Sorting technologies

Case study about a MSW sorting facility in Norway

IEA Bioenergy: Task 36

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Case study about a MSW sorting facility in Norway - IVAR

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Preface

This report explores lessons on sorting technologies for waste in the field of material and energy valorisation of waste within the framework of IEA Bioenergy Task 36. The purpose of this report, as all the work carried out by Task 36, is to showcase examples from which countries can get inspiration and support in implementing solutions in the waste/resource management and Waste-to-Energy sector that would facilitate their transition towards circularity.

IEA Bioenergy Task 36, working on the topic 'Material and Energy Valorisation of Waste in a Circular Economy', seeks to raise public awareness of sustainable energy generation from biomass residues and waste fractions including MSW as well as to increase technical information dissemination. As outlined in the 3-year work programme, Task 36 seeks to understand what role energy from waste and material recycling can have in a circular economy and identify technical and non-technical barriers and opportunities needed to achieve this vision.

See http://task36.ieabioenergy.com/ for links to the work performed by IEA Bioenergy Task 36.

Summary

The IVAR plant combines post-sorting of residual waste with recycling of some of the plastic waste fractions. At the plant five different fraction of plastics, four fractions of paper, bio-waste, glass, and metal packaging are separated. In total 83.2 % by weight of the incoming waste is sent to energy recovery (WtE) and 16.8 wt% is recovered for material recycling. It is estimated that approx. 82 wt% of the plastic in the waste is separated. Today they also have spare capacity to receive more waste for sorting, however the costs are relatively high and the economic incentive from the sales of the sorted materials are not enough. The largest renumeration comes from the Norwegian producer responsibility schemes for sorting plastic, metal packaging and beverage cartons.

The bottle neck of the recycling industry with the current state of the art is the quality of the plastic waste. Only part of the plastic waste is suitable for recycling (have a market for the recycled material). New solutions for both plastic sorting and recycling is needed to increase the impact and circularity from the recycling. It will be crucial to find solutions for low quality and mixed plastic materials. There also need to be measures put in place to create a market pull for the recycled material.

While all the recycled material generates positive climate effects, the recycled plastic generates double gains. It reduces the emissions for the production of virgin plastics and at the same time it reduces the direct fossil CO_2 emissions generated by the WtE plant. Considering upcoming regulations in Norway, with increased CO_2 taxes, the investments for more residual sorting plants in Norway is likely to increase.

Background

There is a global urge for CO_2 emissions mitigation and Waste-to-energy (WtE) incineration plants are pointed out as an important source with potential for improvement/reduction. It is estimated that for each ton of waste burned, 0,7-1,7 tonnes of CO_2 are released depending on the type of waste feedstock[1]. Fossil-derived plastics account for a significant part of the waste incinerated and, therefore, are responsible for fossil CO_2 emissions from the incineration plants.

The WtE sector in Northern Europe is looking for solutions to become carbon neutral. An alternative is to act upstream and reduce the amount of fossil-based waste that ends up in the combustible mixed waste for incineration. This could be achieved by promoting plastic source separation by means of new and more strict policies or price incentives, while material recovery is supported. Downstream, Carbon Capture Storage (CCS) and Carbon Capture Utilization (CCU) technology represents a promising alternative that has recently gained lot of attention and, therefore, many incineration plants in northern Europe have on-going projects in this area. CCS/CCU retains both the bio- and fossil-CO_2 in the flue gas emitted by the plants. An intermediate solution to these two is the implementation of advanced waste sorting systems prior to the incineration plant. This alternative leads to a positive reduction on carbon emission while recovering material (i.e., plastics) for reuse or recycling for a more efficient use of it. It is noteworthy that all alternatives are compatible and could complement each other.

This report presents an example of a mixed waste sorting facilities in Norway where the process facilitates material recovery prior to incineration.

IVAR Forus (Norway): IVAR is an integrated waste sorting plant (WSP) and plastic recycling plant that sorts out up 5 different types of plastics from the household mixed residual waste by using near infra-red technology (NIR) and turns them into flakes or pellets than can be used for manufacturing purposes. Currently, approx. 82 wt% of plastics in the mixed residual waste are sorted out, but only half of it is suitable for mechanical recycling. In addition, the plant sorts out metals and paper as well.

