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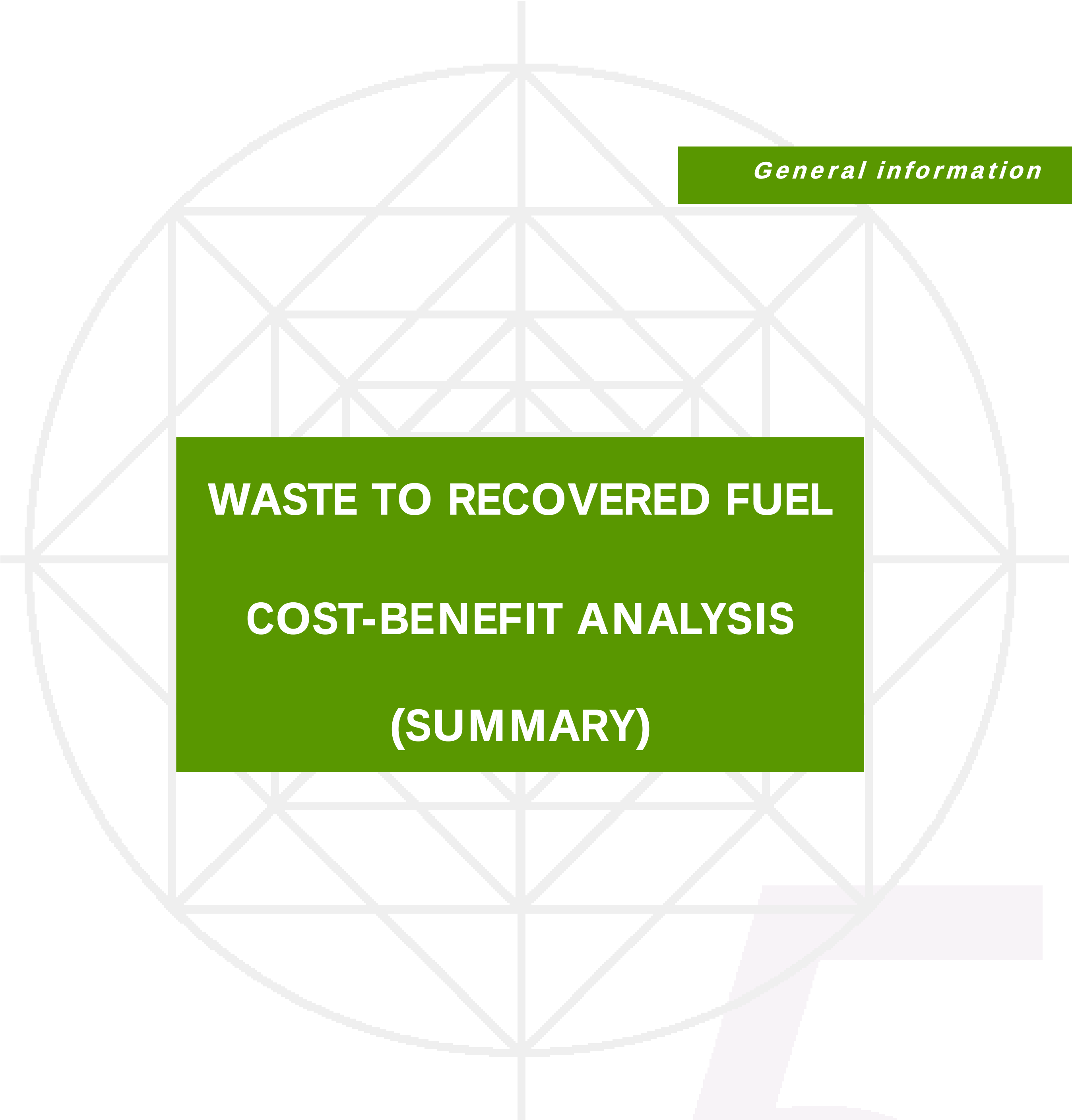

WASTE TO RECOVERED FUEL

COST-BENEFIT ANALYSIS

(SUMMARY)

ENERGIE

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Waste to Recovered Fuel
Cost-Benefit Analysis

