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Plastics in Mixed Household Waste

Potential Reduction of Carbon Emissions through Material Recycling and Incineration with CCS

mepex

Vocabulary

MSW = Municipal Solid Waste; mixed household waste; mix of recyclable and non-recyclable materials

Residual waste = non-recyclable or unwanted materials; residues after mixed waste sorting where recyclable material have been extracted

WtE = Waste to Energy; incineration of waste with energy recovery

CCS = Carbon Capture and Storage

EPR = Extended Producer Responsibility

PRO = Producer Responsibility Organization

MWS = Mixed Waste Sorting = Mechanical sorting facility/plant that processes unsorted MSW and extracts recyclables like plastic and metals and leaves a non-recyclable residual waste fraction

CO_2 tax = Norwegian Incineration tax set per ton fossil CO_2 incinerated. Independent of EU Emissions Trading System (EU ETS) for CO_2 quotas.

Background

Mepex has carried out a simplified study for TOMRA, calculating costs and climate benefits across the plastics value chain from municipal solid waste (MSW). Scenarios have been developed to assess increased sorting and material recycling of plastics, both with and without carbon capture and Storage (CCS) following waste-to-energy (WtE) of MSW. The calculations are based on MSW from Oslo as a case study.

Introduction

To achieve national environmental and climate targets, significant emission reductions and substantially higher levels of material recycling will be required. Current trends indicate that progress is falling behind schedule. Carbon Capture and Storage (CCS) at waste-to-energy (WtE) facilities is an effective solution to reduce direct CO_2 emissions but does not contribute to meeting EU targets for waste sorting and material recycling. The most effective measure to increase recycling rates is the establishment of facilities for mixed waste sorting.

Mepex has carried out an environmental-economic analysis of alternative solutions for handling plastics in MSW. The study also assesses how sorting and WtE with CCS can be combined to further reduce the climate footprint. Plastics separated through mixed waste sorting are assumed to be forwarded to advanced sorting facilities for further sorting and subsequent material recycling.

The analysis compares four scenarios:

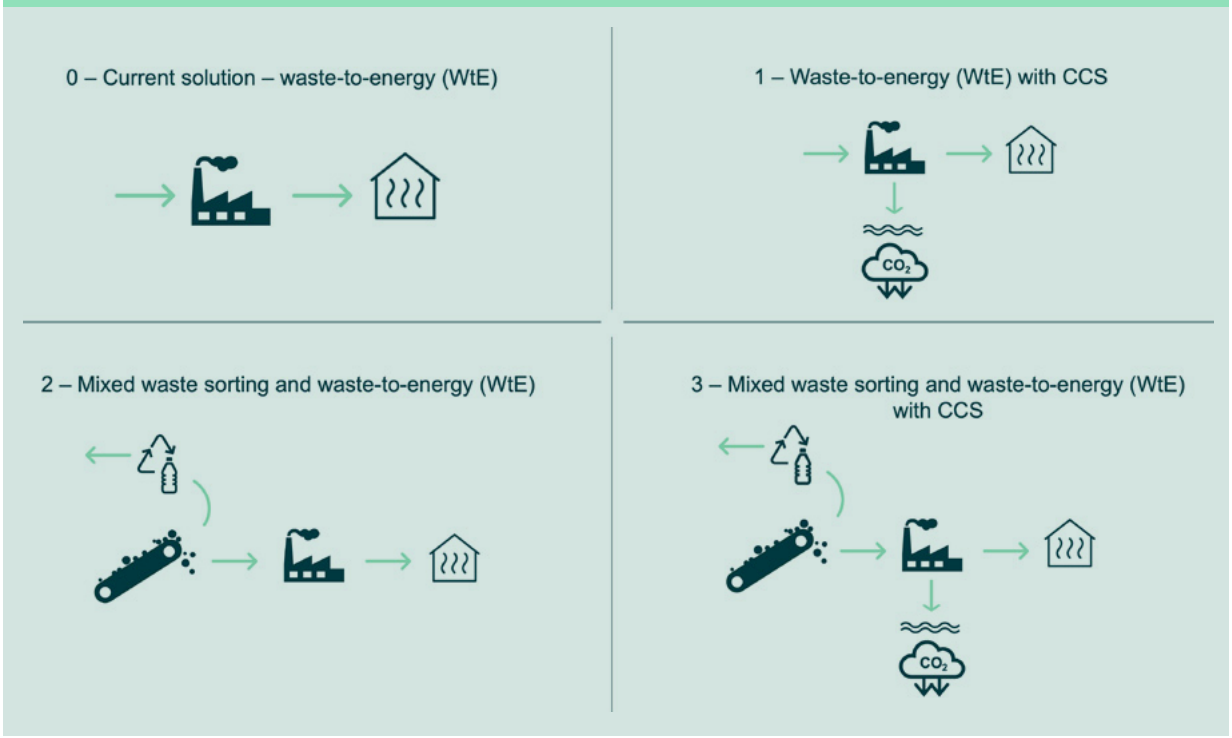
0) MSW to incineration (WtE) without CCS (current solution)

