Executive Summary

PVC Recovery Options

Environmental and Economic System Analysis

Commissioned by VINYL 2010

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PE EUROPE GMBH
Life Cycle Engineering

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Goal

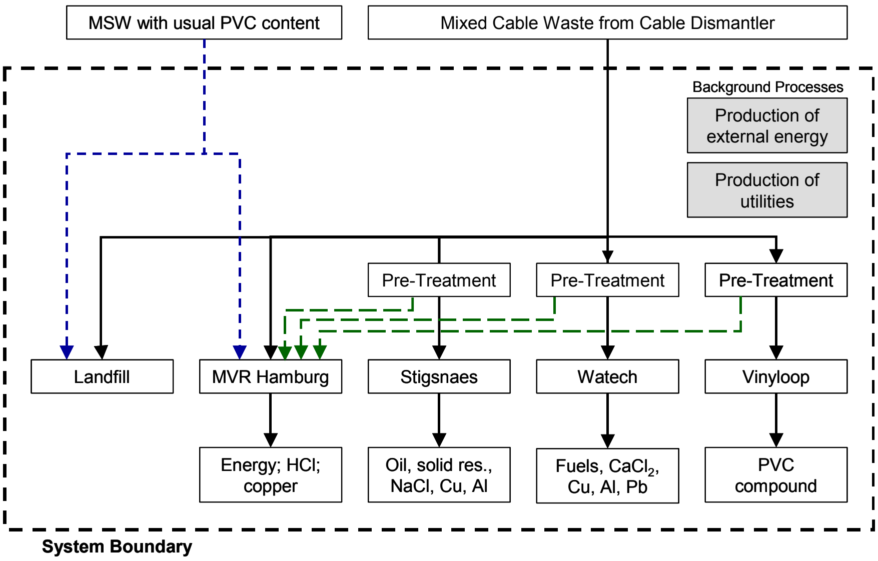
The PVC industry supports an integrated waste management approach under the concept of Eco-efficiency. The concept of Eco-efficiency is promoted by the *World Business Council for Sustainable Development*, and it is further adapted here according to the goal of this study. The term Eco-efficiency comprises an efficient use of raw materials, a minimum impact of emissions and waste, and an overall balance of benefits and burdens in an environmental and economic way. In order to investigate different end of life treatment options and identify optimisation potentials for PVC-rich waste with respect to these criteria, this study was conducted. To this aim, an "Environmental and Economic System Analysis" of different processes and waste recovery options was performed. Mixed cable waste has been chosen as it represents a complex, large waste stream for PVC waste products and shows similarities with waste streams from other plasticised PVC applications. The environmental parameters were selected with reference to current international discussion. The study was performed in accordance with the Life Cycle Assessment methodology described in ISO 14040 ff. The economic parameters per option were based on gate fees. The gate fee was calculated by the operators under comparable boundary conditions.

Scope

The function of the systems under study is "processing of 1 t mixed cable waste". The technologies generate different quantities and qualities of recovered products (see below). The four investigated recovery technologies can be characterised as follows.