Summary

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- ACE, the Alliance for Beverage Cartons and the Environment (Belgium)
- APME, Association of Plastics Manufacturers in Europe (Belgium)
- ASSURRE, Association for the Sustainable Use and Recovery of Resources in Europe (Belgium)
- Borealis Polymers Ltd, Co-ordinator (Finland)
- C.C. Umwelt AG (Germany)
- DUNI AB (Sweden)
- Essent Milieu (Netherlands)
- Eurelectric (Belgium)
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- SCORIBEL (Belgium)
- Slough Heat & Power (United Kingdom)
- Trienekens AG (Germany)

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Recovered Fuel is a fuel of uniform quality that meets public user-oriented specifications. It is prepared from selected pre- and post-use, non-hazardous combustible waste in a dedicated process applying a quality assurance system. (Definition given in THERMIE report Fuel and Energy Recovery, DIS-1375-97-FI)

1. INTRODUCTION

Integrated Resource and Waste Management (IRWM), implemented in a spirit of shared responsibility, is an important means to reach a sustainable society. The maximum benefit should be extracted from primary natural resources and wastes that cannot be prevented. Although there are on-going efforts to continuously improve efficiency within all industrial sectors, the dependency on fossil fuels, especially on coal, is expected to prevail in modern society.

Despite successful prevention, waste will always be produced as a result of human activities. Waste is subject to detailed EU regulation setting binding targets for recovery, including recycling. Inorganic waste materials like glass and metals can be recovered as material in thermal processes. Organic combustible materials like wood, paper, board, plastics and rubber can be recovered both as material and as a fuel to be used for the production of heat and electricity.

The objective of this study is to evaluate the overall effects of different recovery options for non-hazardous combustible waste on national welfare, by means of Cost-Benefit Analysis. The study compares (a) dedicated incineration of mixed MSW with Energy Recovery and (b) Fuel Recovery for substituting fossil fuel in a co-combustion process to (c) direct landfill. It is acknowledged that the Commission has contracted a separate study on re-use and material recovery of packaging waste in the Union.

The present study is part of the project Waste to Recovered Fuel, which is co-funded by the ENERGIE Programme of the 5th FP of the European Commission and by an industrial consortium representing all stakeholders (contract NNE5-1999-533).

2. COST-BENEFIT ANALYSIS

Cost-Benefit Analysis (CBA) can be used for the assessment of sustainable integrated resource and waste management. In this study it is based on a dedicated computer model developed by GUA, Austria. The *system identification* defines boundary limits for material and energy balances. It includes all relevant waste management operations, as well as all primary production processes, which may be utilised for recovery purposes. The *functional unit* used in this CBA is Euro per person and year.

Internal costs are defined as fixed and variable direct costs related to the processes. External costs are defined as costs of all direct and indirect environmental and social impacts related to the operation. Emissions are translated into monetary units by applying the principle of *averting costs*. These are defined as (known) process costs, necessary to reduce emissions to a specified level. The processes applied are those reducing the relevant emissions most cost-efficiently.

The CBA calculation gives the total system costs, internal and external, of an analysed recovery scenario, including the avoided costs of the corresponding substituted primary production processes.

The Cost-Benefit Balance (CBB), the difference in cost between the baseline scenario and an analysed scenario, is the final result of CBA. A positive figure means an overall cost benefit compared to the baseline scenario. Comparison of several CBBs advises on the most economic solution.

3. BASIC ASSUMPTIONS AND SCENARIOS

In this CBA the *analysed scenario* identifies the detailed input and output parameters of a specific system. 45 separate data combinations are analysed in the study.

Fixed parameters are: number of citizens (500,000), number of households (200,000), fraction of multi-family houses (50 %), fraction of single family houses (50 %), amount of combustible waste from industry and trade (100 kg/person/year), size of MSW incinerator (150,000 t/year), energy efficiency at co-combustion (same as for primary fuel), free access to deliver electricity to the grid and sufficient solid fuel consumption to be substituted by recovered fuel.

Variable parameters (low, medium, high) are: amount of MSW per person, share of bio-waste, share of packaging waste, efficiency of separate collection, collection system used, energy recovery efficiency at MSW incineration, cost level of labour and investments as well as demand of district or process heat. These are combined to form three Model Regions, basically representing the situation in South, Central and North Europe.