[1] Pollution inventory reporting – incineration activities guidance note, available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/923125/Pollution-inventory-reporting-incineration-activities-guidance-note.pdf

Plant description

IVAR WSP

IVAR[2] Forus waste sorting plant (figure 1) is located in Forus Miljøpark (Environmental Park) in the southwestern Norway. It is owned by 12 municipalities[3] and gives service to 350 000 inhabitants approximately in the region of Stavanger (Norway). The residual sorting plant is in full operation since January 2019. The waste collection in the region is based on comprehensive source separation systems for bio-waste, paper, glass and metal packaging, electrical & electronic equipment (WEEE), wood and hazardous waste, among others, resulting in a separation rate for household waste of approx. 66 % by weight.

The IVAR WSP comprises three plants in the same facility: one residual waste post-sorting plant combined/followed by a plastic washing and extrusion plant, and one paper waste sorting system that works independently. What makes the Forus plant unique is that it offers the possibility of recovering up to five plastic waste fractions from household residual mixed waste.

Figure 1. IVAR Forus integrated residual waste post sorting plant and plastics washing and extrusion plant.

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[2] IVAR constructs and operates municipal facilities for water supply, wastewater and waste treatment. It is owned by 12 municipalities and gives service to approx. 350 000 inhabitants. More info available in the link https://www.ivar.no/english/. Access: 04/11/2021.
[3] IVAR website, available from: https://www.ivar.no/plastic/. Access: 02/11/2021.

The waste sorting plant (WSP) has the capacity to handle 66 ktons/year/shift (40 tons/hour) of mixed residual waste from households. The residual waste undergoes an automated sorting process where metals (ferreous and non-ferreous), paper and plastics are sorted out. Although it has the license to operate two shifts which would double its capacity, it is not needed at this moment (November 2021) since the plant only receives c.a. 50 ktons/year of household waste.

The technology available at IVAR plastics recycling plant allows to sort and separate five types of plastics: (i) LDPE (low density polyethylene) (film); (ii) HDPE (high density polyethylene); (iii) PP (polypropylene); (iv) PET (polyethylene) and (v) PS (polystyrene) in addition to two mixed plastic fractions (one rigid and one film). The plastic washing and extrusion plant has a capacity of c.a. 8 ktons of rigid plastic - or 3,3 ktons of plastic film per year. The technology used for sorting plastics is near infrared light (NIR)-machines LDPE, HDPE and PP material sorted is treated at the facility and turned into pellets for further applications in the manufacturing industry. PET (transparent bottles) and PS are sold as baled material for further treatment (i.e., washing) at other facilities in Central and Eastern Europe. Metals, that have been sorted out, are sold to recycling firms.

The paper sorting plant runs in parallel and independently from the residual waste sorting plant. This plant receives sorted paper from households, has a capacity of 23 ktons/year and separates paper waste into four different categories: (i) corrugated cardboard; (ii) cardboard/mixed paper; (iii) Tetra Pak (i.e., beverage containers) and (iv) de-ink paper (i.e., magazines and newspapers). As for plastics, the technology used for sorting paper-based materials is NIR-machines. The different sorted fractions are sold to paper mills as raw material. At this moment (2021), the plant received c.a. 14 ktons of paper waste from households plus c.a. 2 ktons of paper from the residual waste sorting plant. In this way, source sorted paper with higher quality is mixed with paper recovered from the residual waste.

The remaining household residual waste is transported by conveyor belt (350 m length) directly to the Forus Energigjenvinning (WtE plant) bunker. Forus WtE is located at Forus Miljøpark[4] and converts residual sorted waste into power and district heating. As the sorting plant, Forus WtE plant is owned by the intermunicipal company IVAR, in addition to the regional energy supplier (electricity and remote heating) Lyse Neo, which is also owned by several municipalities. IVAR and Lyse Neo own 43 % of the WtE plant each and the rest (14 %) is owned by 4 smaller intermunicipal waste companies in southwestern Norway.

A total of 17 employees works at the three plants together. Waste collection vehicles for paper and residual waste come in every workday (Mon-Fri except public holidays) between 07:30 and 15:00 and unload the waste in separate areas in the reception area.

[4] IVAR 24, available from: https://www.ivar.no/getfile.php/133034-1178180688/IVAR%20Dokumenter/IVAR%20Engelsk.pdf. Access: 04/11/2021.

