in-depth knowledge based on detailed data and information is needed.

Climate protection demands all efforts to reduce CO_2 emissions as soon as possible. In addition to the CO_2 reduction potential, this study also highlights the potential for resource savings to give a comprehensive overview of the route towards a sustainable development of European waste management.

The objectives of this study are:

- To analyse and present the CO_2 reductions already achieved by the holders of waste in cooperation with the waste management industry within the EU 27
- To identify and present the still untapped potential of avoiding CO_2 emissions within the EU 27 and thereby determine the possible contribution of the holders of waste and the waste sector to the CO_2 reduction target set by the European Union (20% reduction in 2020).

Furthermore, we also provide an overview of the resource saving potential when waste is recycled or used as fuel for energy recovery. We thereby determine the possible contribution to the targets set in the waste strategy, climate and energy policies of the European Union These figures – esp. for recycling efforts - are also included and presented in this study as they are of particular importance to member states and other stakeholders.

The intention of the study is to help the EU decision-makers in their aims to reduce CO_2 levels for real by 2020. It also seeks to contribute in establishing a sustainable European society where waste is (re)used in an effective and efficient way. Lastly, it attempts to help increase energy efficiency, thereby reducing the dependence on fossil fuels. The study identifies the contribution member states can make to successfully reach these targets by diverting their waste from landfilling and increase their recycling and energy recovery performance.

2. Methodology

2.1 Data Basis and Reference Scenario

In order to identify the potential for avoiding CO_2 emissions we have developed several scenarios representing political options for achieving higher ranking aims such as “strengthening of resource savings by using secondary materials”, “improving the resource efficiency” as well as “improving the energy efficiency of industrial processes”.

The reference scenario was built on the statistical basis for waste streams important to material recycling and energy recovery in the EU. This data basis was developed within a Study of Waste Streams in 2007, commissioned by the Institute for Prospective Technological Studies (IPTS) of the European Commission’s Joint Research Centre.[1]

Until then, no consistent data basis was available. Based on the European Waste Statistics Regulation, it was only in 2004 that for the first time the member states were obliged to submit relevant data on waste generation and waste management to EUROSTAT.

An evaluation of available data for 2004 has shown that data for several waste fractions is available only on a highly aggregated level. Also, the completeness and quality of data differs from member state to member state.

Looking at individual waste streams, all available data was structured, analysed, verified and revised by Prognos and INFU (University Dortmund) to render them as reliable as possible.

In total, 18 waste streams were considered (see Table 1). Each one can be used as secondary raw material by means of recycling or energy recovery/ thermal treatment. They all can thus have a positive impact on resource and energy use.

[1] Study of Waste Streams and Secondary Materials in the EU, publication in preparation;
The main results were summarized in the European Atlas of Secondary Raw Material, 2008
(http://www.prognos.com/Download-Sekundaerrohstoffatlas-Europa.478.0.html).

Table 1: Overview of alternatives in waste management for 2004

No.	Waste stream*	Generation (potential)	Total disposal**	Recycling	Energy recovery	*Recycling rate****	Recycling / Energy recovery + (selected) Incineration****	
		[Mt]	[Mt]	[Mt]	[Mt]	*[in %]*	*[Mt]*	*[in %]*
1	glass	21,6	10,9	10,7	0,0	***50%***	10,7	***50%***
2	paper	79,5	35,3	44,2	0,0	***56%***	54,0	***68%***
3	plastics	26,2	17,0	4,5	4,7	***35%***	13,7	***52%***
4	iron & steel	102,6	24,9	77,7	0,0	***76%***	77,7	***76%***
5	aluminium	4,6	1,6	3,1	0,0	***66%***	3,1	***66%***
6	copper	1,4	0,5	0,9	0,0	***62%***	0,9	***62%***
7	zinc	1,2	0,5	0,7	0,0	***58%***	0,7	***58%***
8	lead	1,0	0,4	0,6	0,0	***63%***	0,6	***63%***
9	other metals	1,2	0,7	0,5	0,0	***39%***	0,5	***39%***
10	wood	70,5	24,7	21,7	24,0	***65%***	53,0	***75%***
11	textiles	12,2	8,3	2,8	1,1	***32%***	6,2	***51%***
12	rubber & tyres	3,2	0,7	1,6	0,9	***78%***	2,6	***82%***
13	biowaste	87,9	55,1	28,8	4,0	***37%***	46,5	***53%***
14	solid fuels	70,1	55,0	0,0	15,1	***22%***	29,2	***42%***
15	oil containing waste	7,4	4,4	2,2	0,8	***41%***	5,6	***75%***
16	solvents	1,6	0,6	0,4	0,6	***61%***	1,5	***90%***
17	ashes & slag	131,4	48,4	82,9	0,0	***63%***	82,9	***63%***
18	minerals	1.794,4	1.025,2	769,2	0,0	***43%***	769,2	***43%***
Total		**2.417,9**	**1.314,0**	**1.052,6**	**51,3**	***46%***	**1.271,6**	***48%***

* *Recovered metals directly returned to manufacturing without further processing (cycle scrap) are not included.*
** *Disposal includes landfilling, incineration as disposal (D 10) and other disposal operations*
*** *Without incineration in Municipal solid waste incineration and other disposal operations*
**** *Recycling + Energy recovery in comparison to the waste amount generated (including incineration in Municipal solid waste incineration plants)*

Based on the figures for 2004, a total of 2,4 billion tonnes of waste fractions from several waste sources were analyzed (e.g. as municipal solid waste, construction & demolition waste, end-of-life-vehicles, industrial waste, electrical equipment, mining residues etc.).

We have assessed that about 46% (1,103 Mt) of all waste generated in 2004 has been recycled or used for energy recovery (R 1 formula), while the remaining 54% (1,314 Mt) has been disposed of – mostly at landfills or by incineration (D10 operations = incineration on land).

This CO_2 reduction study considers those of the above mentioned cluster of 18 material waste streams that can contribute significantly to the further reduction of CO_2-emissions. Also, further waste sources contributing to reduce to CO_2 emissions were added. These material waste streams are:

1. Paper
2. Plastics
3. Glass
4. Steel

5. Aluminium
6. Copper
7. Wood
8. Textiles
9. Rubber waste (here mainly used tyres)
10. Biodegradable waste
11. Mineral demolition waste (nearly 50% of the mentioned material waste stream in Table 1)
12. Solid fuel waste

These material waste streams amount to1.16 Mt or approx. 48% of the total waste generated in 2004. Our analyses focuses on the contribution these material waste streams can make towards CO_2 reduction compared to the use of primary energy and materials (substitute processes).

In addition to this material waste stream-specific approach, we also analysed

13. waste from municipal solid waste (MSW), which is in 2004 (reference year) been disposed of (remaining MSW)

for its current CO_2 burden and reduction potential. Our calculations are based on the assumption that more material waste streams will be recycled or energy recovered. As a consequence, it would be possible to avoid remaining waste being disposed of (landfilling or incineration D10).

Remaining waste from MSW is defined as municipal solid waste without waste which is recycled or currently used for energy recovery.

The **reference scenario** was compiled for the above-mentioned material waste streams based on the waste management situation in the EU 27 member states for 2004. The data for 2004 was extrapolated to the situation in 2006. The extrapolation took into consideration current legal framework developments in the EU (e.g. ban on landfill for used tyres) as well as current waste management developments in selected EU 27 member states (e.g. ban of landfill for biodegradable waste in Germany since 1 June 2005).

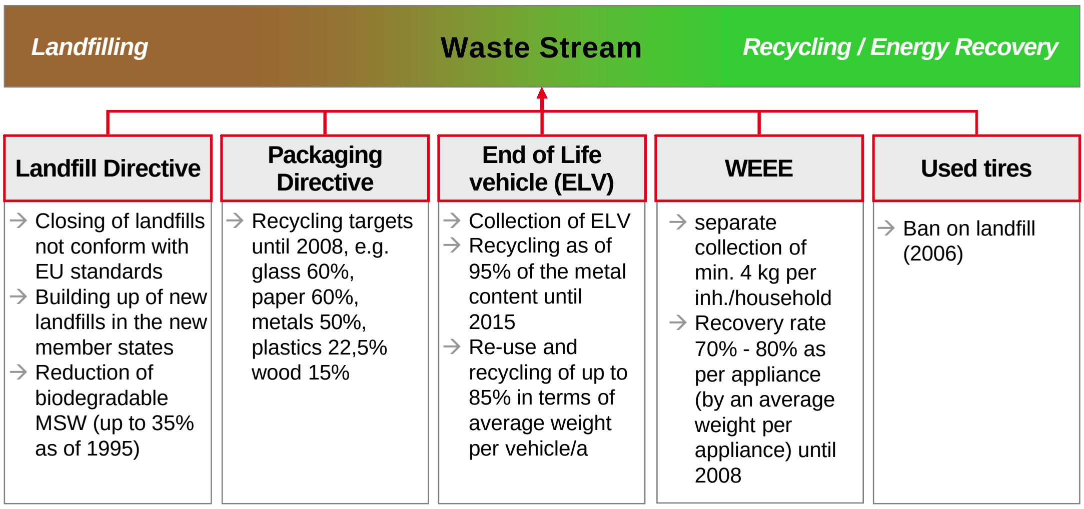
2.2 Framework Conditions for Future Scenarios (2020)

In order to analyse future CO_2 reduction potential that waste management in the EU 27 member states could achieve, we defined a total of four further scenarios for the year 2020.

The scenarios are based on the reference scenario and the following assumptions:

- Any waste is handled by either public or private waste collectors or the holder disposes of the waste himself in compliance with all set measures.
- The waste volumes remain constant as of 2004. Further developments regarding an increase or decrease of waste volumes generated are not calculated due to the methodology on CO_2 emission assumptions in the scenarios.
- The composition of waste sources like MSW, construction & demolition waste, packaging waste, end-of-live vehicles or WEEE is frozen at the status quo as of 2004.
- No future technological changes, changes of collection systems etc. are considered.
- All targets of the current European waste regulation were achieved in all EU 27 member states. The relevant regulations are summarized in the following figure:

Figure 1: Implementation of current legislation



The implementation of the current legislation means:

- Dumping or uncontrolled disposal of waste is prohibited and effective control mechanisms are developed,
- The targets of the existing waste framework are achieved
- Effective recycling procedures are promoted, based on the waste hierarchy.

The four scenarios were developed from four different assumptions.

The scenarios are:

- **Scenario 1 - Business As Usual:**

Scenario 1 describes the status quo of development as shown in figure 1. The further development of waste management is limited to the implementation of the existing legal framework without new Waste Framework Directive (WFD) in place.

This “status quo scenario” does not take into consideration any further targets for selected material waste streams or any significant market dynamics or influences (except for the ongoing normal future price development based on the situation in the last years).

Member states are improving the prevention of waste, but no EU-wide targets are set. The scenario is based on the waste amounts generated in 2004, no further increase/decrease is calculated.

Scenario 1 is therefore the minimum scenario.

- **Scenario 2 - Modernised European Waste Framework:**

  Scenario 2 adopts the framework conditions as described for scenario 1. In addition, an extension of the EU waste legislation following a revised WFD is assumed, characterised by the follwing developments: Waste hierarchy will be introduced as a general rule, setting priority for recycling over energy recovery, taking into account life cycle thinking. For incineration plants, the R1 status will be granted if they achieve an energy efficiency of 65% for new and 60% for existing incineration plants.

  Further modifications of the scenario 2 are mainly to an increase of recycling targets for packaging waste. Targets will be assumed also for selected waste sources like municipal solid waste (50% recycling) and construction & demolition waste (70% recycling). Backfilling of construction & demolition waste on landfills is counted as a recovery option.

  A future Biowaste Directive would strengthen the existing targets for biodegradable waste, based on the Landfill Directive. For the biodegradable waste from municipal solid waste, we have calculated with a recycling and energy recovery rate of 80%.

- **Scenario 3 - Strict and Ambitious European Legislation:**

  Based on scenario 2, further assumptions mainly include further increase of recycling targets for packaging waste. The targets for recovery of municipal solid waste and construction & demolition waste will be assumed with 60% and 80%, respectively.

  For this scenario, we also assume a landfill ban for biodegradable waste from municipal solid waste as well as for all higher calorific fractions.

- **Scenario 3a - Ambitious European Legislation plus Market:**

  Scenario 3a is an alternative to scenario 3. For scenario 3a we assume additional market influences and dynamics. While scenario 3 is based only the normal market influence as assumed for scenarios 1 and 2, more significant market influences are modelled in scenario 3a. There, the market dynamics impact on the price for primary energy and raw materials as well as on the market reacting flexibly to certain waste management options (recycling, other recovery and energy recovery).