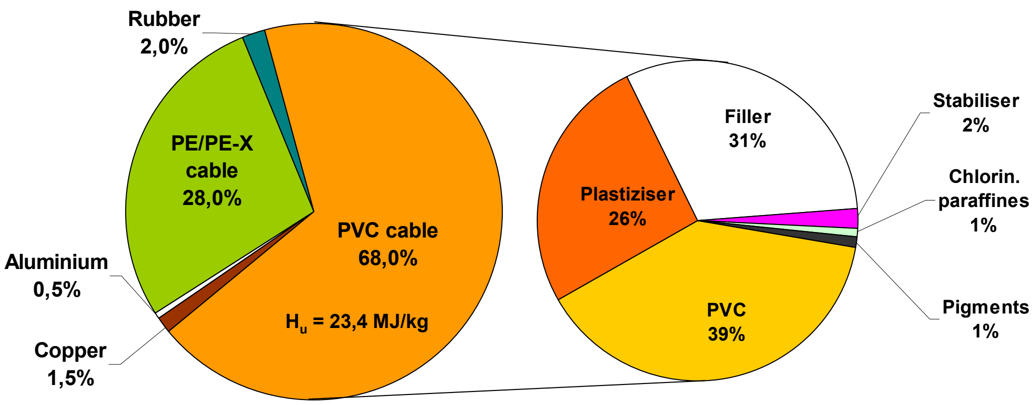
- **The municipal waste incineration** in the ***MVR Hamburg*** facility in Germany with the recovered products electricity, heat, HCl, and metal(s).
- **The feedstock recycling** with the ***Watech*** process of RGS90 A/S in Denmark. It uses pyrolysis followed by purification and extraction steps. The recovered products are $CaCl_2$, coke, pyrolysis oil (condensate) and metal(s).
- **The feedstock recycling process** of ***Stigsnæs*** Industrimiljø A.S. in Denmark is a hydrolysis followed by post-heating (pyrolysis) of the dechlorinated solid fraction. The recovered products are NaCl, hydrocarbon (C_nH_m) fractions, solid residue for the production of sandblasting material, and metal(s).
- **The mechanical recycling** with the ***Vinyloop*** process developed by Solvay S.A. uses solvents and is based on selective dissolution, separation and precipitation of the PVC compound. The recovered products are PVC compounds and metal(s).
- **Landfilling** was chosen as the reference option of this study; there are no recovered products.

The method of "system expansion" is used to make the different options and the individual products comparable (for a detailed description of system expansion see chapter 2.3 of the Final Report). The data used were provided by the owners of the technologies (core process data of the individual recovery processes), or otherwise taken from the GaBi databases (background data of materials, auxiliaries and energy production). The country specific situation was considered, and – if relevant – a parameter variation for an average European situation was calculated.



System boundaries for the systems under study

For this study the steering group of this project defined a reference composition of the cable waste. The largest part of the mixed cable waste is the PVC fraction (68%), which is made of PVC, filler, plasticiser, and other additives.



Composition of the mixed cable waste

Hence, the input to the system is 1 t of mixed cable waste. The system under study includes process specific pretreatment of the mixed cable waste, excluding collection and dismantling from the conductor materials.

Any relevant background processes, e.g. production of materials, energy and auxiliary materials to run the technologies are within the system boundaries. Outputs of the system are environmentally relevant substances (emissions, waste, wastewater) and marketable recovery products. According to the method of system expansion for comparison the alternative production routes are added. The study has been submitted to independent experts from EMPA (Switzerland) for a critical review.

Environmental assessment

The study focuses on the following environmental criteria:

- Primary energy consumption (non renewable resources)
- Global Warming Potential (GWP 100 years)
- Acidification Potential (AP)
- Characteristic emissions on inventory level, e.g. dioxin (PCDD), lead (Pb)
- Hazardous waste, municipal and inert waste, wastewater.

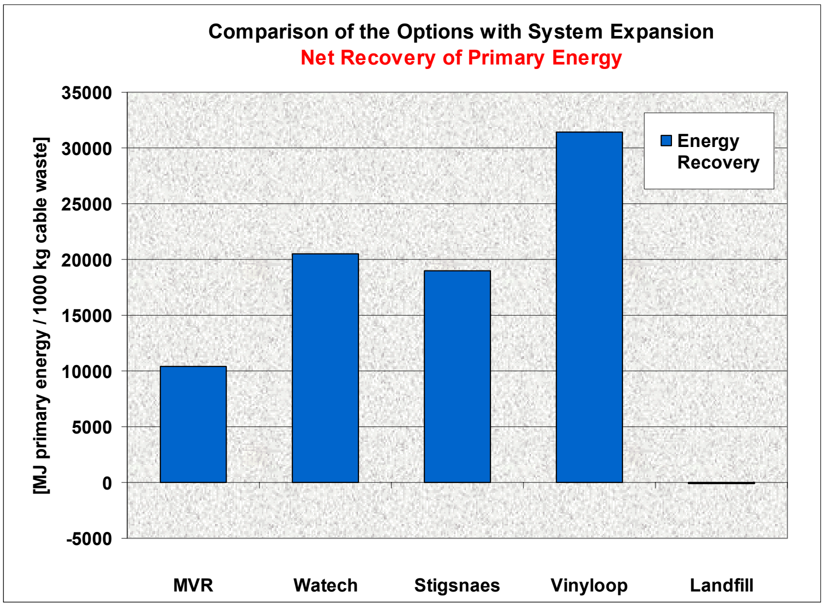
All elementary flows with a significant contribution to the selected environmental categories are considered within the calculations.