Sorting Technology

IVAR FORUS INTEGRATED WSP & PLASTIC RECYCLING PLANT

Technology description

This section includes a description of IVAR's WSP and plastic washing and extrusion plant. The paper waste sorting system has been mentioned in the previous section to provide the whole overview of IVAR Forus's installations; however, it is out of the scope of this report, and it will not be described in this section.

Residual waste sorting plant

Mixed residual waste collected from the entire region reaches IVAR's waste sorting plant by collection vehicles. Before the waste enters the actual sorting system, it undergoes a 2-step coarse sorting at the reception hall. First, the residual waste passed by finger screen where objects bigger than 350 mm are sent to a shredder to be ground into smaller pieces, while material between 0 and 350 mm goes through two bag openers. Afterwards, both streams are mixed and placed on the conveyor belt for being forwarded to the post-sorting facility.

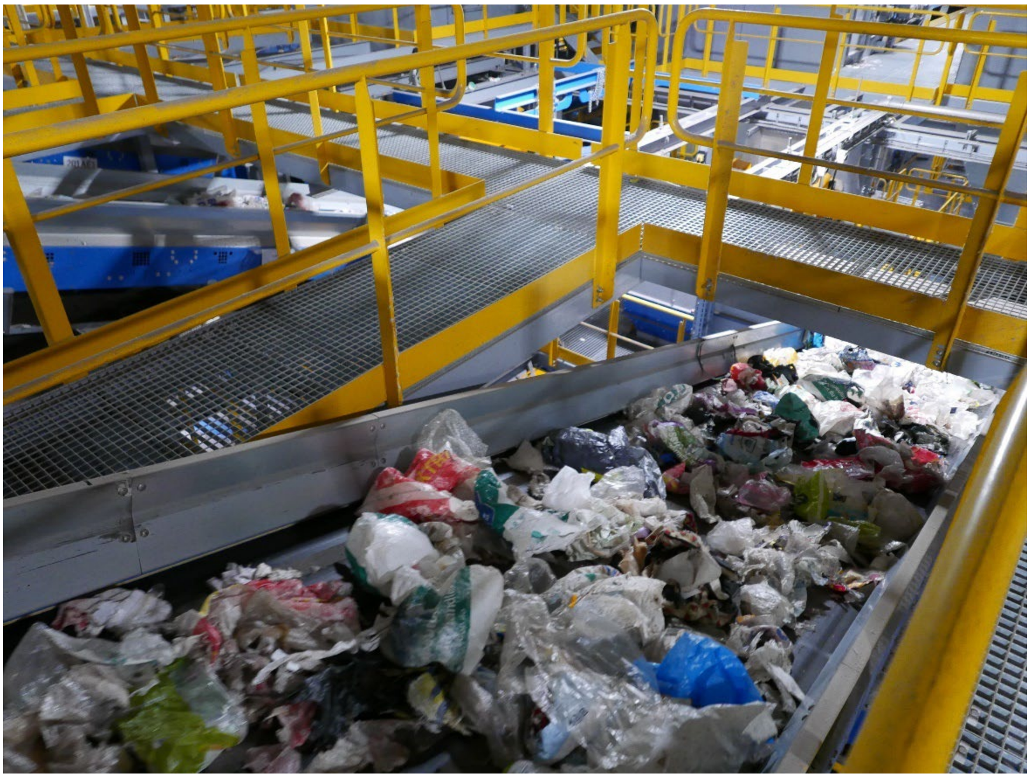


Figure 2. Residual waste before passing by the shredder and bag openers and on its way to the post-sorting plant.

The material entering the sorting system passes through two drum sieves in series which divides the material into 3 streams with different sizes: (i) Fines (< 60 mm); (ii) material 60-150 mm, and (iii) material 150-320 mm. Fines (< 60 mm) from this screening are approximately 34 % of the total input (by weight) and contain 50 wt% bio-waste (mainly food waste), 16 wt% paper (mainly hygiene and kitchen paper), 1 wt% wood and 4 wt% ferrous and non-ferrous metals that are removed with the help of an over band magnetic separator and an eddy current separator. All the metals are sold directly to the scrap metal market. The remaining combustible fraction is sent to incineration.

The other two waste streams (60-150 and 150-320 mm) undergo several rounds of automated sorting based on near infrared light (NIR).