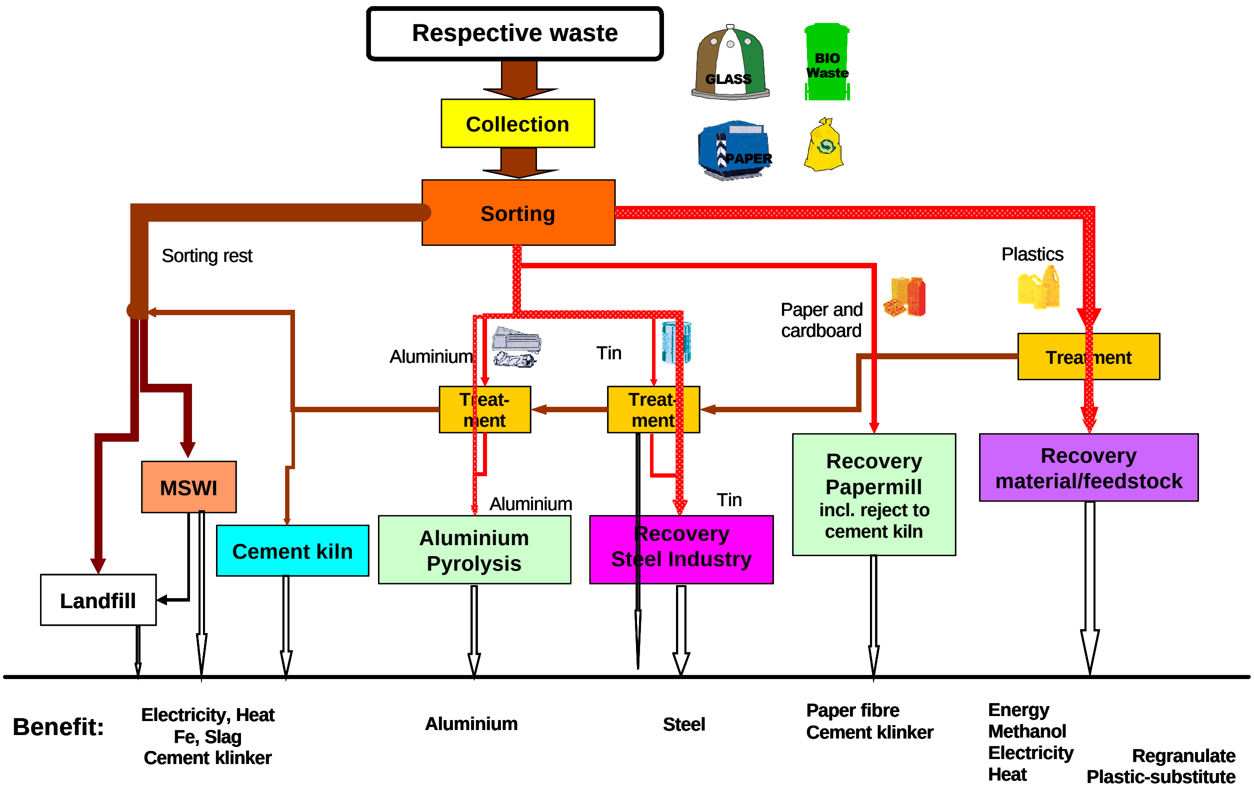
2.3 System Boundaries

The system boundaries for calculating the CO_2 equivalent emission factors for the waste materials start with the generation of the waste. They include – where appropriate – the collection, sorting and further treatment of the materials. The system boundaries end at a secondary raw material level equal to a primary raw material or function. These primary raw materials are calculated to this point of equivalency and regarded as a benefit of the waste management option. Details are given below.

This approach is only valid if the total amount of waste input is constant for the different options for comparison.

The figure below illustrates an example of the system boundaries for different waste materials.

Figure 2: System boundaries for different waste materials



2.4 CO_2 Equivalents

The CO_2 equivalent emission factors presented are rough estimations. They are not differentiated on a country by country basis and represent a best assumption for the situation within the EU 27.

The following table gives an overview of the CO_2 equivalent factors for the various waste management activities and their equivalent primary raw material or function. All values are given per tonne of waste material.

The CO_2 equivalents for using waste as secondary raw material were calculated for the selected material waste streams. All the steps of waste management from collection, transport, sorting to recycling etc. were analysed. In order to identify the CO_2 benefits or burdens, the results were compared to the CO_2 equivalents when using primary materials and energy sources. The difference between CO_2 equivalents for secondary raw materials and primary sources forms the CO_2 equivalent displayed in the last column. This final factor was used in the model.

Table 2: Overview of the CO_2 equivalents

Material Waste Stream	Item	CO_2 emissions	Benefit (+) / Burden (-)
		kg CO_2-equivalent	kg CO_2-equivalent
Paper	Production of deinking pulp (DIP) from waste paper and energy	180	840
	Production of primary fibre and energy	1,000	
Plastics	Production of PE/PP flakes from plastic waste and energy (SF = 0,7)	1,040	160
	Production of primary PE/PP and energy	1,200	
	Production of R-PET from plastic waste and energy (SF = 1)	960	1,640
	Production of primary PET and energy	2,600	
	Production of R-PS from plastic waste and energy (SF = 0,9)	1,100	1,700
	Production of primary PS and energy	2,800	
	Production secondary PVC from plastic waste and energy (SF = 0,9)	790	740
	Production of primary PVC and energy	1,530	
Glass	Provision of waste glass	20	180
	Savings by the substitution of 1 t of primary glass through secondary glass at a calculation point of 75 % secondary glass share	200	
Steel	Production of steel from electric arc furnace route (estimate for secondary)	no valid data	1,000
	Production of steel from blast furnace route (estimate for primary)		
Aluminium	Production secondary aluminium	700	11,100
	Production primary aluminium	11,800	
Copper	Production secondary copper	1,690	1,180
	Production primary copper	2,870	
Wood	Production of press board from waste wood (use in dry environment)	319	56
	Production of press board from new wood (use in dry environment)	375	
	Production of press board from waste wood (use in moist environment)	366	65
	Production of press board from new wood (use in moist environment)	431	
	Energy recovery of wood	70	920
	Electricity produced (credit)	510	
	Heat produced (credit)	480	

Material Waste Stream	Item	CO_2 emissions kg CO_2-equivalent	Benefit (+) / Burden (-) kg CO_2-equivalent
Textiles	Ship transport of textiles	32	2,818
	Production 1 t cotton (1/3)	*10,500*	
	Production 1 t of polyester (2/3)	*3,300*	
	Substituted textile (substitution factor = 0.5)	2,850	
	Co-incineration of textiles	400	1,570
	Substitution of fossil fuels	1,970	
Rubber	Material recovery of used tyres for asphalt use and associated uses	460	1,800
	Substituted materials and energy by recovery of used tyres	2,260	
	Co-incineration of waste tyres	1,940	1,000
	Substitution of fossil fuels	2,940	
Biowaste	Compost production and application	87	8
	Production and use of fertilizer and organic substance (e.g peat) in a functional equivalent to compost	95	
	Compost production and application (carbon sink allocated)	*35*	*60*
	Production and use of fertilizer and organic substance (e.g peat) in a functional equivalent to compost	95	
	Anaerobic digestion, energy generation and compost production of biowaste	57	81
	Electricity and heat substitution and substitution of compost application	138	
	Anaerobic digestion, energy generation and compost production of biowaste (carbon sink allocated)	*-8*	*146*
	Electricity and heat substitution and substitution of compost application	138	
Solid fuel waste	Co-incineration of SRF/ RDF in a cement kiln	440	1,040
	Substitution of fossil fuels co-incineration cement kiln	1,480	
	Co-incineration of SRF in an optimised MSWI	440	460
	Electricity and heat substitution	900	
	Co-incineration of SRF/ RDF in a coal power plant	450	1,060
	Substitution of fossil fuels co-incineration coal power plant	1,510	
Mineral demolition waste*	Shredding, crushing by mobile devices	14	0
	Winning of primary mineral material	14	
Residual waste	Incineration of residual waste	300	70
	Electricity and heat substitution (EU average for WtE-plants)	370	
	Incineration of residual waste	300	240
	Electricity and heat substitution (optimised WtE-plant)	540	
	Biological stabilisation and co-incineration of residual waste	250	70
	Substitution of fossil fuels	320	
	Landfilling of residual waste - rate for landfill gas 20% (average)	1,080	-1,080
	Landfilling of residual waste with subtraction of carbon sink	780	-780
	Optimised landfilling of residual waste - rate for landfill gas 50%	690	-690
	Landfilling of residual waste with subtraction of carbon sink	390	-390

SF = substitution factor

* only mineral fraction, other waste materials from construction & demolition waste (e.g. metals, plastics, wood, glass etc.) considered in the single material waste streams.

If we calculate the CO_2-equivalents for mixed construction & demolition waste, we will obtain a positive CO_2 emission benefit, which is additional show in detail in the main report.

2.5 Clusters of Member States

To underline the different starting positions of EU member states and their current and further contribution to CO_2 reductions, a differentiation was made between current recycling/incineration (R/R) states[2] and landfill states. The states in the two clusters will follow individual paths to a further reduction of CO_2. Landfill states will focus more on implementation of best practices than R/R states. The latter will have to develop new routes to further reduce CO_2.

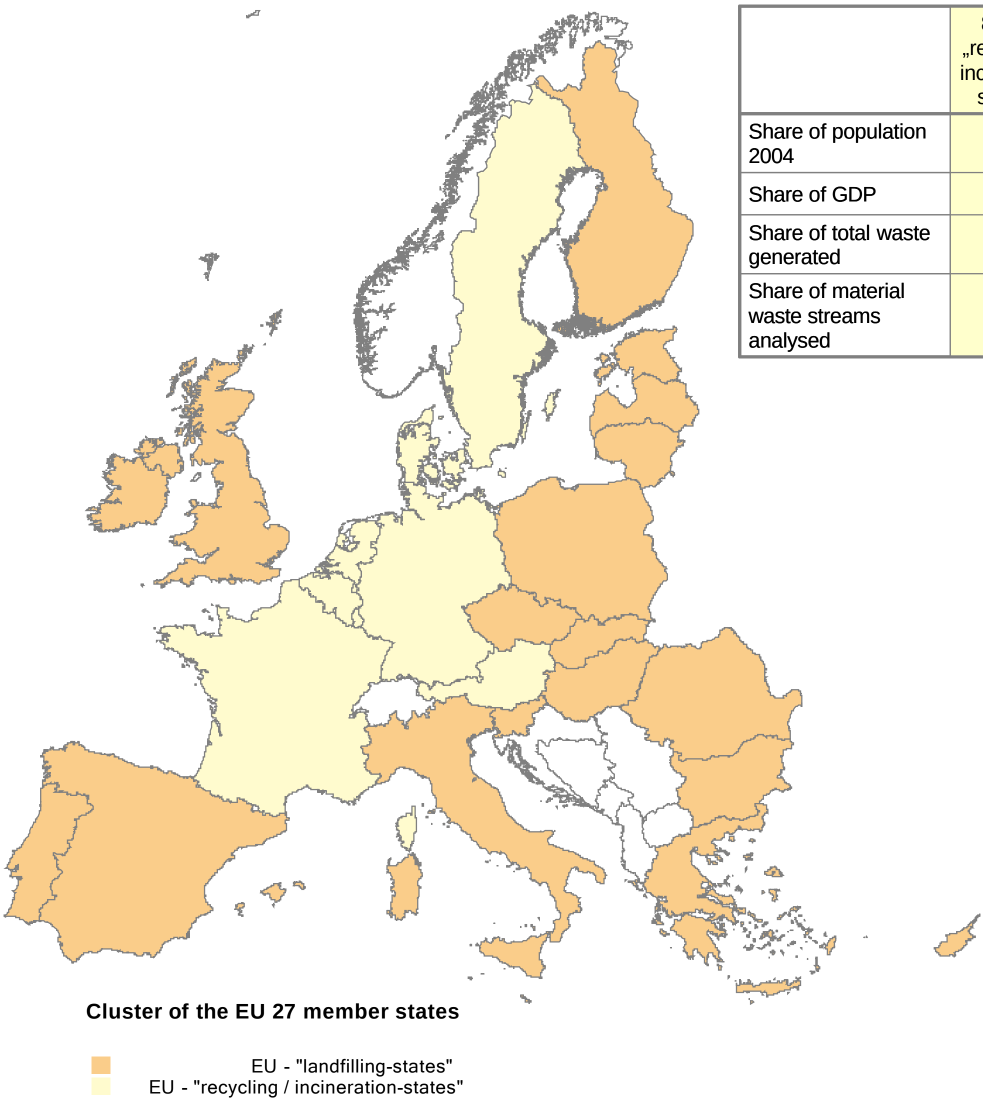
- 8 EU – "recycling/incineration states" have high recycling and incineration rates for remaining waste (featuring a relatively high energy recovery). These are: Austria, Belgium, Denmark, France, Germany, Luxembourg, The Netherlands, and Sweden. We show their actual contribution to resource savings, CO_2 reduction potential and future trends.

- 19 EU – "landfilling states" have lower recycling and high landfilling rates for remaining waste. We show their actual contribution to resource savings, CO_2 reduction potential and future trends.

The groups are illustrated in the following figure. The differentiation is based on the waste management of municipal solid waste in 2006. Countries with a recycling/recovery share of more than 60% were considered "recycling/incineration (R/R) states", while the remaining member states were added to the cluster of "landfilling states".

[2] The allocation of the EU 27 member states is based on their currently preferred waste management. As the treatment status for municipal waste incineration plants with high energy recovery is under discussion this management option was considered as recovery potential.