The Energy Recovery case assumes a modern MSW incineration plant equipped with different energy conversion systems where the energy produced substitutes energy from primary sources, i.e. coal (I-coal), fossil natural gas (I-gas) or a European mix of primary energy sources (I-mix). Electricity efficiency in condensing mode is 25 % based on the lower heating value of input fuel. Overall energy efficiency for production of combined heat and power (CHP) is 80 % (up to 100 % for a plant with flue gas condensation).

The Fuel Recovery case includes three basic processes for the production of recovered fuel from selected non-hazardous combustible waste, i.e. low yield in the form of fluff (FP-1), medium yield in the form of soft pellets (FP-2) or high yield in the form of hard pellets (FP-3). The storable fuel may be used in four different combustion technologies, i.e. Cement Kiln (CK), Circulating Fluidised Bed (CFB), Pulverised Coal (PC) or in gasification with consequent combustion of the gas in PC (gasPC). All operations are “state of the art” fulfilling European legislation. Energy efficiencies are assumed to be unchanged for a reasonable range of 5 – 30 % primary fuel substitution.

The *Baseline Scenario* is the reference that does not contain the studied fuel and energy recovery processes. It is direct landfilling of all wastes not being recycled as in the analysed recovery scenarios. The landfill operation fulfils the technical requirements of the Landfill Directive and is equipped with energy recovery from landfill gas. The examination period of landfilling is 10,000 years, since also long term effects are considered in the CBA.

The averting costs used for air- and water pollutants[1] are evaluated by the Institute of Public Finance and Infrastructure Policy at the Vienna University of Technology. They are derived from the averting costs quoted in recent scientific literature. The costs applied for Hg and Pb emissions are proportionate to the averting costs of Cd according to their toxicity for humans.

4. RESULTS

From the 45 analysed data combinations 5 principal scenarios are selected for presentation here. Data for the baseline, landfill and incineration scenarios as well as for primary processes are derived from the GUA data bank. Data for the fuel recovery scenarios, low, medium and high yield, are acquired from the operations of Essent Milieu VAM in the Netherlands, Trienekens AG in Germany and Ewapower in Finland respectively.

The mass balances (figure 1) show the diversion of combustible waste from landfill. For the scenarios involving incineration only process ashes are landfilled. The high yield fuel preparation, combined with organic recovery of biowaste, and consequent landfilling of rejects, meets the Landfill Directive targets.

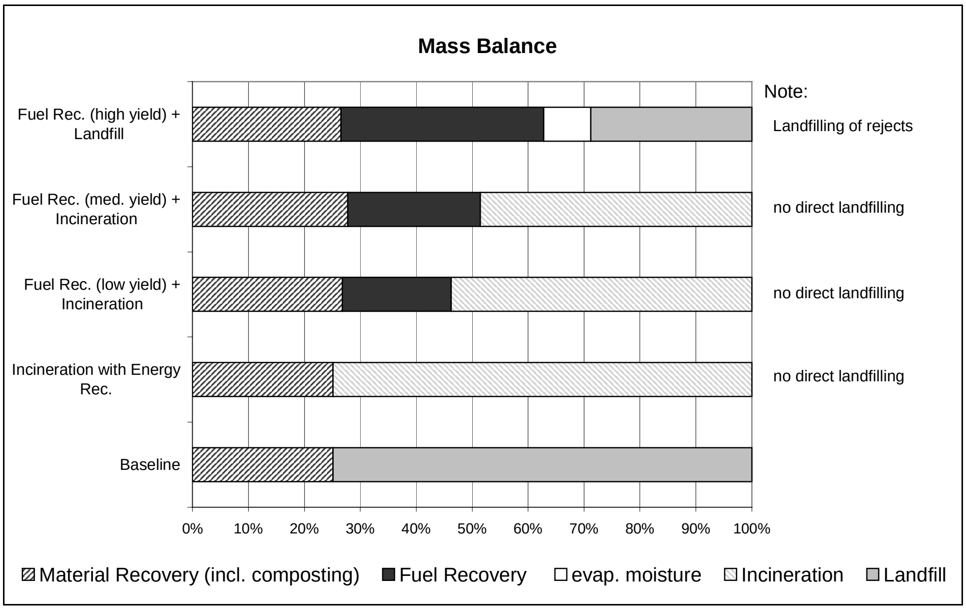

Figure 1: Mass balances of selected scenarios.

The energy balances give the amounts of electricity and heat produced. The amount of electricity varies significantly amongst the cases (figure 2).