- In the *first NIR set* (3 units), plastics are separated from the rest of the mainstream. The NIR sensors recognize plastic and remove it from the stream by using compressed air. The plastic streams go to ballistic separators (3 units) where heavy plastic objects are separated from flat and light ones, in other words, hard plastic and foil are separated. There is also a small fines fraction outcome from the ballistic separators.

- The non-plastic fraction outcome from the first NIR set goes through a *second NIR set* that will sort out paper. Mixed paper is sorted out exclusively from the 150-320 mm stream to avoid separation of hygiene and kitchen paper pieces. From 60-150 mm stream only beverage cartons (i.e., Tetra Pak) are sorted out. The mixed paper (c.a. 3,6 % by weight of the total input or ca. 2 kton) is sent to the paper sorting system for further processing, while sorting residues first passes through metal separation before ending up at incineration.

- The light plastic fraction (plastic film) from the ballistic separators goes to *another NIR set* (3 units) that separates LDPE film from the light plastics. The film fraction continues for *further NIR-based separation* (3 units) where impurities (i.e., non-PE materials) that still remain are removed from the PE fraction to increase the quality of the final product. The PE/film is collected and stored in a bunker and then baled separately from other types of plastics for further processing in the washing plant. PE/film outcome from the process is approx. 6,3 wt% of the material input. The residual 2D-mixed plastic fraction is sent to incineration (8,9 wt% of the material input).

Figure 3. The plastic items are mechanically sorted out from the main waste stream at ballistic separators before being transported onto NIR machines for separation based on plastic type. Source: https://www.ivar.no/ettersorteringsanlegg/. Access: 10/11/2021.

- The rigid plastic fraction ("3D") from the ballistic separators follows *a cascade of NIR machines* (4 units) that separates PET, PP, PE and PS consecutively. All these fractions go as well through another *set of NIR sensors* (4 units) for improving its quality by removing impurities such as metals, paper or multi-layer plastics. The rest of 3D mixed plastic is incinerated. As for the PE/film, the different sorted plastic fractions are collected, stored separately, and pressed into bales for selling or being processed. PET (mainly bottles) and PS are sold for further processing outside of the IVAR's facilities, in Central and Eastern Europe, while PP and HDPE enter the plastic washing and extrusion IVAR plant. Regarding flows, HDPE is 1 wt% of the total income, PP is 1,4 wt%, PS 0,2 wt% and PET 0,4 wt%, while residual mixed plastics from 3D makes up to 5,3 wt%.

  The quality of the mixed plastics 3D and 2D is quite low in terms of its recyclability. All the plastic suitable for recycling have been removed and the remaining consists mainly of non-plastic impurities (26 wt%). Historically, they are sent to incineration. As of January 2022, the mixed plastics are used as refuse derived fuel (RDF) in a cement kiln in Denmark. The benefits from this includes a higher energy recovery in the cement kiln than in the WtE plant that previously incinerated the material, the plastics replaces other fossil fuels in the cement kiln, and in Denmark it is also recognised to some part as material recycling since the ash components in the plastics goes into the cement. Another benefit is that the CO_2 tax for the WtE plant has decreased as a result of not taking in this plastic.

List of equipment at the IVAR WSP sorting plant:

- 1 shredder
- 2 bag openers
- 2 drum screens – Length: 12 m and 14 m. Diameter: 3.6 m
- 2 star sifters
- 1 vibration sifter
- 3 ballistic separators
- 22 NIR sorting machines
- 2 over band magnets
- 2 eddy current sorters (non-magnetic metals)
- 2 balers
- 2.1 km of conveyor belt installed at the sorting plant + 0.3 km to the WtE plant

Based on calculation using an input of 50 kton of mixed residual waste for the Forus WSP (figure 4), 16.8 wt% of the material is recovered and includes all the single plastic factions (i.e., HDPE, LDPE, PP, PET and PS), ferrous and non-ferrous metals and paper-based materials. Mixed plastics account for 14.2 wt% incoming residual waste and are sent to incineration together with two residual fraction (fines < 60 mm and material > 60 mm) that account for 69 wt%. In total, 83.2 wt% of the incoming waste is sent to incineration and 16.8 wt% is recovered for material recycling.