Figure 3: Clusters of EU 27 member states



	8 EU – „recycling / incineration states“*	19 EU – „landfilling states“
Share of population 2004	40%	60%
Share of GDP	51%	49%
Share of total waste generated	41%	59%
Share of material waste streams analysed	51.5%	48.5%

3. Main Results

The main results for all analysed material waste streams and for the remaining waste from municipal solid waste can be summarized as follows:

Material Waste Streams

1. In the reference year 2004, the realised CO_2 emission reduction through recycling, recovery or energy recovery in the analysed material waste streams (without remaining waste) reached a total amount of approx. 207 Mt CO_2 equivalents.

2. For 2006, we have calculated a total CO_2 emission reduction of 223 Mt CO_2 equivalents due to increased rates for recycling, recovery and energy recovery of the material waste streams.

3. In the four future scenarios for 2020, we have calculated the following total sums of CO_2 emission reduction by recycling, recovery or energy recovery of the analysed material waste streams:

    - 268 Mt CO_2 equivalents in scenario 1, based on the implementation of the current legislation. In other words, CO_2 emission reductions would be increased by approx. 30% compared to 2004.

    - 279 Mt CO_2 equivalents in scenario 2 (assuming the new WFD and recycling targets for MSW and construction & demolition waste, but without a ban of landfilling for biodegradable and high calorific waste) - a reduction increase of approx. 44% compared to 2004.

    - 303 Mt CO_2 equivalents in scenario 3 (new WFD, higher recycling targets for MSW and construction & demolition waste as in scenario 2, as well as a complete ban on landfilling for biodegradable and high calorific waste in all member states)

      and

    - nearly 320 Mt CO_2 equivalents in scenario 3a (simulated "free-market", five step waste hierarchy as principle guideline and stronger market price conditions, as well as a complete ban of landfilling for biodegradable and high calorific waste in all member states). The CO_2 emission reduction potential increases to 55% and more compared to 2004 in these two scenarios.

Remaining waste from Municipal Solid Waste

1. In 2004, the disposal of remaining waste from MSW within EU 27 produced a CO_2 emission burden of 113 Mt CO_2 equivalents due to high methane emissions from landfilling.

2. In scenarios 1 and 2, this CO_2 emission burden from landfilling decreases to 30 Mt and 13 Mt, respectively, as member states enhance recycling and energy recovery

for the waste steams and prefer other treatment operations, such as incineration in Waste to Energy (WtE) plants and fuel preparation for remaining waste from MSW.

3. In the scenario 3 there is no longer any CO_2-emission burden due to a complete ban on landfilling for biodegradable and high calorific waste in all member states. Instead, this waste is thermally treated in WtE plants or prepared to be used as a fuel.

A more detailed explanation will be given in the following paragraphs.

3.1 Results for Material Waste Streams in the EU 27 Member states

The following table illustrates the CO_2 reductions for the 12 material waste streams analysed (including solid fuels) in the EU 27 member states in the reference year 2004, in 2006 as well as, the CO_2-reduction *potential* of the four future scenarios for 2020.

In the reference year 2004, the CO_2 emission reduction realised through recycling, recovery or energy recovery reached a total of approx. 207 Mt CO_2 equivalents.

For 2006, we calculated a total emission reduction of approx. 223 Mt CO_2 equivalents due to increased rates through recycling, recovery and energy recovery in the material waste stream markets in all the member states. For Germany, we found a particularly significant increase in CO_2 emission reduction, amounting to 6 Mt CO_2 equivalents compared to 2004. This is a result of more waste being recycled and used for energy recovery following the ban on landfilling biodegradable waste since June 2005.

For the future 2020 scenarios we have calculated total CO_2-emission reductions of nearly 269 Mt CO_2 equivalents in scenario 1, 297 Mt CO_2 equivalents in scenario 2, and nearly 304 to 320 Mt CO_2 equivalents in scenario 3 and scenario 3a.

Scenario 1 - Business as Usual:

For scenario 1, our analyses resulted in a minimum reduction potential of up to 269 Mt CO_2 equivalents. This is an increase of 30% of CO_2 emission reduction in 2020 as compared to 2004.

Responsible for the reduction potential is the full implementation of the current existing EU waste regulation, with recycling targets for packaging materials and the amount of biodegradable waste going to landfills down to 35% of the total waste generated 1995 (1998).

Scenario 2 - Modernised European Waste Framework

In scenario 2, the total potential for emission reduction could be 297 Mt CO_2 equivalents, 44% more than in 2004.

The CO_2 reduction potential, in this case, is based mainly on recycling targets for MSW and construction & demolition waste, without taking into consideration a ban on landfilling for biodegradable and high calorific waste. The new WFD would enable MSW incineration plants with energy efficiency to achieve the R1 status as energy recovery plants.

Scenario 3 - Strict and Ambitious European Legislation

In scenario 3 we have calculated the potential for emission reductions at 304 Mt CO_2 equivalents (47% more than in 2004). This is due to the new WFD, higher recycling targets for MSW and construction & demolition waste (as in scenario 2) and with a ban on landfilling for biodegradable and high calorific waste.

Scenario 3a - Ambitious European Legislation plus Market

The highest CO_2 emission reduction of 319 Mt (55% more than in 2004) was found as a result of scenario 3a, based on a simulated “free market”, a general rule of the five step waste hierarchy in the WFD, and stronger market price conditions than in the other scenarios.

In 2020, for the 8 EU - recycling/incineration (R/R) states the CO_2 emission reduction is approx. 43 Mt CO_2 equivalents (38%) higher than in 2004, totalling 112 Mt. The current 19 EU - landfill states could increase CO_2emission reductions to 164 Mt CO_2 equivalents. Compared to 94 Mt CO_2 equivalents in 2004, this is an increase of 74%.

The 19 EU – landfilling states will have higher CO_2 reduction potential compared to the 8 EU - recycling/incineration states. This is due to the fact that the 8 EU - recycling/incineration states have already saved a great deal of CO_2 due to strict regulations for landfilling MSW and high recycling standards. These countries will continue to improve their balance. For the EU – landfilling states the reduction rate will be higher in all scenarios mainly due to the reduction in the share of waste going to landfills and corresponding higher recycling and/or energy recovery rates.

Table 3: Reduction of CO_2 emissions trough recycling, recovery and energy recovery in the analysed material waste streams in the EU 27 countries

Greenhouse gas reduction of waste stream recycling, recovery and energy recovery in t CO_2 equivalent						
	reference year 2004	2006	scenario 1 2020	scenario 2 2020	scenario 3 2020	scenario 3a 2020
AT *	5,448,000	5,916,000	6,599,000	7,101,000	6,971,000	7,772,000
BE *	6,584,000	7,055,000	7,886,000	8,651,000	8,860,000	9,791,000
BG	2,048,000	2,293,000	3,421,000	3,747,000	4,105,000	4,445,000
CY	119,000	132,000	261,000	311,000	307,000	340,000
CZ	2,649,000	2,989,000	4,307,000	4,840,000	5,152,000	5,428,000
DK *	2,590,000	2,621,000	2,780,000	3,167,000	3,425,000	3,538,000
EE	954,000	1,034,000	1,385,000	1,525,000	1,575,000	1,653,000
FI	4,322,000	4,466,000	5,084,000	5,190,000	5,534,000	5,632,000
FR *	29,126,000	30,772,000	35,329,000	39,579,000	41,652,000	42,341,000
DE *	49,202,000	55,107,000	60,239,000	63,963,000	63,837,000	66,911,000
GB	24,579,000	26,469,000	34,826,000	39,273,000	40,923,000	42,553,000
GR	2,100,000	2,304,000	3,621,000	4,302,000	4,240,000	4,420,000
HU	2,756,000	2,951,000	4,006,000	4,456,000	4,592,000	4,864,000
IE	1,177,000	1,271,000	1,901,000	2,233,000	2,335,000	2,416,000
IT	22,860,000	24,135,000	29,800,000	32,832,000	34,101,000	35,527,000
LV	102,000	113,000	157,000	190,000	193,000	204,000
LT	775,000	858,000	1,089,000	1,230,000	1,277,000	1,324,000
LU *	336,000	360,000	421,000	452,000	474,000	493,000
MT	80,000	95,000	158,000	184,000	201,000	202,000
NL *	7,710,000	8,350,000	9,842,000	10,566,000	10,508,000	11,436,000
PL	6,896,000	7,466,000	10,877,000	12,847,000	13,000,000	13,949,000
PT	1,525,000	1,633,000	2,321,000	2,659,000	2,539,000	2,815,000
RO	5,383,000	5,775,000	8,407,000	9,454,000	9,949,000	10,277,000
SK	1,140,000	1,252,000	1,630,000	1,936,000	2,093,000	2,152,000
SI	442,000	489,000	671,000	801,000	839,000	880,000
ES	14,486,000	15,324,000	19,645,000	22,696,000	24,089,000	25,216,000
SE *	11,495,000	11,787,000	11,866,000	12,934,000	10,728,000	13,250,000
EU 27	**206,900,000**	**223,000,000**	**268,500,000**	**297,100,000**	**303,500,000**	**319,800,000**
EU - "recycling/ incineration-states" *	112,491,000	121,968,000	134,962,000	146,413,000	146,455,000	155,532,000
EU - "landfilling-states"	94,409,000	101,032,000	133,538,000	150,687,000	157,045,000	164,268,000

The following table illustrates the relative performance of CO_2 emission reduction trough recycling, recovery and energy recovery in the analysed material waste streams for every member state for the four future 2020 scenarios.

Table 4: Development of CO_2 emission reduction trough recycling, recovery and energy recovery in the analysed material waste streams for the EU 27 countries (Index 2004 = 100)

Greenhouse gas reduction of waste stream recycling, recovery and energy recovery (Index 2004 = 100)						
	reference year 2004	2006	scenario 1 2020	scenario 2 2020	scenario 3 2020	scenario 3a 2020
AT *	100	109	121	130	128	143
BE *	100	107	120	131	135	149
BG	100	112	167	183	200	217
CY	100	111	219	261	258	286
CZ	100	113	163	183	194	205
DK *	100	101	107	122	132	137
EE	100	108	145	160	165	173
FI	100	103	118	120	128	130
FR *	100	106	121	136	143	145
DE *	100	112	122	130	130	136
GB	100	108	142	160	166	173
GR	100	110	172	205	202	210
HU	100	107	145	162	167	176
IE	100	108	162	190	198	205
IT	100	106	130	144	149	155
LV	100	111	154	186	189	200
LT	100	111	141	159	165	171
LU *	100	107	125	135	141	147
MT	100	119	198	230	251	253
NL *	100	108	128	137	136	148
PL	100	108	158	186	189	202
PT	100	107	152	174	166	185
RO	100	107	156	176	185	191
SK	100	110	143	170	184	189
SI	100	111	152	181	190	199
ES	100	106	136	157	166	174
SE *	100	103	103	113	93	115
EU 27	100	108	130	144	147	155
EU - "recycling/ incineration-states" *	100	108	120	130	130	138
EU - "landfilling-states"	100	107	141	160	166	174

Table 5: Development of CO_2 emissions from disposal and waste treatment operations of remaining municipal waste (MSW) in the EU 27 member states

Total greenhouse gas reduction of residual waste disposal in t CO2 equivalent **					
	reference year 2004	2006	scenario 1 2020	scenario 2 2020	scenario 3 / 3a 2020
AT *	-603,000	-194,000	-10,000	49,000	99,000
BE *	-225,000	-49,000	-6,000	32,000	71,000
BG	-3,333,000	-2,992,000	-894,000	-446,000	130,000
CY	-518,000	-521,000	-211,000	-88,000	28,000
CZ	-2,421,000	-2,555,000	-492,000	-171,000	93,000
DK *	53,000	15,000	48,000	100,000	93,000
EE	-413,000	-407,000	-84,000	-40,000	13,000
FI	-1,197,000	-1,308,000	-408,000	-132,000	72,000
FR *	-10,880,000	-10,677,000	-3,480,000	-1,781,000	962,000
DE *	-4,770,000	1,407,000	881,000	830,000	760,000
GB	-21,575,000	-18,991,000	-5,368,000	-2,563,000	1,017,000
GR	-4,750,000	-4,612,000	-1,268,000	-580,000	175,000
HU	-4,635,000	-4,071,000	-1,673,000	-866,000	276,000
IE	-1,739,000	-2,065,000	-575,000	-289,000	90,000
IT	-18,581,000	-17,264,000	-4,440,000	-2,689,000	819,000
LV	-661,000	-729,000	-246,000	-129,000	42,000
LT	-1,239,000	-1,321,000	-310,000	-150,000	45,000
LU *	-28,000	-33,000	-5,000	-1,000	8,000
MT	-198,000	-243,000	-67,000	-26,000	5,000
NL *	-67,000	201,000	103,000	122,000	115,000
PL	-9,987,000	-9,729,000	-2,657,000	-1,282,000	389,000
PT	-3,517,000	-3,038,000	-1,028,000	-379,000	204,000
RO	-7,179,000	-7,631,000	-2,370,000	-1,206,000	377,000
SK	-1,159,000	-1,347,000	-303,000	-139,000	39,000
SI	-788,000	-780,000	-268,000	-139,000	45,000
ES	-13,410,000	-11,169,000	-4,341,000	-1,783,000	687,000
SE *	-119,000	-1,000	48,000	101,000	93,000
EU 27	**-113,939,000**	**-100,103,000**	**-29,425,000**	**-13,644,000**	**6,747,000**
EU - "recycling/ incineration-states" *	-16,639,000	-9,330,000	-2,422,000	-549,000	2,202,000
EU - "landfilling-states"	-97,300,000	-90,772,000	-27,003,000	-13,095,000	4,545,000

negative figures: CO_2 equivalent burden (methane emissions from landfilling); positive figures: CO_2 reduction
**: MSW-disposal (D1, D10) for 2004, 2006, scenario 1 and MSW-treatment in scenarios 2, 3 and 3a
energy recovery in WtE-plants - R1 and fuel preparation
… without CO_2 reduction from metal recycling (e.g. ashes and slag), this is calculated in the waste metal streams

3.2 Results for the Single Material Waste Streams in the Scenarios for 2020

The following table illustrates CO_2 reductions for the individual analysed material waste streams going to recycling, recovery and energy recovery compared to the defined reference process in the EU 27 in 2004 and 2006. It also shows the CO_2 reduction *potential* in the four future scenarios for 2020.