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[1] air pollutants: $CO_{2\ bio}$, $CO_{2\ foss}$, CH_4, CO, SO_2, HCl, NO_x, NMVOC, Dust, CFC, Cd, Hg, Pb;
water pollutants: COD, NH_4, Cd, Hg, Pb.

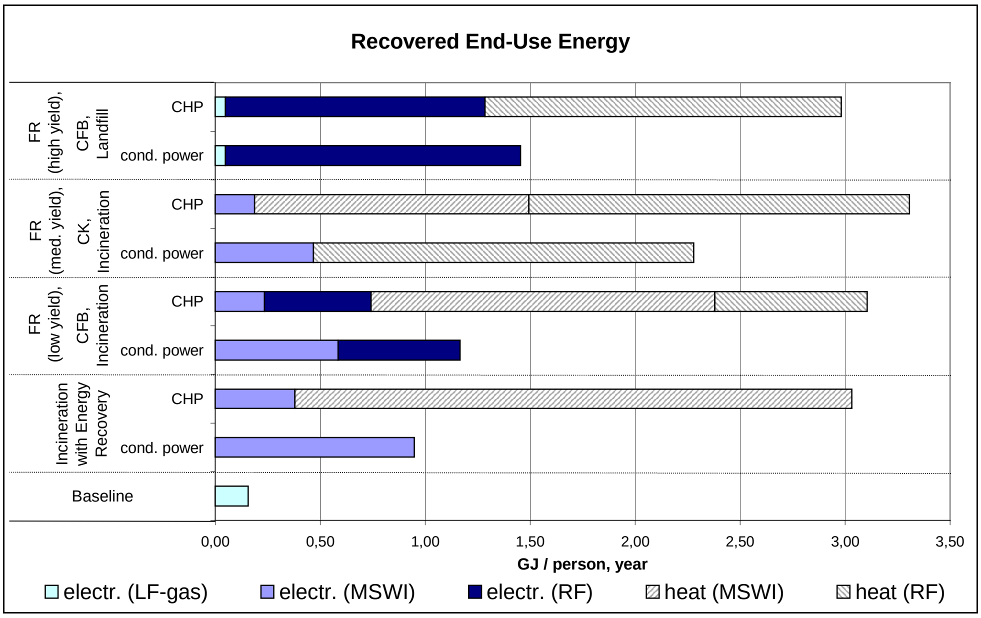

Figure 2: Production of end-use energy in selected scenarios

Regarding emissions of greenhouse gases (Global Warming Potential, GWP, figure 3) Energy Recovery and Fuel Recovery save 50 - 300 kg CO_2 equivalents per person and year. This corresponds to 20 - 50% of the total GWP of substituted primary production. In comparison with the baseline scenario, direct landfilling, as much as 250 - 500 kg CO_2 equivalents can be saved. The main reduction of greenhouse gases results from the substitution of fossil fuels (fossil CO_2 emissions) and from the diversion of biodegradable waste from landfill (CH_4 emissions).