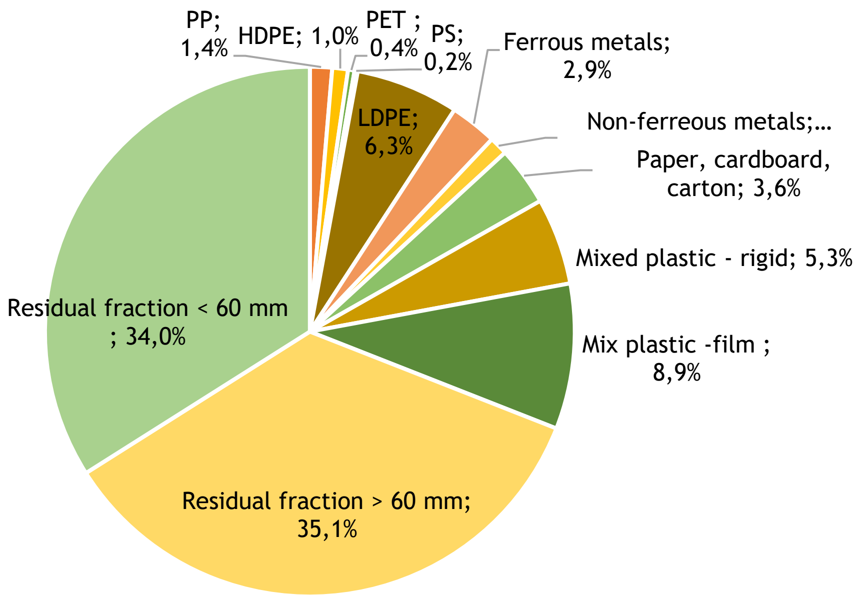


Figure 4. IVAR's plant performance. Calculated output from IVAR's Forus waste sorting plant calculated for 50 kton of residual waste. All percentages are by weight.

The quality of the baled plastic sorted out at the plant can be measured by the "purity" of the different plastic fractions, meaning by "purity" the percentage of the right plastic type in that fraction. For all the five types of plastics sorted out, the "purity" in the baled material is higher than 95 wt% (table 1).

Table 1. Ratio of right plastic type in each of the different plastic fractions (type of plastic) sorted out at IVAR's facility in Forus.

Type of plastic	LDPE (film)	HDPE	PP	PET	PS
"Purity" [wt%]	96	98	98	96	95

Another parameter that can be measured is the yield, or the ratio of a specific plastic type recovered at the plant (how much of the incoming material of that type that is separated to the correct fraction). As shown in table 2, the yield differs from 52 wt% for PET bottles to 90 wt% for LDPE. A lower recovery rate means that the share of plastic objects insufficiently designed for recycling was high. The limitations in the design for recycling can be that a plastic packaging is incorporated in a large paper sleeve, which then makes the detectors recognise it as a paper package, or the use of carbon black for the colouring of black packages, which the NIR detectors are incapable of recognising.

Table 2. Yield of each type of plastic fed into IVAR's sorting facility that can be recovered from the residual waste for being recycled.

Type of plastic	LDPE (film)	HDPE	PP	PET	PS
Plastic yield [wt%]	90	86	68	52	54

Plastic washing and granulating plant

Once the HDPE, LDPE and PE have been sorted out at the WSP plant, they are fed into the plastic washing and granulating plant where they are prepared for recycling. Each plastic type is treated separately. The process consists mainly of size reduction, washing, drying and extrusion. At the end of the process the plastic waste has turned into pellets that can be sold to be used by the manufacturing industry that makes new plastic products.

Figure 5. Baled plastic sorted out from the mixed residual household waste at IVAR's post-sorting plant in Forus and ready for being sold to plastic product manufactures (PET and PS) or fed into IVAR's plastics washing and extrusion plant (HDPE, LDPE and PP).

Once the plastics reach the washing and granulating plant the plastics are chopped into small pieces (flakes) that are washed several times before being dried in a centrifuge The plant has two parallel washing lines and gives the opportunity to wash with hot water (70-80 °C). The hot water for the washing process is provided by the nearby WtE facility. The plastic flakes pass to a double screw extruder with downstream filter (100/180 microns) where they are melted to produce plastic pellets that are stored in silos and ready to be sold to the plastic manufacturing industry. The system gives the possibility to take out washed and dried plastic flakes before extrusion in case they would like to use them for other purposes.