1) MSW to incineration (WtE) with CCS

2) MSW to mixed waste sorting, with residues to incineration (WtE) without CCS

3) MSW to mixed waste sorting, with residues to incineration (WtE) with CCS.

Figure 1 - The analysis compares four scenarios



CASE: CITY OF OSLO

The analysis uses Oslo, capital of Norway, as a case study. Oslo is Norway's most densely populated municipality, accounting for approximately 12% of the national population. The City of Oslo has adopted a climate strategy aiming to reduce emissions by 95% by 2030 compared with 2009 levels. The future carbon capture plant at Klemetsrud is one of the key measures in the strategy, that from 2030 is designed to capture CO_2 from their WtE facility that incinerates 400,000 tonnes of waste annually. This represents approx. 25% of Norway's WtE capacity, significantly more than Oslo's population alone would justify. Thus far, Oslo has no plans for further plastics separation from MSW prior to incineration.

The calculations are based on approximately 92,500 tonnes of MSW collected annually through Oslo's current collection system. To reduce the number of variables, plastics already source-separated through their optical bag sorting system, have been excluded. The analysis mainly draws on publicly available data sources and includes all costs.

A simplified climate account has been developed for the 12,800 tonnes of plastics in MSW annually sent to WtE facilities. Only the effect of increased plastics sorting is included, meaning emission reductions from the separation of other fractions (e.g., metals) are not accounted for. Key assumptions are presented in the annex.

Greenhouse Gas Emissions

Results from the climate calculations show that the combination of mixed waste sorting and subsequent waste-to-energy (WtE) of residuals with CCS is the best environmental solution. This option reduces CO2 emission by 40% (11,800 tonnes CO_2 per annum) compared to WtE with CCS alone, which is the planned solution. Mixed waste sorting would additionally result in approx. 7,000 tonnes of plastics annually becoming secondary raw material, based on an 85% sorting yield and 54% recycling yield of plastics from MSW. Climate benefits from district heating and electricity production from incinerated plastics are also included in the calculations.

Figure 2 - Reduced greenhouse gas emissions

Cost Assessment

Total costs were first calculated, then distributed according to relevant financing sources.

The results show that the combination of CCS and plastics separation in mixed waste sorting achieves almost the same cost per tonne of CO_2 avoided as sorting alone—around NOK 1,700/tonne CO_2—while CCS alone costs about NOK 3,700/tonne CO_2. Sorting and recycling yield the lowest cost per tonne of plastics recycled, at approximately NOK 4,100/tonne plastic, including advanced mechanical sorting.

A separate calculation shows how these costs may be financed externally through Extended Producer Responsibility (EPR) fees, state subsidies, avoided CO_2 taxation, and municipal waste fees. Even with high state subsidies for CCS, municipal costs per tonne of plastics to WtE with CCS are significantly higher than for sorting and delivering plastics to Producer Responsibility Organizations (PROs). By contrast, the combination of sorting and CCS provides municipalities with a net financial gain. It is emphasized that EPR only covers plastic packaging from the Norwegian market, not all plastics.