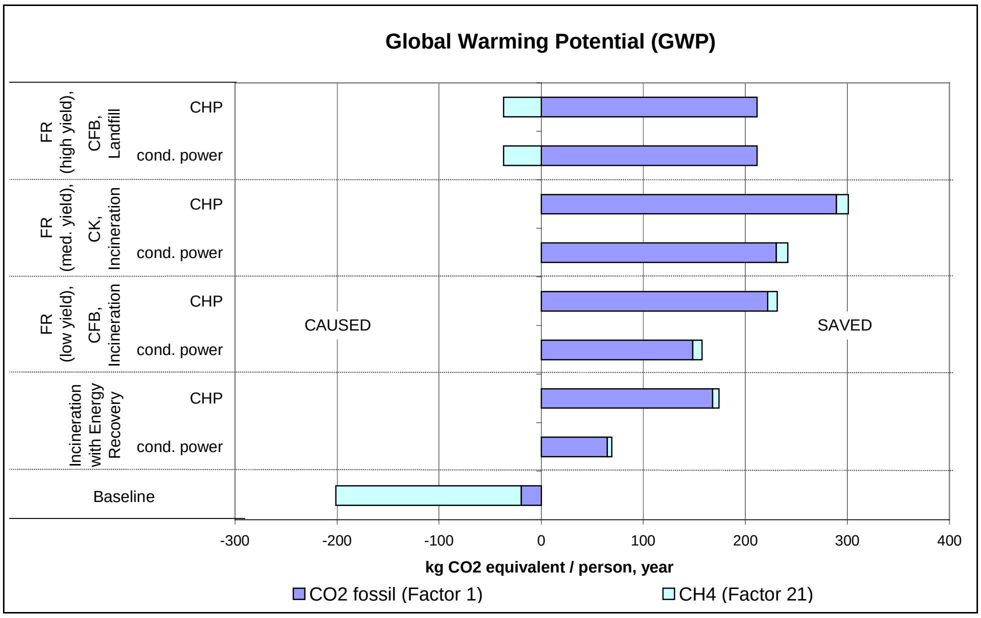

Figure 3: Global warming potential for selected scenarios

The final macro economic benefit (figure 4) is highly influenced by the total amount of energy produced. The model does not distinguish between the production of electricity and heat. Most favourable is the substitution of coal. Condensing power (electricity only) from dedicated MSW incineration, which substitutes electricity from fossil gas, does not give a macro economic benefit.

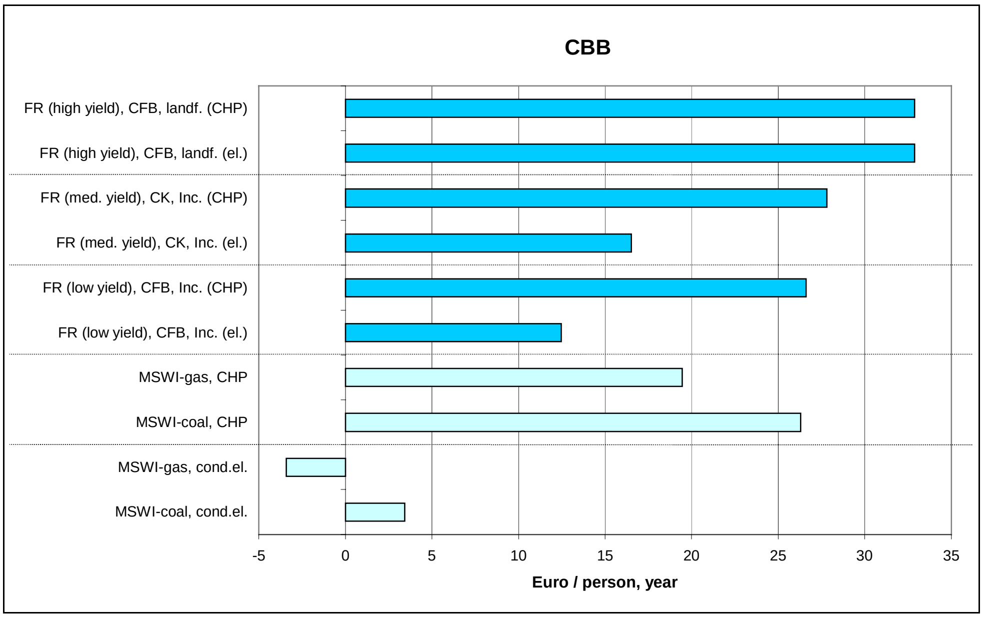

Figure 4: Cost-Benefit Balance of selected scenarios compared to landfill.

The study shows clearly that the internal costs of direct landfilling are lower than the internal costs of any recovery operation. However, when including external costs the results change, and both Energy Recovery and Fuel Recovery show a benefit for the Society in the order of 5 – 30 Euro per person and year. This is mainly due to averting costs for emissions from landfill and to averting costs for fossil CO_2 emissions, saved through energy and fuel recovery. 50 % of the combustibles in MSW is considered to be of biogenic origin.

The study shows even better results for high yield fuel preparation for co-combustion in pulverised coal power plant. However, the economy of fuel pulverisation technology is not yet proven for recovered fuels in general, so these results are not as valid as those for cement kiln and fluidised bed combustion.

5. CONCLUSIONS

The cost-benefit analysis undertaken concentrates on the management of residual waste from households and commercial/industrial facilities after secondary materials have been separated for eco-efficient recycling.