To minimise the water footprint of the plant, the water is cascaded so that it is reused at a lower functional level (counter current with the material to be washed). Afterwards the water is treated locally at the plant. Solid residuals from the washing and from the wastewater plant is sent for incineration.

Figure 6. Plastics from IVAR's plastics washing and extrusion plant. Left hand side image: plastic flakes. Right hand image: plastic pellets ready for being sold to the plastic goods manufacturing industry.

Efficiency and costs

The technology available at IVAR’s sorting plant allows recovering 16.8 wt% of the residual mixed waste from households in the form of plastics, metals, and paper-based materials versus the 83.2 wt% of the total input that goes to energy recovery. It is estimate that around 82 wt% of the total plastics present in the residual waste are sorted out and sold for either further processing before being recycled or to serve as refused derived fuel (RDF). However, the plant still has room for increasing material sorting (see section Advantages and Limitations*)*.

The estimated investing cost for building IVAR’s integrated post-sorting plant and plastics washing and extraction in Forus is about 700 mill NOK (71 million €). The project was envisioned with the idea that sorting of the residual waste before being incinerated would not represent extra costs for the inhabitants of the region. This could only be achieved if the gate fee for delivering mixed household waste at the sorting plant would be equal to/or lower than the gate fee for incineration. Unfortunately, this goal has yet not been achieved and the gate fee for the sorting plant is at this moment 40 €/ton higher than the incineration one.

It is obvious that the income from selling recyclables as raw material is far from being sufficient to cover the sorting costs at the Forus WSP. In Norway, the waste sorting plants receive a renumeration from Norwegian producer responsibility schemes for sorting plastic and metal packaging as well as for beverage cartons. These renumerations represent a much higher income to a waste sorting plant than the sales income from sorted materials.

Advantages and Limitations

IVAR plant is unique because combines in the same facility both post-sorting of residual waste and a washing and extrusion plant for plastics recovered from it, as well as a plant for paper sorting. This disposition prevents from transporting the waste, saving time, reducing costs and emissions.

The plant still has room for increasing material sorting: PP film and PET trays have the potential to be sorted out for mechanical recycling or plastic could be separated from 2D mixed plastic stream. For further details, go to section *Future Plans*.

Environmental Aspects

IVAR WSP's mission is to recover material with potential for recycling or reuse from the mixed household waste that, otherwise, would be incinerated. In this way, it contributes to a more efficient and sustainable use of the resources. The residual waste output from IVAR's plant contains less plastic than non-post sorted mixed residual waste, leading to lower direct CO_2 emissions when burnt at the WtE plant. A study commissioned by IVAR estimated that the climate mitigation effect of increased material recycling from the plant comes up to – 33 000[5] tons CO_2-eq./per year

Each person living in the area where IVAR's plant is located disposes ca. 33 kg of plastic/year (including synthetic textiles). Since the plant is in operation, it is estimated that the plastic sorted has increased from 9 to 27 kg/person/year which marks a significant increase. Of these 27 kilos, 12,6 kg are sent to material recycling.

Other aspects

POLICY ASPECTS

Norway plans to introduce a national regulation that will force municipalities to reach 60 % sorting of plastic from household by 2030. In addition, Norway has implemented (as of 1 January 2022) a waste incineration tax on fossil CO_2 that will correspond to 25 % of the total CO_2 tax that is approx. 2000 NOK/ton CO_2-eq (200 €/ton CO_2). At the same time a standardized emission factor for incineration of waste is set to 0,55 which means that the current tax for incineration of waste is 192*0,55=106 NOK/ton CO_2. The waste incineration tax will most probably increase towards 100 % of the total CO_2 tax within the coming five years. Based on this, it is expected that more post-sorting facilities will be built in the country. The Norwegian Environmental Agency (Mdir) supports the use of automatic sorting to help in the achievement of these goals and refers to a need of 11 plants of this type in the country to cover residual household waste handling. In addition, there is a local initiative from Stavanger municipality that aims at reducing the greenhouse emissions in the region and where the incineration plant is an important part of it.

[5] Pre-study made by Mepex, Kjell Fredriksen, 2013

SOCIAL AND BEHAVIOURAL ASPECTS

IVAR facility in Forus has created new 17 jobs and increased exploitation of the local waste creating a new value out of it.