Table 6: Overview of the results for the single material waste streams in the scenarios for EU 27 member states

	CO_2 reduction of waste recovery in t CO_2 equivalent					
material waste streams	reference year 2004	2006	scenario 1 2020	scenario 2 2020	scenario 3 2020	scenario 3a 2020
glass	1,926,000	2,044,000	2,568,000	3,086,000	3,319,000	3,319,000
paper / cardboard *	36,258,000	40,165,000	49,369,000	54,523,000	55,682,000	55,682,000
plastics *	6,051,000	6,624,000	9,258,000	10,451,000	11,051,000	11,457,000
iron & steel	77,711,000	81,462,000	87,222,000	92,016,000	96,247,000	96,247,000
aluminium	33,995,000	35,897,000	40,676,000	43,693,000	44,777,000	44,785,000
copper	507,000	542,000	640,000	688,000	708,000	708,000
wood *	23,342,000	24,835,000	28,554,000	29,831,000	20,386,000	30,014,000
textiles *	9,672,000	10,654,000	16,965,000	19,126,000	21,654,000	20,994,000
biowaste **	617,000	676,000	1,674,000	2,124,000	2,708,000	3,260,000
rubber & tyres *	3,509,000	3,981,000	4,209,000	4,297,000	4,569,000	4,340,000
mineral C & D waste	0	0	0	0	0	0
solid fuel waste	13,214,000	16,144,000	27,366,000	37,309,000	42,417,000	49,010,000
Total (without solid fuels)	**193,600,000**	**206,900,000**	**241,100,000**	**259,800,000**	**261,100,000**	**270,800,000**
difference to 2004		13,300,000	47,500,000	66,200,000	67,500,000	77,200,000
to 2004 in %		7%	25%	34%	35%	40%
Total (with solid fuels)	**206,800,000**	**223,000,000**	**268,500,000**	**297,100,000**	**303,500,000**	**319,800,000**
difference to 2004		16,200,000	61,700,000	90,300,000	96,700,000	113,000,000
to 2004 in %		8%	30%	44%	47%	55%

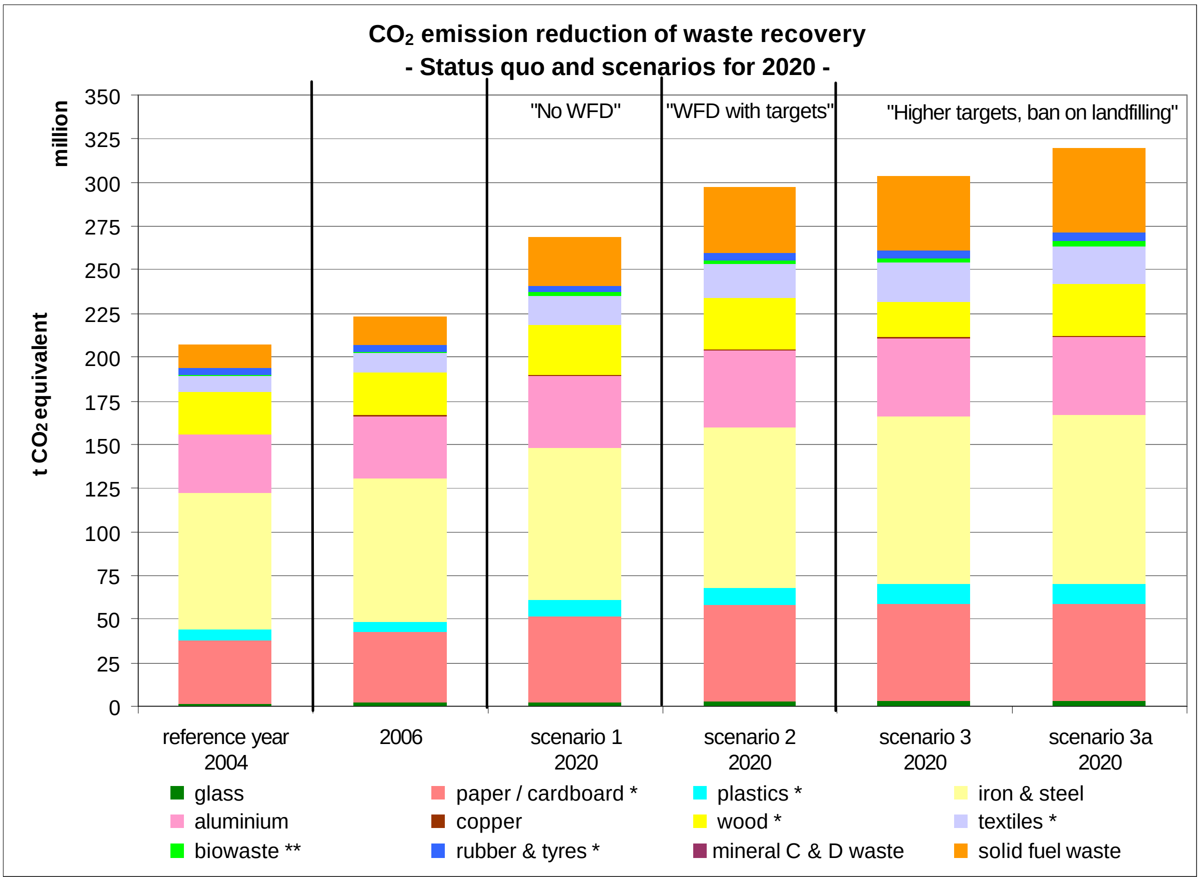
* without incineration in MSWI (D10 or R1 -status) in all scenarios
** biowaste data calculated without carbon sink effect

Through recycling and energy recovery, CO_2 emissions are reduced by 207 Mt in the reference year 2004. The largest contributions to CO_2 reductions come from iron and steel (37.5%) paper and cardboard (17.5%), aluminium (16.5%), and wood (11%). The share of the remaining material waste streams in total CO_2 reductions amounts to 17.5%. For mineral construction and demolition waste, this study could not identify CO_2 reductions or emission burdens from recycling and recovery.

In the four scenarios for 2020, CO_2 emissions are further reduced. The extra CO_2 reductions range from 30 % in scenario 1 (totalling 268.5 Mt) to 55 % in scenario 3a (totalling 320 Mt). In addition to reductions from the material waste streams iron and steel, paper and cardboard, aluminium and wood, the shares of textiles and solid fuels – whose share rise particularly strongly – become important for CO_2 reductions through recycling and energy recovery.

The figure below illustrates the results in the four scenarios compared to the reference year 2004 and the year 2006. Scenarios 3 and 3a show the consequences of ambitious European legislation in conjunction with market effects, resulting in the highest CO_2 emission reductions.

Figure 4: Visualised results for the single material waste streams in the scenarios for EU 27



* without incineration in MSWI (D10 or R1 -status) in all scenarios
** biowaste data calculated without carbon sink effect

The following table contains the results for the cluster of 8 EU - recycling/incineration states. Though recycling efforts and energy recovery, CO_2 emission reductions for all material waste streams amount to 112.5 Mt in the reference year 2004. With these reductions, those 8 particularly progressive EU member states already account for about 54.5% of the total CO_2 reductions of all 27 EU states in that year.

The largest contributions to CO_2 reductions come from iron and steel (34%), paper and cardboard (18.5%), aluminium (16.5%) und wood (13.5%). The total share in CO_2 reductions of the remaining material waste streams equals about 17.5%.

In the four 2020 scenarios, CO_2 emissions are further reduced, with the additional reductions ranging from 20% in scenario 1 (totalling 135 Mt) to 38% in scenario 3a (totalling 155.5 Mt). The increase in CO_2 emission reductions until 2020 is projected to be relatively smaller than in the EU 27 as a whole because these 8 states already have a higher level of recycling and recovery in the reference year 2004.

Table 7: Results for the single material waste streams in the scenarios for "EU 8 - Recycling/ incineration states"

	CO_2 reduction of waste recovery in t CO_2 equivalent					
waste streams	reference year 2004	2006	scenario 1 2020	scenario 2 2020	scenario 3 2020	scenario 3a 2020
glass	1,114,000	1,149,000	1,280,000	1,456,000	1,546,000	1,546,000
paper / cardboard	20,930,000	23,249,000	25,855,000	27,408,000	28,180,000	28,180,000
plastics	3,894,000	4,190,000	4,649,000	4,999,000	5,279,000	5,459,000
iron & steel	38,519,000	40,369,000	41,707,000	43,835,000	45,401,000	45,401,000
aluminium	17,386,000	18,629,000	20,572,000	21,982,000	22,515,000	22,515,000
copper	235,000	257,000	292,000	314,000	323,000	323,000
wood	15,127,000	15,821,000	16,997,000	17,324,000	10,109,000	16,880,000
textiles	5,958,000	6,373,000	7,621,000	8,606,000	9,331,000	9,173,000
biowaste	437,000	468,000	1,094,000	1,295,000	1,527,000	1,721,000
rubber & tyres	1,766,000	1,866,000	1,881,000	1,905,000	2,030,000	1,918,000
mineral C & D waste	0	0	0	0	0	0
solid fuel waste	7,142,000	9,608,000	13,002,000	17,302,000	20,223,000	22,424,000
Total (without solid fuels)	**105,400,000**	**112,400,000**	**121,900,000**	**129,100,000**	**126,200,000**	**133,100,000**
relative to 2004		7,000,000	16,500,000	23,700,000	20,800,000	27,700,000
to 2004 in %		7%	16%	22%	20%	26%
Total (with solid fuels)	**112,500,000**	**122,000,000**	**135,000,000**	**146,400,000**	**146,500,000**	**155,500,000**
relative to 2004		9,500,000	22,500,000	33,900,000	34,000,000	43,000,000
to 2004 in %		8%	20%	30%	30%	38%

*: without incineration in MSWI (D10 or R1 -status) in all scenarios
**: biowaste data without calculated carbon sink effect

The following table shows the results for the cluster of 19 EU - landfilling states. By means of recycling and energy recovery, CO_2 emissions from all material waste streams are reduced by 94 Mt in the reference year 2004. Those 19 member states which pursue a predominantly landfill-focussed strategy account for about 45.5% of the total CO_2 reductions of all 27 EU states in 2004.

The largest contributions to CO_2 reductions come from iron and steel (41.5%), paper and cardboard (16%), aluminium (17.5%) und wood (8.5%). The total share in CO_2 reductions of the remaining material waste streams equals about 16.5%.

In the four 2020 scenarios, CO_2 emissions are further reduced, with the additional reductions ranging from 42% in scenario 1 (totalling 134 Mt) to 74% in scenario 3a (totalling 164 Mt).

The increase in CO_2 emission reductions until 2020 is projected to be relatively larger than in the EU 27 as a whole because these 19 states have a lower level of recycling and recovery in the reference year 2004.