Averaged over all scenarios and regional conditions investigated (45 data sets), the annual economic benefit that can be achieved for the national welfare is in the order of 15 - 40 Euro/person. The study shows that fuel and energy recovery can save 2 - 5 GJ/person (= 50 - 125 kg of oil equivalent). This corresponds to some 10 % of the solid fuel consumption and to 2 - 4 % of total fossil fuel consumption in Europe. It is a significant contribution to the Kyoto targets.

The main conclusions of the CBA are:

- All recovery scenarios show a significant reduction of greenhouse gas emissions, carbon dioxide and methane, compared to the baseline scenario, landfilling. The reduction is proportionate to the diversion of combustible waste from landfill and yield of recovered fuel.
- All the recovery options studied give an economic benefit to the Society, except the one where electricity generated by waste incineration substitutes electricity generated by a gas fired power plant.
- The more Recovered Fuel that can be diverted to energy production, the higher the benefit. The fuel recovery options are generally a little better than the incineration options with energy recovery.
- Fuel recovery is especially well suited in sparsely populated regions where relatively small decentralised fuel production plants can deliver recovered fuel to existing power plants or plants for production of material products.
- For larger cities or regions with an existing incineration plant, a combination of fuel recovery combined with direct incineration with energy recovery seems to be a preferred option.

6. DISCUSSION

For practical reasons, the Cost-Benefit analysis is based on average available data processed by a dedicated computer model that builds on previous experience and work of GUA.

A sensitivity analysis (figure 5) based on “medium assumptions” (averaged over all Model Regions investigated) shows how the results of this CBB are influenced by variation of with input parameters.

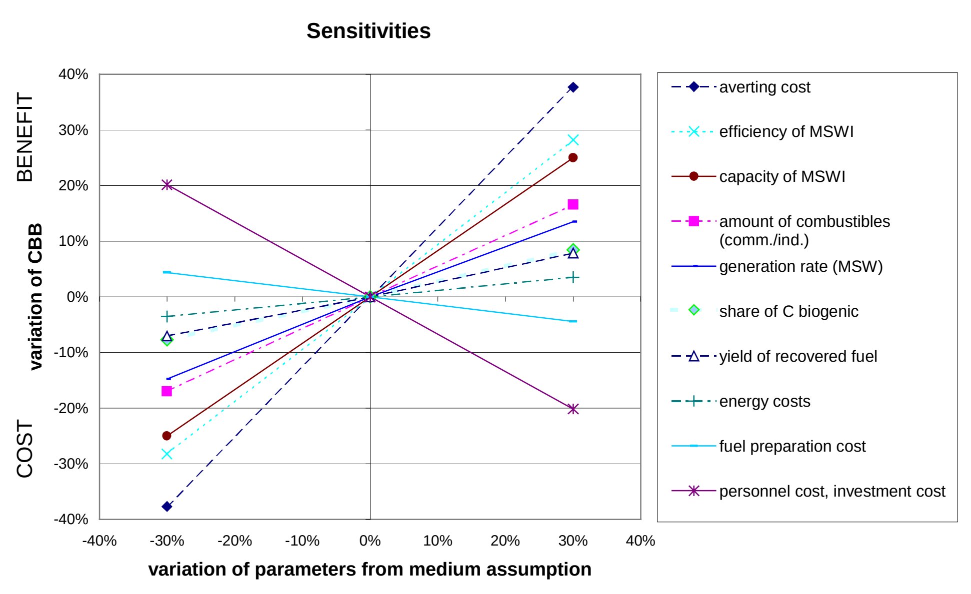

Figure 5: Sensitivity of CBB

The significance of input parameters to the results can be grouped in the following order:

1. The (external) averting costs have the greatest influence on the results. They affect landfilling the most, because of the long calculation period, 10,000 years, without discounting. A calculation period of 100 years for landfilling roughly reduces the results by one third, but does not change the overall conclusions or affect the internal ranking of the analysed recovery scenarios.
2. The energy efficiency and size of the MSW incinerator. The influence of (direct) labour and investment costs are also high. It is noted that Fuel Recovery in general is a decentralised option involving smaller units, more job opportunities and less investment compared to dedicated MSW mass burn facilities.
3. The amount of waste and especially the amount of non-recyclable combustible waste. This makes Fuel Recovery a favoured option in industrialised regions.
4. The share of biogenic carbon in combustible waste and the yield of recovered fuel have a less significant influence on the results.
5. The (direct) costs of primary energy sources and of recovered fuel production affect the results only to a minor degree.