Figure 3 - Total costs per tonne

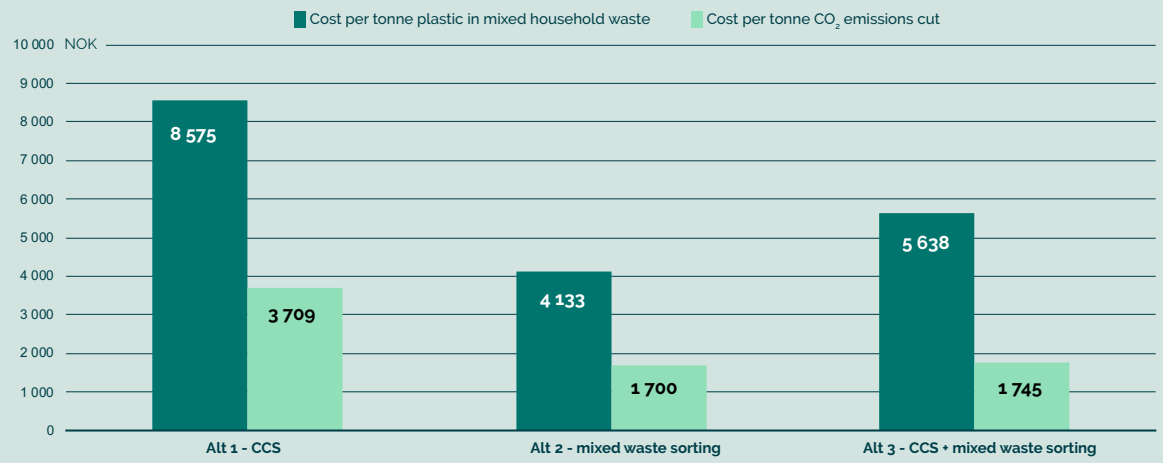
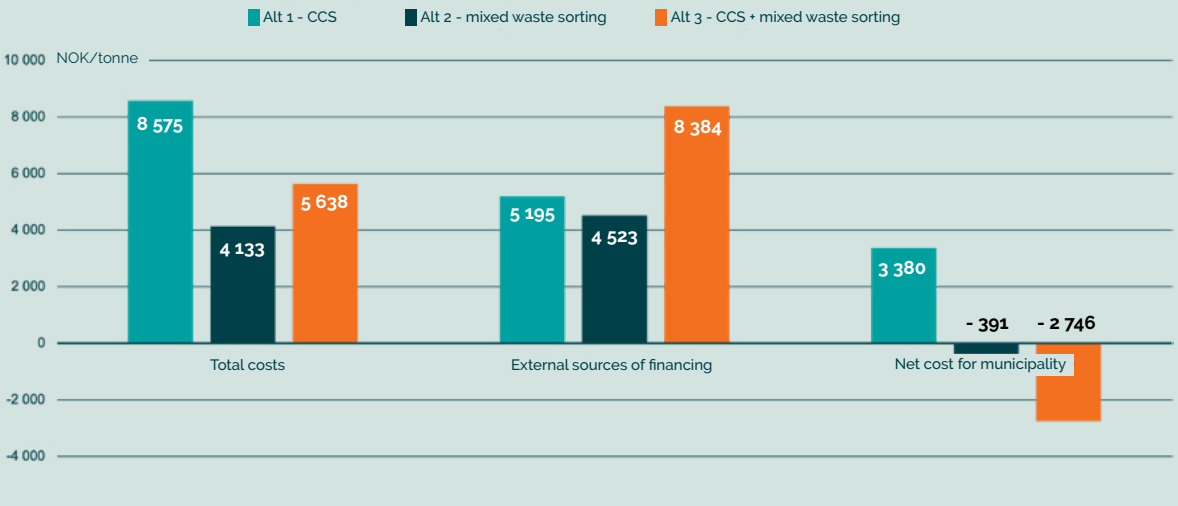


Figure 4 - Financing and net cost per municipality



An additional calculation shows how the cost of mixed waste sorting would affect municipal waste fees if this were the financing model. The total cost of mixed waste sorting at NOK 4,133/tonne equates to approx. NOK 150 per household (12,800 tonnes of plastics across 350,000 Oslo households). When factoring in EPR coverage and reduced CO_2 tax from WtE, it is estimated that the municipality of Oslo avoids a net cost increase.