Table 8: Results for the single material waste streams in the scenarios for “EU 19 – landfill states”:

	CO_2 reduction of waste recovery in t CO_2 equivalent					
material waste streams	reference year 2004	2006	scenario 1 2020	scenario 2 2020	scenario 3 2020	scenario 3a 2020
glass	812,000	895,000	1,289,000	1,630,000	1,773,000	1,773,000
paper / cardboard	15,328,000	16,916,000	23,514,000	27,116,000	27,502,000	27,502,000
plastics	2,157,000	2,434,000	4,608,000	5,452,000	5,771,000	5,998,000
iron & steel	39,192,000	41,093,000	45,515,000	48,181,000	50,846,000	50,846,000
aluminium	16,610,000	17,268,000	20,104,000	21,711,000	22,262,000	22,262,000
copper	271,000	285,000	348,000	374,000	385,000	385,000
wood	8,215,000	9,014,000	11,557,000	12,507,000	10,277,000	13,135,000
textiles	3,715,000	4,281,000	9,345,000	10,520,000	12,322,000	11,821,000
biowaste	180,000	208,000	580,000	828,000	1,181,000	1,540,000
rubber & tyres	1,743,000	2,115,000	2,328,000	2,392,000	2,539,000	2,422,000
mineral C & D waste	0	0	0	0	0	0
solid fuel waste	6,072,000	6,536,000	14,363,000	20,007,000	22,193,000	26,586,000
Total (without solid fuels)	**88,200,000**	**94,500,000**	**119,200,000**	**130,700,000**	**134,900,000**	**137,700,000**
relative to 2004		6,300,000	31,000,000	42,500,000	46,700,000	49,500,000
to 2004 in %		7%	35%	48%	53%	56%
Total (with solid fuels)	**94,300,000**	**101,000,000**	**133,600,000**	**150,700,000**	**157,100,000**	**164,300,000**
relative to 2004		6,700,000	39,300,000	56,400,000	62,800,000	70,000,000
to 2004 in %		7%	42%	60%	67%	74%

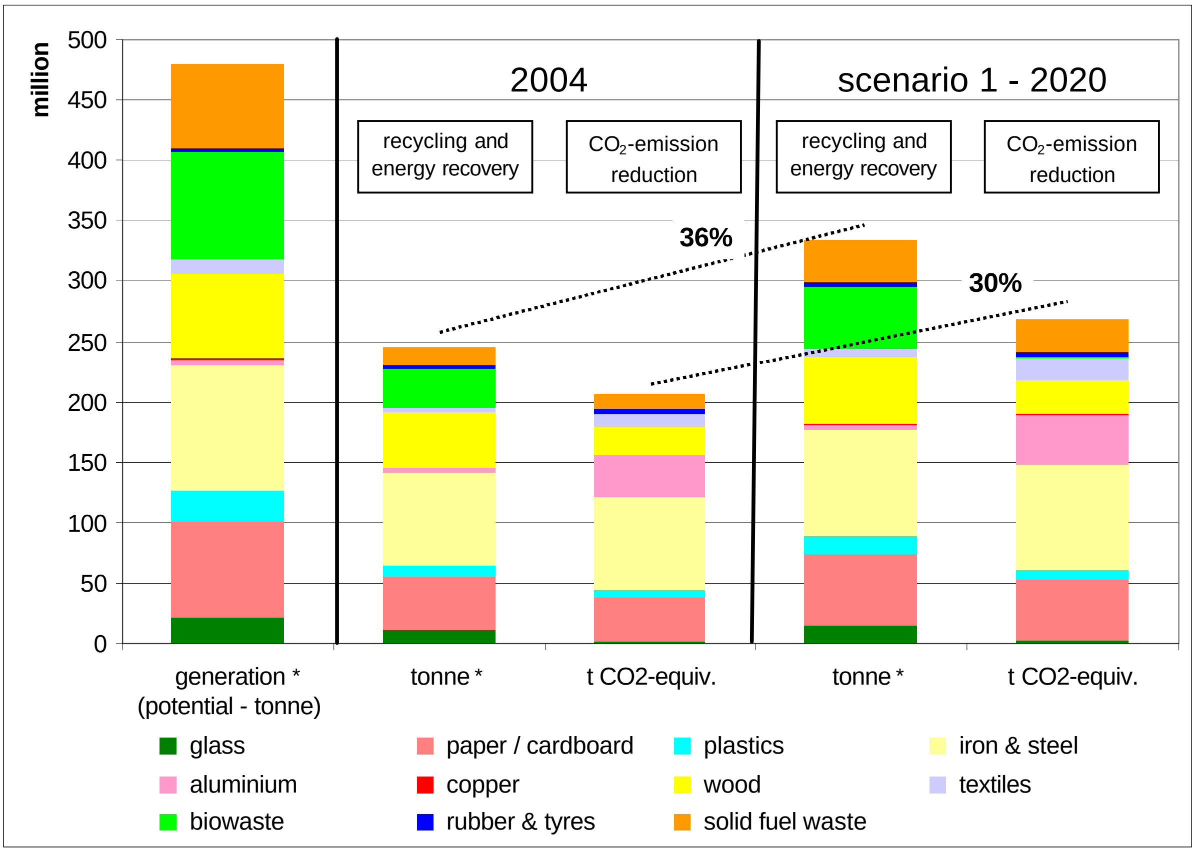
3.3 Total Results in the Four 2020 Scenarios for Material Waste Streams and Remaining Waste from MSW

The following sections display and discuss the results for the four scenarios for 2020.

Scenario 1 - Business as Usual:

The figure below shows the results for scenario 1 in comparison to our reference year 2004, and to the total potential of material waste streams for recycling, energy recovery and disposal.

Figure 5: Overview of the results in scenario 1 compared to 2004



*: without construction and demolition waste (generation potential: 858 Mt; recycling & recovery 2004: 611 Mt, 2020: 672 Mt)

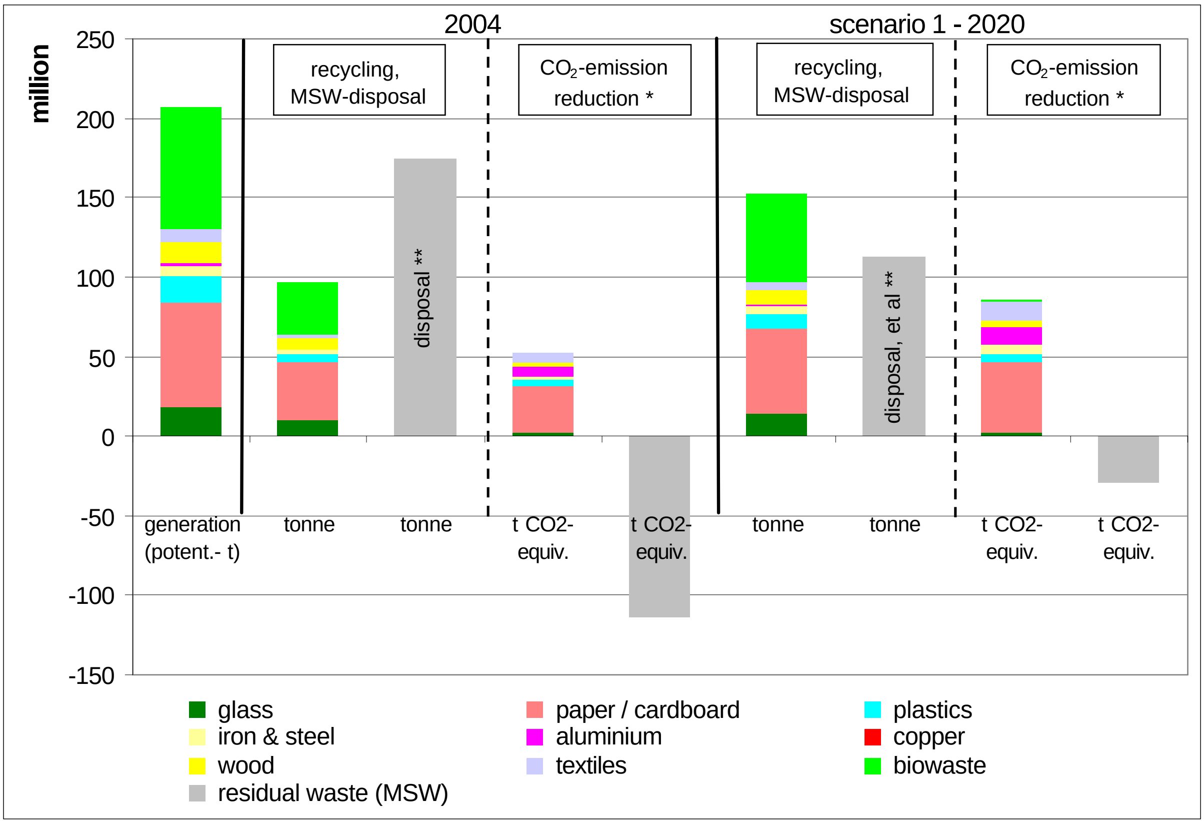
In scenario 1, until 2020 the amount of waste for recycling and energy recovery will increase by 36% (89 Mt) compared to 2004, thus totalling 335 Mt (without construction and demolition waste, which will increase by 61 Mt).

As a result, CO_2 emissions will be reduced by another 62 Mt CO_2 (about 30%). Consequently, in scenario 1 some 269 Mt CO_2 equivalents can be saved compared to new manufacturing of products or energy generation („EU 27 – energy mix 2004“).

In the year 2020, recycling of paper and cardboard, of iron and steel, aluminium, wood and solid fuels contributes the largest share in the CO_2 reductions of the waste management sector.

The following figure depicts the resulting CO_2 reductions for the **recycling of municipal solid waste** compared to the reference year and to the potential of total waste generated. In addition, the figure shows the CO_2 contribution stemming from remaining waste disposal which will see a substantial decrease in landfilling.

Figure 6: Overview of the results in scenario 1 only for recycling/recovery and disposal (D operations like landfilling and D10) of MSW



*: negative data: CO_2-emission burden (methane emission from landfilling)
**: Disposal (landfilling, D 10), other incineration (WtE - R1) and fuel preparation

In 2020 scenario 1, the amount of recyclable municipal solid waste (MSW) will increase by 55 Mt (57%) compared to 2004, reaching a total of 152 Mt. At the same time, the amount of remaining MSW for disposal or treatment will decrease by 62 Mt (36%) due to recycling activities. Some 113 Mt will remain.

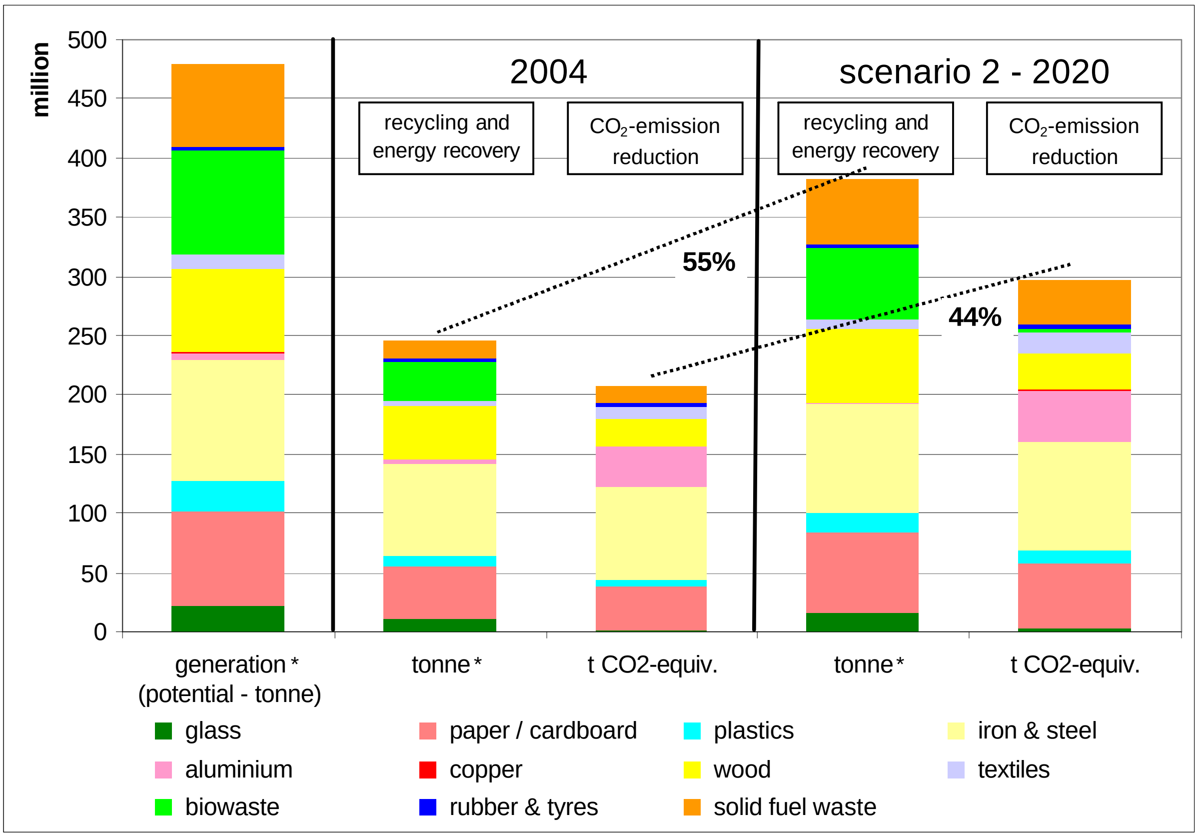
As a result of MSW recycling and energy recovery, CO_2 emissions decrease by approx. 34 Mt CO_2 equivalents (about 64%). In scenario 1, recycling processes thus help to save about 86 Mt CO_2 equivalents compared to new product manufacturing. Recycling of paper and cardboard will by far make the most important contribution to these future CO_2 reductions.

At the same time, CO_2 emissions from disposal (excluding all R1 operations) and fuel preparation of remaining waste from MSW will shrink by 84.5 Mt (74%). The remaining CO_2 burden from landfilling, incineration (excluding R1) and fuel production will amount to 29 Mt CO_2 equivalents.

Scenario 2 - Modernised European Waste Framework

The figure below shows the results for scenario 2 in comparison to our reference year 2004 and to the total potential of material waste streams for recycling, energy recovery and disposal.