When introducing the Forus WSP in 2019, the existing kerbside collection of source-separated mixed plastic packaging in the municipalities has ceased. IVAR needed – together with the municipalities – to launch a campaign to tell the people that automated sorting of plastics was more efficient and environmentally friendly than separate collection at household level.

Only a few households were forced to subscribe to a bigger grey bin for residual waste, which costs a bit more per year. The big majority of households managed to put all plastics back into the existing bin for mixed waste.

Another envisaged problem was that people could interpret the fact that IVAR had erected a plant to sort different types of waste, as an invitation to not to separate waste at home at all. IVAR and the affiliated municipalities had to inform the citizens explicitly to keep on separating organics, glass, paper, WEEE, hazardous waste and so on.

Among the private households the Forus WSP and its function is well known now, and it looks like people haven't changed their behaviour notably - except with regard to plastic collection.

Future Plans

As it was mentioned in the section *Efficiency and Costs*, the plant still has room for increasing material sorting. There are two types of plastics which have the potential to get sorted and sent to mechanical recycling: PP film and PET trays. There are emerging downstream solutions in Europe to make use of these to material types. The Forus WSP could separate 1000 tons of PP film and PET trays from 50 000 tons of residual household waste. On the other hand, these materials are costly to recycle, and the economic incentive to sort is low.

Another 1000 tons of plastic material could be sorted from the 2D mixed plastic stream at the Forus WSP. These are synthetic fibre-based textiles. There are ongoing assessment studies on establishing chemical recycling solutions for PET and polyester in Northern Europe. Even soiled polyester textiles could be recycled this way.

IVAR has also done some studies on further recycling of the "fines" stream (0-60 mm). Technically it would be possible to extract more than 1000 tons of glass cullets for recycling as well as 6000 tons of organics suitable for anaerobic digestion and biogas production. However, both sorting processes are technically demanding and cost intensive.

In addition, IVAR is trying to involve municipalities in southwestern Norway to deliver their residual waste to the Forus WSP since it still has 16 000 tons of free capacity at shift 1, and a second shift could be set up if needed. However, a limiting factor is the incineration capacity of energy plant. The incineration plant's capacity is nearly fully exploited today and 16 000 tons more of waste received at the WSP means 11 000 tons more waste to burn.

Lessons learned / recommendations

The challenge of plastic recycling

With today's state-of-art recycling technology only the pure, high quality recyclates can be reused on the market, and the remaining ones ends up in energy recovery. The bottle neck for recycling industry with the technology available now is the quality of the plastic waste. This means that no matter how much plastic the sorting plants recover, only part of it will be suitable for recycling.

It is expected that the plastic demand will keep increasing during the coming years and so do the amount of it found in the waste. Thus, investments to solve the problem of plastic handling are expected, such as new solutions for both plastic sorting and recycling technologies in the market. Furthermore, an important effort will be made to find solutions for low quality and mixed plastics which are the most complex plastic fractions to deal with. However, it is important to keep in mind that there will always be a remaining fraction that will need to be incinerated – those plastics that compromise the quality of the final product such as contaminated plastics that can be harmful for the humans or the environment or plastics with very low quality that have gone too many times over recycling cycles[6].

Waste sorting facilities and incineration plants should have common interests

Waste sorting facilities can help to reduce the amount of plastic with high quality and recycling potential that goes to incineration nowadays. At the same time, some technical solutions can help to clean the plastic and remove impurities. In this way, the sorting facilities would be helping the WtE plants to handle waste with lower CO_2 carbon footprint and reduce their CO_2-emissions. Removing plastics from the combustible waste stream has an economic consequence for the WtE plants: a reduction of the costs associated to the CO_2 tax on incineration. The question is: can modern sorting plants provide a combustible residual waste free of fossil-plastics? Is that something reasonable in the future?