There are several uncertainties, and future market developments may affect costs. Some key considerations include:

- A tax on virgin plastics would be a natural consequence of a comprehensive carbon pricing regime. Today's system is skewed, as there is currently no established carbon credit market for recycled plastics.
- Higher CO_2 prices through emission trading and taxation will improve the profitability of both separation and CCS and may be an important driver for further development.
- Reducing the fossil share in residual waste to WtE, increases the share of biogenic CO_2 captured. Willingness to pay for non-fossil carbon credits in the voluntary market is currently likely higher than the value of avoided CO_2 tax from WtE.
- Significant cost savings could be realized if source separation of plastics were phased out in favor of mixed waste sorting, which is not included in the analysis. It is unlikely that municipalities will receive full cost coverage for both systems from EPRs. There is uncertainty regarding levels of EPR cost coverage and how mixed waste sorting costs should be allocated between plastics and other waste fractions. National guidelines are currently being assessed but are not yet clear on this point.

SENSITIVITY ANALYSIS

A simplified sensitivity analysis has been carried out to assess how variations in key assumptions could influence the results.

Increased investment for mixed waste sorting

Oslo has estimated investment at NOK 1 billion including land, while Mepex' calculation uses NOK 500 million. Doubling the investment raises mixed waste sorting costs by 31% from around NOK 4,100/tonne to NOK 5,400/tonne.

Increased EPR coverage for plastics packaging

If the share of costs allocated to plastics packaging increases from 37.5% to 50%, this adds about 30% to costs. Combined with a NOK 1 billion investment, mixed waste sorting costs rise to NOK 6,660/tonne.

Higher fossil carbon price

With CO_2 taxes increasing from today's NOK 882/tonne to NOK 2,000/tonne by 2030 (as announced by the government), projects become more profitable. For mixed waste sorting, this increases external financing by 43% and yields a net municipal gain exceeding NOK 1,900/tonnes plastic. Such carbon price increases offset higher investment and EPR coverage assumptions.

Reduced plastics sorting yield

The assumed plastics sorting yield of 85% may be too high in practice. Reducing this to 70% lowers climate benefits by 17.5% for mixed waste sorting alone, and by only 5% when combined with CCS.

DISCUSSION

Combination of Sorting and CCS Provides Greatest Environmental Benefit and Lowest Net Costs

EU targets for plastics separation from MSW cannot be achieved by source separation alone. Plans to establish CCS facilities cannot be seen as a substitute for mixed waste sorting facilities. The combination of mixed waste sorting and subsequent WtE with CCS clearly emerges as the best solution both environmentally and economically. Additional economic gains may be realized by phasing out current plastics source separation system in Oslo.

Regulatory Framework for Mixed Waste Sorting Provides Competitive Advantage

WtE plants should consider pre-sorting with plastics separation even when pursuing CCS ambitions. This may be a clear competitive advantage, as clients increasingly demand documented recycling rates for mixed waste. Norway could gain a competitive advantage over Sweden, since Norwegian regulations allow mixed waste sorting of plastics to substitute for source separation and to qualify for EPR cost coverage.

Reduced Investment Risk

The new Extended Producer Responsibility (EPR) framework (effective 1 July 2025) reduces investment risk for mixed waste sorting facilities, even though the exact level of coverage remains unclear. Outlets for mixed plastics from mixed waste sorting are secured through the national advanced plastic sorting plant OMRÅ, established by Tomra and PRO for plastic, Plastretur. Plastics from mixed waste sorting must meet quality requirements and remain separate from source-separated plastics through the plant.