Figure 7: Overview of the results in scenario 2 compared to 2004



*: without construction and demolition waste (generation potential: 858 Mt; recycling & recovery 2004: 611 Mt, 2020: 715 Mt)

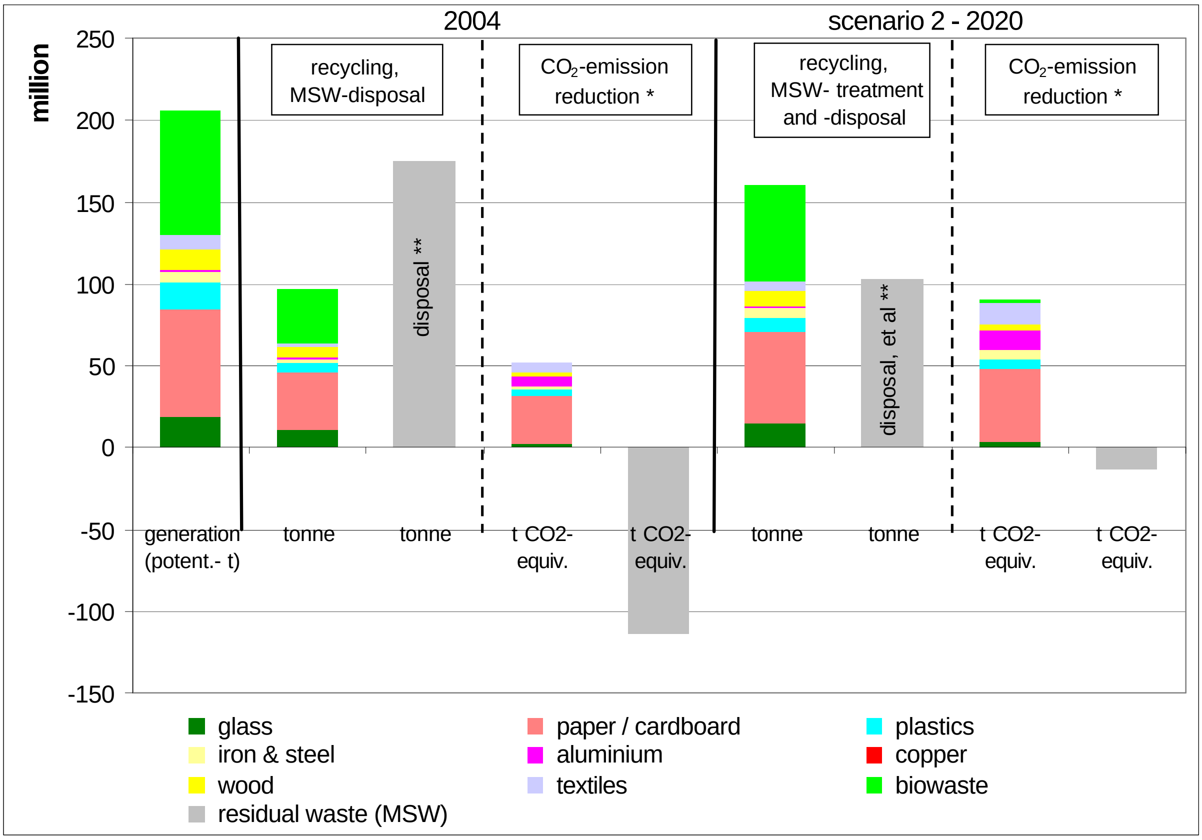
In scenario 2, the amount of waste recycled or energy recovered will increase by 136 Mt (55%) compared to 2004, thus totalling 382 Mt (without recyclable construction and demolition waste, which will increase by 104 Mt).

As a result, CO_2 emissions will increase by additional 90 Mt CO_2 equivalents (about 44%). In scenario 2 , some 297 Mt CO_2-equivalents can be saved compared to new product manufacturing from the relevant materials or energy generation (“EU 27 – energy mix 2004”).

The figure below shows the CO_2 reduction resulting from MSW recycling compared to the reference year 2004 and to the total potential of waste generated. Moreover, the figure depicts the CO_2 contribution stemming from remaining waste disposal (excluding all R operations) which will see a substantial decrease in landfilling.

In 2020 scenario 2, the amount of MSW to be recycled will rise by 66% (64 Mt) compared to 2004, totaling 161 Mt. At the same time, MSW remaining waste for disposal and treatment (including R 1 operations and fuel preparation) will fall by 72 Mt (41%), with about 103 Mt. remaining.

Figure 8: Overview of the results in scenario 2 only for recycling/recovery of MSW and disposal (D operations like landfilling and D10) and treatment (R1 and fuel preparation) of remaining waste from MSW



*: negative data: CO_2-emission burden (methane emission from landfilling)
**: Disposal (landfilling, D 10), other incineration (WtE - R1) and fuel preparation

Until 2020, recycling and energy recovery of MSW will reduce CO_2 emissions by another 38 Mt CO_2 (about 72%) compared to 2004. Consequently, in scenario 2, recycling processes will save about 90 Mt CO_2 equivalents compared to the manufacturing of new products. Recycling of paper and cardboard will by far make the most important contribution to these future CO_2 reductions.

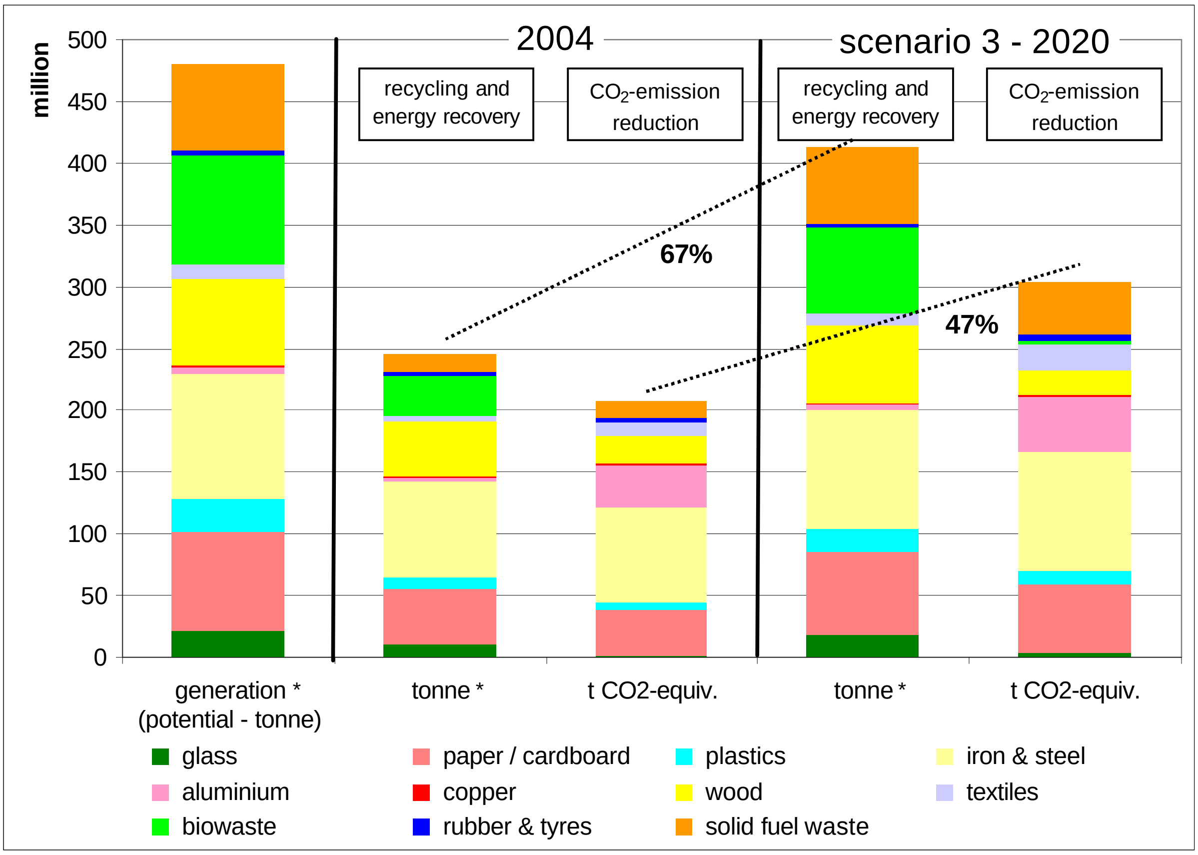
CO_2 emissions from disposal and treatment of remaining waste (including R 1 operations and fuel preparation) will, at the same time, drop by about 100 Mt (88%). The remaining CO_2 emission burden from landfilling will amount to 13.5 Mt CO_2 equivalents. Compared to scenario 1, scenario 2 has higher CO_2 emission reductions (16 Mt CO_2 equivalents) due to its recycling targets for MSW, better recycling of remaining waste, a higher degree of remaining waste incineration, and alternative fuel preparation for remaining wastes.

Scenario 3 - Strict and Ambitious European Legislation

The figure below shows the results for scenario 3 in comparison to our reference year 2004 and to the total potential of material waste streams for recycling, energy recovery and disposal.

In 2020 scenario 3, the amount of waste recycled and energy recovered will increase by 67% (166 Mt), thus totaling 412 Mt (without recyclable construction and demolition waste, which will increase by 122 Mt).

Figure 9: Overview of the results in scenario 3 compared to 2004



*: without construction and demolition waste (generation potential: 858 Mt; recycling & recovery 2004: 611 Mt, 2020: 733 Mt)

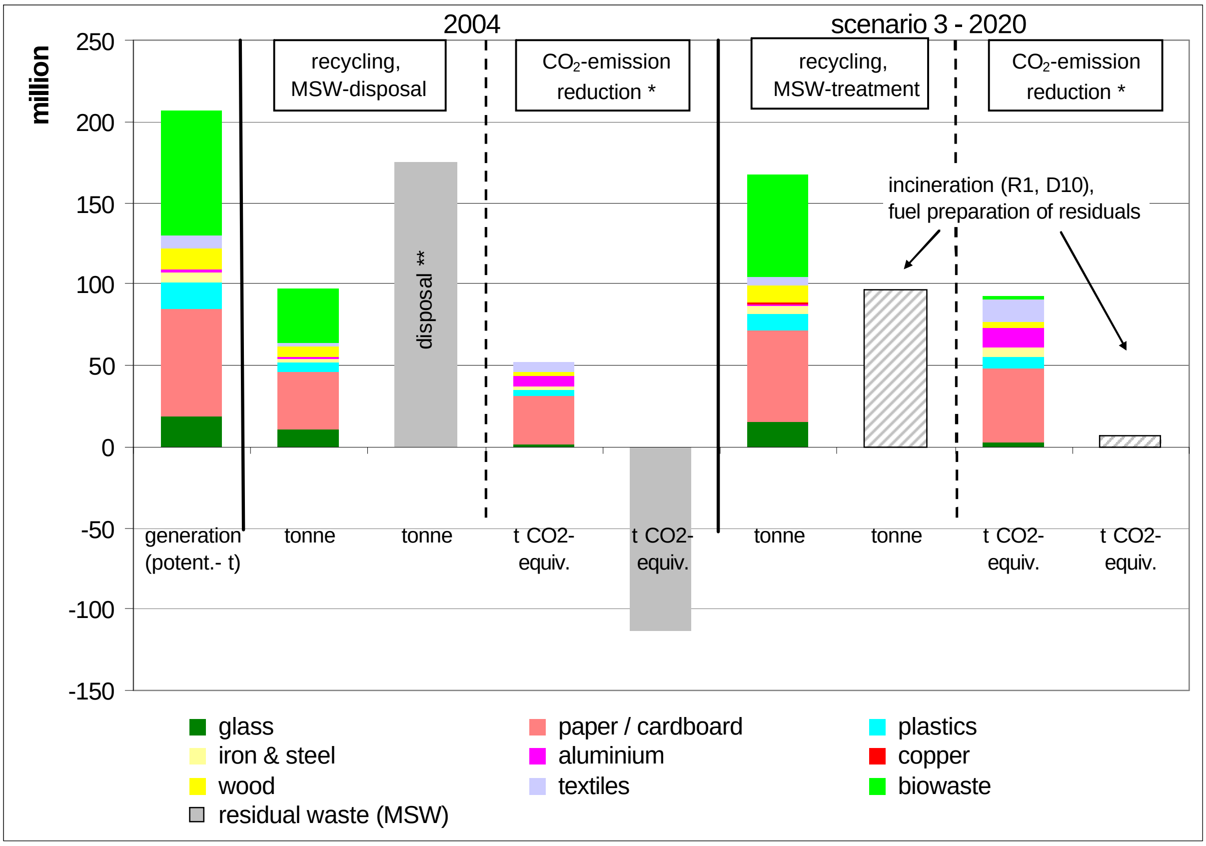
Until 2020, recycling and energy recovery will reduce CO_2 emissions by another 97 Mt CO_2 equivalents (about 47%) compared to 2004. In scenario 3, some 304 Mt of CO_2 equivalents can be saved compared to the manufacturing of new products and energy recovery ("EU 27 – energy mix 2004").

The figure below shows the results for CO_2 reductions through MSW recycling compared to 2004 and to the total potential of waste generated. Moreover, the figure depicts the CO_2 contribution stemming from remaining waste disposal and treatment (including R1 operations and fuel preparation), which will see a substantial decrease in landfilling.

In 2020 scenario 3, the MSW for material recycling will grow by 72% (70 Mt), thus totaling 167 Mt. As a result, remaining MSW for disposal and treatment (including R1 operations and fuel preparation) will shrink by 78 Mt (45%), with 96 Mt remaining.