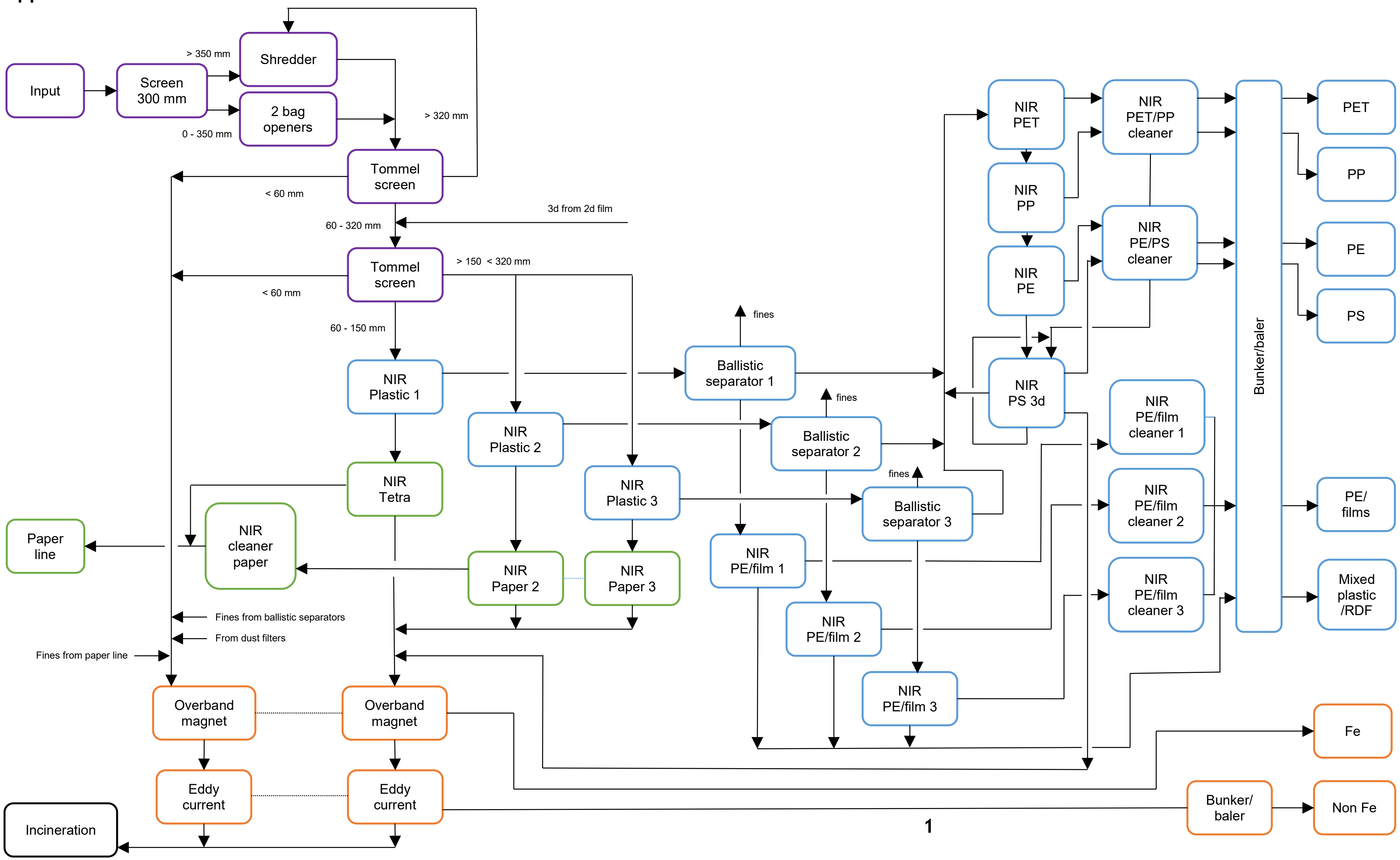
This does not mean that waste sorting before being fed into a WtE plant is the only solution. As mentioned before, a remaining plastic fraction will need to be incinerated and CO_2 emissions will still be released. In those cases, CCS/CCU is a potential solution for mitigating CO_2 emissions.

It seems evident that a synergy comes out from the close collaboration between waste sorting facilities and WtE plants when trying to find solutions to mitigate CO_2 emissions since they have common interests in preventing plastics entering the incinerator. The WtE plant can also provide energy needed for the washing process of the plastic materials. The full potential however will not be realised until there are new methods developed to recycle the more complex plastic streams that the sorting facility also generate.

[6] Techno-economic assessment and comparison of different plastic recycling pathways: a German case study. Volk, R. et al. Journal of Industrial Ecology, https://doi.org/10.1111/jiec.13145.

Appendices

Appendix 1 - Flow chart



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