No Significant Negative Effect for WtE Facilities

Since Norway's WtE capacity is significantly lower than the demand, and over half a million tonnes of MSW is exported annually, increased plastics separation and recycling should not significantly harm Norwegian WtE plants. Previous analyses for Statkraft Varme also show that targets of 65% recycling rate of mixed household waste in MSW will not materially affect the calorific value of residual waste.

Economies of Scale from Increased Sorting Volumes

There has already been invested in national advanced plastics sorting capacity for future needs in Norway. The current challenge is lower than expected volumes of incoming plastics, making the cost per tonne higher than necessary. Increased sorting volumes will both improve resource efficiency and reduce unit costs, strengthening the recycling value chain.

WtE May Hold the Key

Conditions are favorable for investment in increased mixed waste sorting capacity for both municipal and commercial waste. Developments in EPR fees, carbon pricing, and national commitments to advanced plastics sorting and recycling will help finance measures and secure value chains. WtE operators may play a key role in realizing integrated plans for plastics sorting prior to WtE combined with CCS.

Relevance of the Analysis and Need for Further Assessments

It is important to stress that this analysis only covers plastics in current MSW streams and does not represent a comprehensive analysis of changes in Oslo's waste collection and treatment system. Costs of today's system and potential changes to source separation and optical bag sorting are not assessed. A full evaluation of mixed waste sorting in Oslo should be conducted. Nevertheless, the report provides valuable insights into the implications of mixed waste sorting and CCS for the plastics value chain.

ANNEX

About the Calculations

A calculation model has been developed to estimate CO_2 emissions from three alternative scenarios and the current reference solution. For the two scenarios including mixed waste sorting, total establishment and operating costs of the sorting plant have been calculated, followed by cost allocation to assess the share potentially covered by Extended Producer Responsibility (EPR).

Costs of today's system for source separation (or an improved system) are excluded. With future delivery to mixed waste sorting, source separation could be phased out, avoiding associated costs.

Key Assumptions for Climate Calculations:

- Incineration of 1 kg of plastics emits 2.72 kg CO_2.
- 92% of the energy from plastics waste-to-energy (WtE) is utilized for district heating and electricity, displacing Nordic electricity mix.
- 90% of CO_2 from MSW is captured at Klemetsrud WtE plant with CCS, with an additional 5% carbon loss in transport and storage.
- 85% of plastics in MSW are extracted during mixed waste sorting. 75% of this is sorted into material recycling at advanced sorting plants (e.g., OMRÅ). With a 15% recycling loss, 54% of plastics from MSW become new raw material.
- Separated plastics are assumed to provide climate benefits through mechanical recycling. Chemical recycling is excluded from this analysis.
- Net climate benefit from replacing virgin plastics with recycled plastics is estimated at 1.3 kg CO_2 per kg plastics.
- 20% of plastics received at advanced plastic sorting plants are unsuitable for material recycling and are assumed returned to WtE, with or without CCS.

Key Assumptions for CCS Cost Analysis:

- Share of CCS costs allocated to plastics is based on plastics' share of CO_2 emissions in total incinerated waste (400,000 tonnes), i.e., 9.2%.
- Total CCS investment: NOK 8.4 billion, including capture facility and harbor terminal at Oslo Harbor.
- Annual operating costs: NOK 1,261 million, including NOK 180 million for transport and injection.

Key Assumptions for Sorting Facility Cost Analysis

- Total investment in a mixed waste sorting plant: NOK 500 million, capacity 100,000 tonnes per annum
- Advanced sorting costs assumed at NOK 2,750 per tonne of mixed plastics from mixed waste sorting, including treatment of residues.
- Annual costs: NOK 85 million, of which 37.5% allocated to plastics.
- Avoided gate fee for waste-to-energy (WtE): NOK 800 per tonne.