Through MSW recycling, CO_2 emissions will be reduced by about 40 Mt CO_2 equivalents (about 76%) In scenario 3, recycling processes will save some 92 Mt CO_2 equivalents compared to the manufacturing of new products. Recycling of paper and cardboard will by far make the most important contribution to these future CO_2 reductions.

Figure 10: Overview of the results in scenario 3 only for recycling/recovery of MSW and disposal (only D10) and treatment (R1 and fuel preparation) of remaining waste from MSW



*: negative data: CO_2-emission burden (methane emission from landfilling)
**: Disposal (landfilling, D 10), other incineration (WtE - R1) and fuel preparation

At the same time, CO_2 emissions from the disposal of remaining waste will be reduced by about 121 Mt CO_2 equivalents (106% compared to 2004). This will result in CO_2 reductions during the treatment of remaining waste (prevailing for Waste-to-Energy – R1 and fuel preparation) of about 7 Mt CO_2 equivalents. Compared to scenario 1, scenario 3 achieves higher CO_2 reductions (38 Mt CO_2 equivalents) because of its recycling targets for MSW, better recycling of remaining waste, exclusive incineration and fuel preparation of remaining wastes.

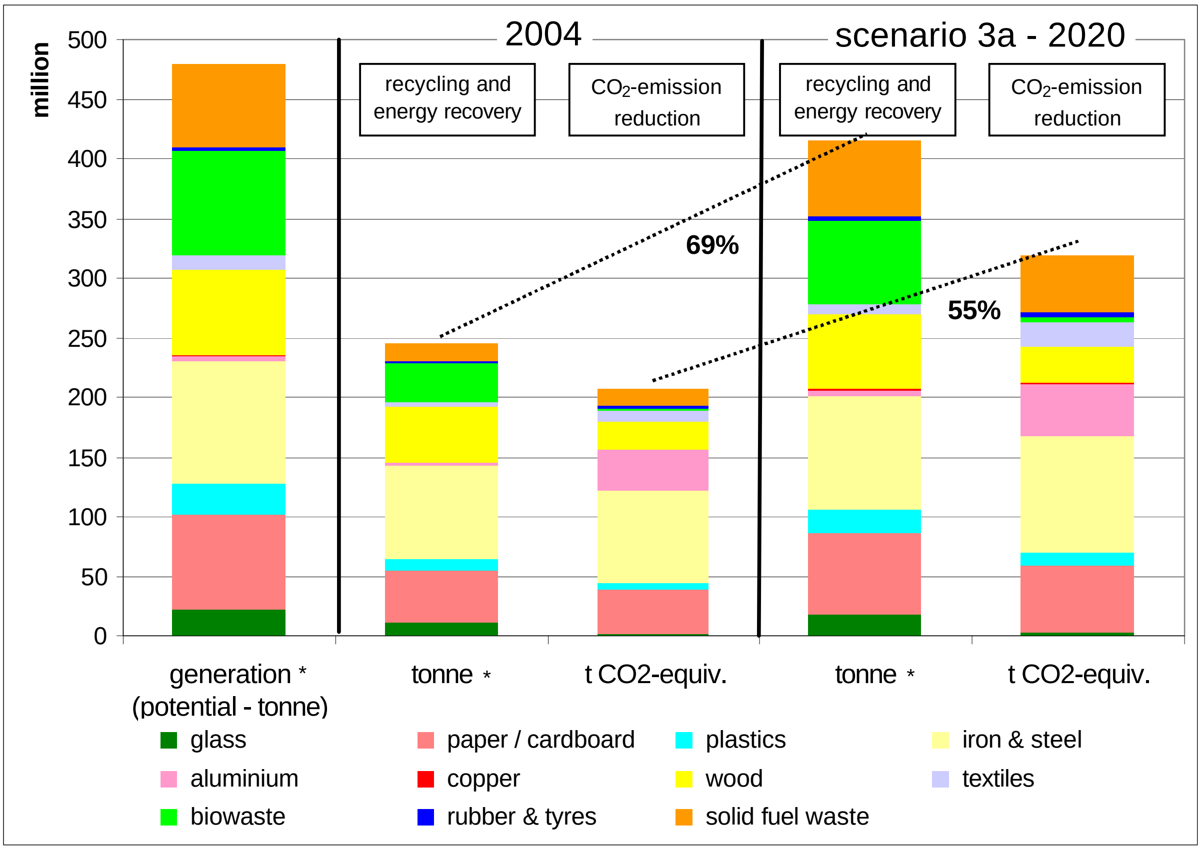
Scenario 3a: Ambitious European Legislation plus Market scenario:

The figure below shows the results for scenario 3a in comparison to our reference year 2004 and to the total potential of material waste streams for recycling, energy recovery and disposal.

In 2020 scenario 3a, the amount of waste recycled and energy recovered will increase by 169 Mt (69%) compared to 2004, thus totalling 415 Mt (without recyclable construction and demolition waste, which will increase by 122 Mt).

As a result, CO_2 emissions will be reduced by another 113 Mt CO_2 (about 55%). In scenario 3a, about 320 Mt CO_2 equivalents can be saved compared to the reference processes of manufacturing of new products or energy generation („EU 27 – energy mix 2004“).

Figure 11: Overview of the results in scenario 3a compared to 2004



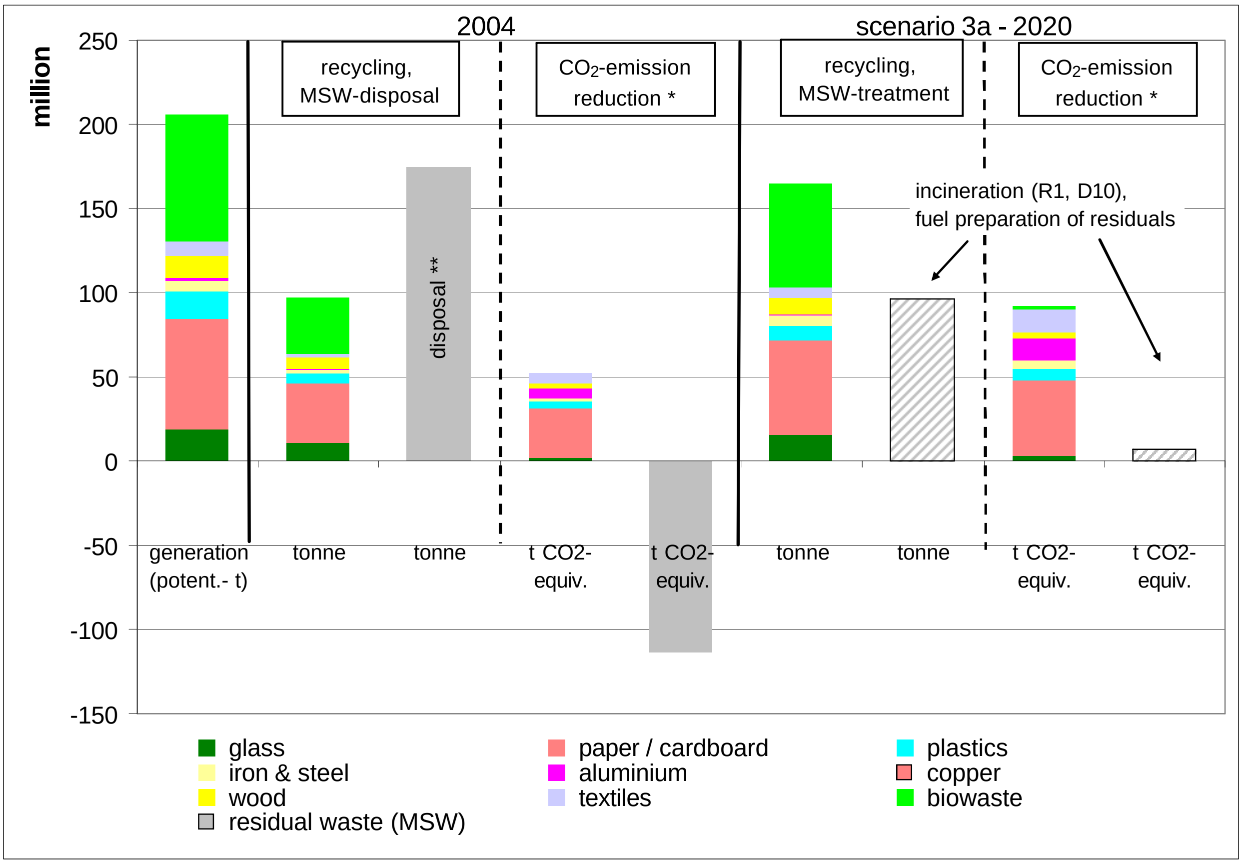
*: without construction and demolition waste (generation potential: 858 Mt; recycling & recovery 2004: 611 Mt, 2020: 733 Mt)

The figure below shows the resulting CO_2 reductions through MSW recycling compared to 2004 and to the total potential of material waste streams generated. Furthermore, the figure contains the CO_2 contribution stemming from remaining waste disposal which will see a substantial decrease in landfilling until 2020.

In 2020 scenario 3a, the amount of recyclable MSW will grow by 67 Mt (69%), reaching a total of 164 Mt. As a consequence, remaining MSW for treatment (R 1 operations, fuel preparation and D10) will diminish by 78 Mt (45%) compared to 2004, with a remainder of about 96 Mt.

As a result, MSW recycling will reduce CO_2 emissions by approx. 39 Mt CO_2 equivalents (about 75%). In scenario 3a, recycling processes will help to save about 92 Mt CO_2 equivalents compared to the manufacturing of new products. Recycling of paper and cardboard will by far make the most important contribution to these future CO_2 reductions.

Figure 12: Overview of the results in scenario 3 only for recycling/recovery of MSW and disposal (only D10) and treatment (R1 and fuel preparation) of remaining waste from MSW



*: negative data: CO_2-emission burden (methane emission from landfilling)
**: Disposal (landfilling, D 10), other incineration (WtE - R1) and fuel preparation

At the same time, CO_2 emissions from the disposal of remaining waste will be reduced by about 121 Mt CO_2-equivalents (106% compared to 2004), resulting in CO_2 reductions during the treatment of remaining waste (prevailing for Waste-to-Energy – R1 and fuel preparation) of about 7 Mt CO_2-equivalents. Compared to scenario 1, scenario 3a results in higher CO_2 reductions (38 Mt CO_2 equivalents) due to its higher recycling targets for municipal solid waste, better recycling and energy recovery of remaining waste, and the ban on landfilling of biodegradable and high-calorific value waste.

3.4 Overview of the Results for the Material Waste Streams and MSW (without recycled/energy recovered fractions)

The following figures give an overview of the main results in the four 2020 scenarios in comparison to the reference year 2004 and to 2006.

Figure 13: CO_2-reduction balance for recycling and energy recovery in the material waste streams and for remaining waste (MSW) treatment options in the 2020 scenarios

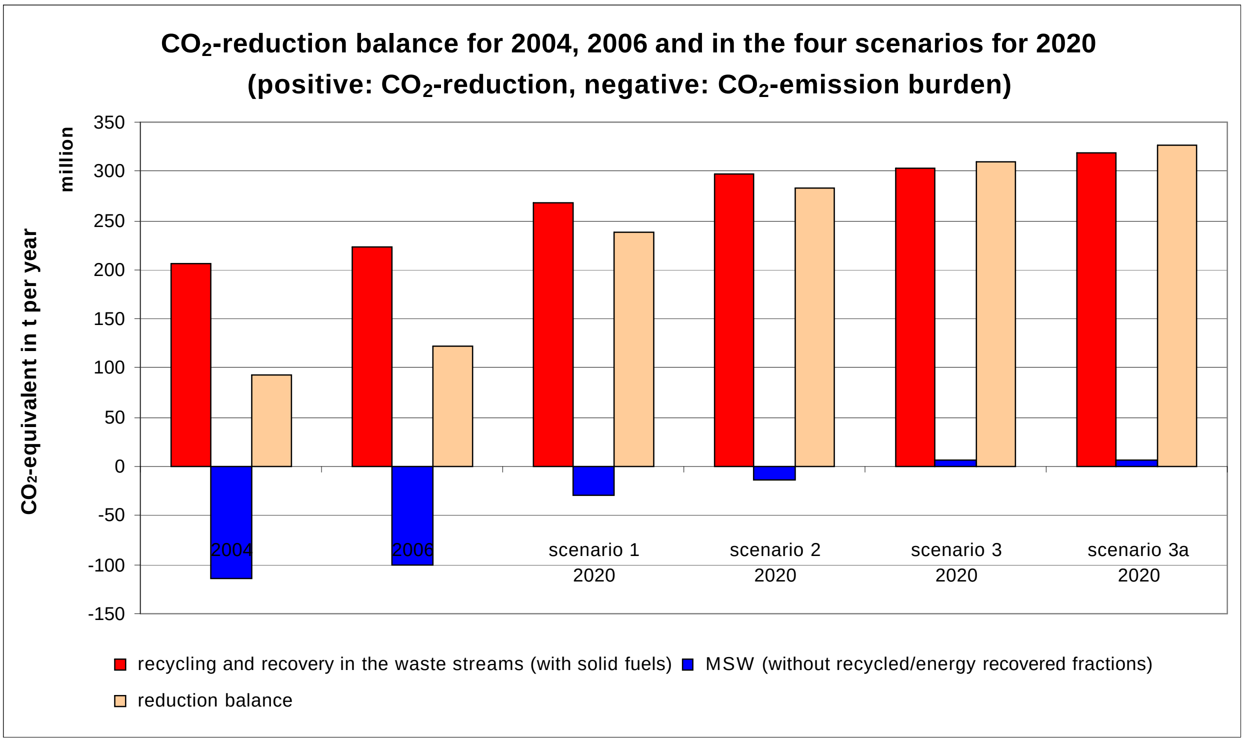
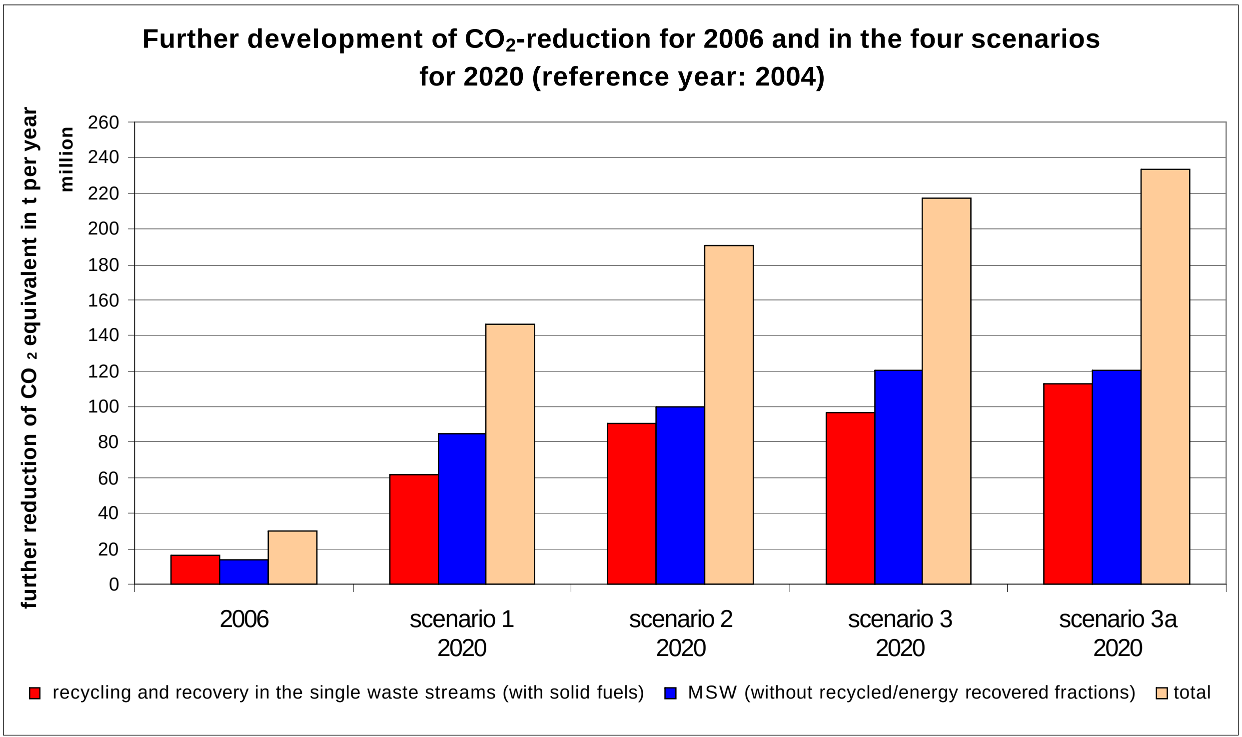


Figure 14: Development of CO2-reduction based on the year 2004, projection for 2006 and for the year 2020 in the four scenarios

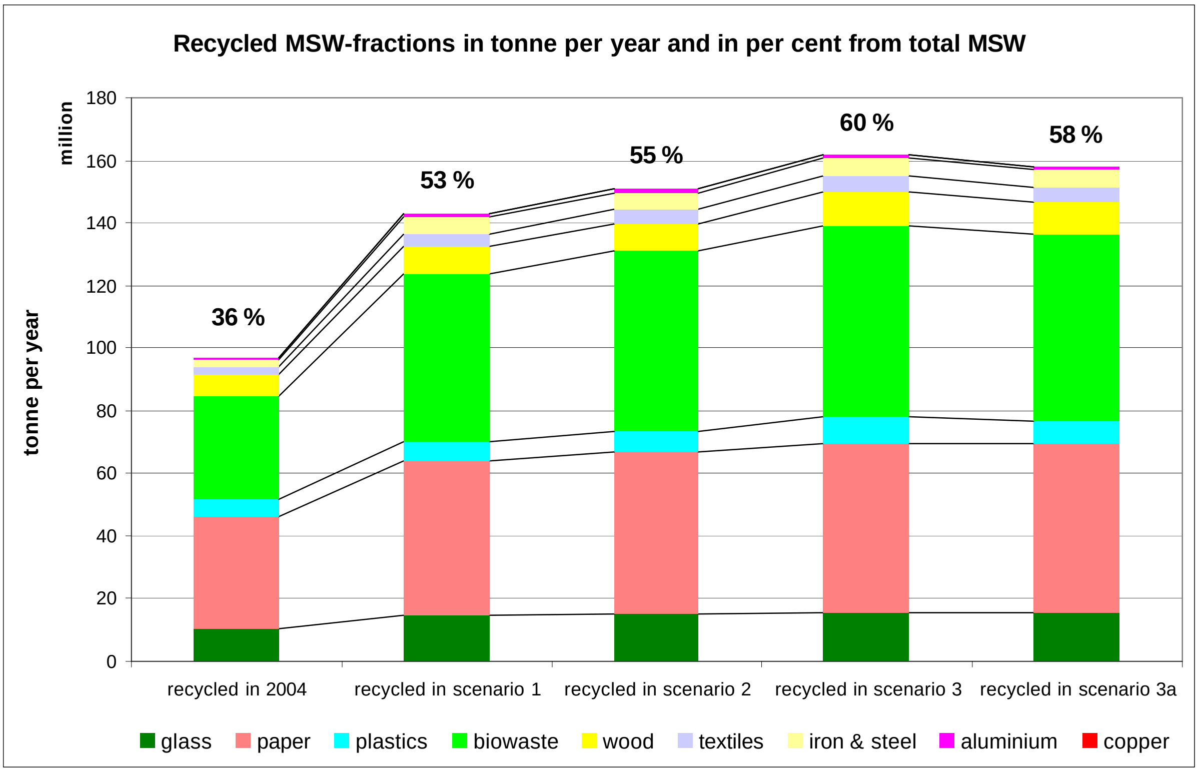


The total CO_2 emission reduction achievable until 2020 in the four scenarios **ranges between 145 and 235 Mt CO_2 equivalents**. These reductions are achieved in addition to those calculated for the material waste streams and MSW (without recycled/energy recovered fractions) for the reference year 2004 .

In all scenarios, the effects of CO_2 emission reduction will be a little higher for MSW remainings than for the analysed material waste streams. The main reasons are the lower methane emissions in scenario 1 and 2 and the zero methane emissions in scenario 3 and 3a from the landfilling operations for MSW (without recycled/energy recovered fractions), as calculated in the four scenarios.

The following figure illustrates the MSW recycling rates achieved in the reference year 2004 and the MSW recycling development in the four scenarios until 2020.

Figure 15: Recycling rates for municipal solid waste (MSW)



In 2004, the EU 27 recycling rate reached 36% (approx. 97 Mt). In addition, further MSW waste fractions not being displayed in the graph were recycled (e.g. plastics, wood, textiles, paper).

That same year only few EU countries achieved a recycling rate of above 50% (Austria, Belgium, Germany, Luxemburg, The Netherlands, Sweden).

In 2020 scenario 1, the average recycling rate for all EU countries climbs to 53%. This is due to the significantly better performance of the cited EU countries of above 70%. Only just below half of the EU countries fail to achieve a recycling rate of 50% in that scenario.

In 2020 scenario 2 the recycling rate rises to an average of 55% for all EU countries. This is due to the significantly better performance of the cited EU countries of above 75%. With few exceptions, all EU countries are now reaching a recycling rate of 50%.

In 2020 scenario 3, the average recycling rate is at 60% for all EU countries, dropping to 58% in scenario 3a due to the higher market flexibility. In both scenarios there remain selected EU members that will stay below the 60% recycling rate based on the available data.

4. Conclusions

The study intends to provide a general orientation for the potential contribution of CO_2 reduction by the EU 27 member states.

In the reference year 2004, about 46% of European waste (1.0 of 2.4 billion tonnes) is recycled or incinerated with energy recovery. The rest is landfilled, incinerated in WtE-plants with and without high energy recovery or treated by mechanical-biological methods for fuel preparation and stabilisation, the remaining waste also for landfilling.

The results clearly show that the main CO_2 emission reduction potential will be achieved by diverting waste from landfilling and implementing national and European waste policies.

The more waste Europe recycles and recovers the greater the CO_2 emission reductions. The European member states would therefore do well to send less waste to landfill and more to recycling and recovery operations.

Recycling and recovery operations will not only reduce CO_2 emission but also substitute important primary sources and fossil energy.

In 2004, waste recycling, reuse and disposal of remaining waste accounted for a reduction in CO_2 emissions of almost 95 Mt, and by 2020 this will have risen to 240 Mt (scenario 1) or even 325 Mt (scenario 3a). This CO_2 reduction is achieved, because the use of secondary materials in production processes (recycling) requires much less energy than the use of primary raw materials.

In this development the decrease of landfilling for remaining waste and the alternative treatment in WtE-plants for energy recovery reduce CO_2 emissions (coming from methane from the landfill sites) in a range of between 85 Mt (scenario 1) and 120 Mt (scenario 3/3a.) until 2020.

The differences between the scenarios are considerable. Scenario 3a renders the best results. This scenario assumes the highest market prices for energy and raw materials, but is also based on implementation of the waste hierarchy as a guiding principle and not a (more compelling) general rule. This allows greater market flexibility and therefore opens up more opportunities for energy recovery.

Nevertheless, there seems to be no basis to the claim that building waste-to-energy plants will reduce the incentive to recycle. The study shows that countries with high waste incineration percentages also achieve high recycling percentages and have a great impact on current and future CO_2 emission reductions.

At Kyoto, EU leaders committed to cutting emissions by at least 20% in the period of 1990 to 2020 (approx. 850 Mt CO_2 equivalents from 4,300 Mt CO_2 equivalents in 1990). With this in mind, the role of waste management with increased recycling and energy recovery of material waste streams and alternative treatment options for the disposal of remaining remaining waste on landfill sites (such as incineration in WtE-plants and fuel preparation) can contribute significantly to reach these targets.

A reduction in CO_2 emissions of between 145 and 235 Mt (**16% - 27%** of the European climate reduction targets) can be achieved. These are in addition to the CO_2 emission reduction we analysed as a basis in 2004 for the material waste streams and the remainings from municipals solid waste.

5. Recommendations

Further development of European waste management towards a resource management is a responsible target for the European Commission, the Council as well as the EU Parliament.

This current study offers a range of solid arguments supporting a continuous and expeditious development in order to reach the right European targets.

For that reason, the renewal of the European waste strategy through a new Waste Framework Directive is of great significance in order to reinforce incentives for a further change towards resource management in all European countries.

Even prior to this study it was undisputed that resource management, which emphasizes a consequent material and energetic use of waste and helps avoid landfilling of biodegradable and high-calorific value waste, will assist in achieving climate protection targets across Europe. Those eight countries that have already stepped up recycling and incineration of waste (Belgium, Denmark, Germany, France, Luxembourg, the Netherlands, Austria and Sweden) have experienced and can confirm these results.

For the first time the full dimension of the contribution of each European country as well as all European countries together towards a reduction of climate gas can be quantified for waste management. And that is new!

We have the following recommendations for the decision-makers revising the Waste Framework Directive:

- The five step waste hierarchy (prevention, reuse, recycling, other recovery including energy recovery, disposal) is a suitable tool to increase the effective (re)use of waste materials and resource conservation.
- Our results of the „CO2 foot print“ do not deliver evidence that the waste hierarchy must be implemented as a “general rule”. Our results rather indicate a tendency that the waste hierarchy should be a „guiding principle”.
- Recycling of, above all, paper, metal, clean plastics, glass, and textiles offers clear and documented advantages towards prevention of climate gas. Therefore, it is our view that recycling of these materials should be clearly supported by a Waste Framework Directive.
- Introduction of binding recycling targets for certain waste, such as municipal solid waste, construction and demolition waste or other waste groups is a significant impulse to step up a better raw materials use of waste in all European countries.
- Reaching recycling targets of, for example, 50% for a material recycling of municipal solid waste or of 70% of construction and demolition waste seem attainable for all EU member states medium- to long-term.
- It is our view that implementation of rules stimulating more energy efficient use of remaining waste materials destined for incineration has significant impact on the

design of an energy efficient resource management and will, therefore, lead to a better climate balance.

- In addition, the consequent abandonment of landfilling for biodegradable waste and waste with high calorific value is one of the key drivers in reaching a sustainable waste management in Europe until 2020.