Economic assessment

The economic comparison of the different recovery options is based on the price the waste owner has to pay to the operator of the recycling facility for the cable waste. This "gate fee" is used as a baseline to assess the economic dimension. The boundary conditions for the calculation of the gate fee are 10 years depreciation time of the plant. Included were individual (and local) costs for pretreatment, utilities and effluents, labour and other direct costs, waste and wastewater treatment and revenues of the recovered products. The calculations are done without the consideration of grants. This leads to an individual "gate fee" of the processes to compare the economic dimension. The operators of the recycling facilities provided the „gate fees". No comprehensive cost analysis was done within the scope of this study.

Environmental Results

In the Final Report (chapter 6), the investigated technologies were assessed with respect to the three impact categories, primary energy demand, global warming potential and acidification potential. The results were considered in comparison with landfilling as the reference option and presented in three different views (comparison of impacts, net recovery and life cycle view, all including system expansion). The net recovery of primary energy (see figure) is a good way of showing the results, but to get a comprehensive overview the other aspects under study should be considered as well.



Net recovery of primary energy with system extension

All investigated options recover more **primary energy** by supplying different products than needed to operate the processes. Conversely, the reference case landfilling shows no recovery of primary energy (small burdens due to operation of the landfill). For instance, the net recovery of primary energy of the MVR plant is approximately 11000 MJ per ton of cable waste. This means, if the recovered materials were to be substituted by "virgin" production processes (with electricity, steam and HCl produced by conventional processes), an additional demand of 11000 MJ/t of primary energy would be necessary. With the same rationale, all analysed recovery options reach the goal of energy recovery compared to landfilling.

Concerning the **GWP**, waste incineration in the MVR plant has the highest impact potential. The cable waste is incinerated and thus nearly all carbon content of the cable waste is converted into CO_2. Furthermore, the products (electricity and steam) account only for relatively low GWP savings in comparison to the other recovery processes, whilst the feedstock recycling processes applied by Stigsnæs and Watech recover most of the carbon in the form of coke, oil or other hydrocarbons. Best in this respect is the Vinyloop process, which shows a net recovery, as it prevents more GWP than is generated by the process.

All recovery processes show a net **Acidification Potential** benefit. The results are quite similar to Primary Energy. Landfill does not recover any products, but has only burdens due to the operation of the site.

In the reference case of landfilling, the input of 1000 kg of cable waste remains as municipal **waste** for disposal. The MVR incineration reduces the amount of waste to 419 kg in total and separates it into different fractions. The recycling options perform clearly better and are all in the same order of magnitude. Watech generates the smallest amount of waste (~6 kg).

Concerning **lead**, with incineration and landfilling almost 100 % of the input are found as part of waste streams. With the Watech process, nearly 99 % of the lead is concentrated in the recovered heavy metal fraction. With the Stigsnæs process approximately 97 % of the lead is found in the solid product, which is used on-site to make sandblasting products and separated there. Hence, the feedstock recycling processes perform best to separate the lead from the other recovered products. With the Vinyloop process, approximately 99 % of the lead is reused as a stabiliser in the PVC product.

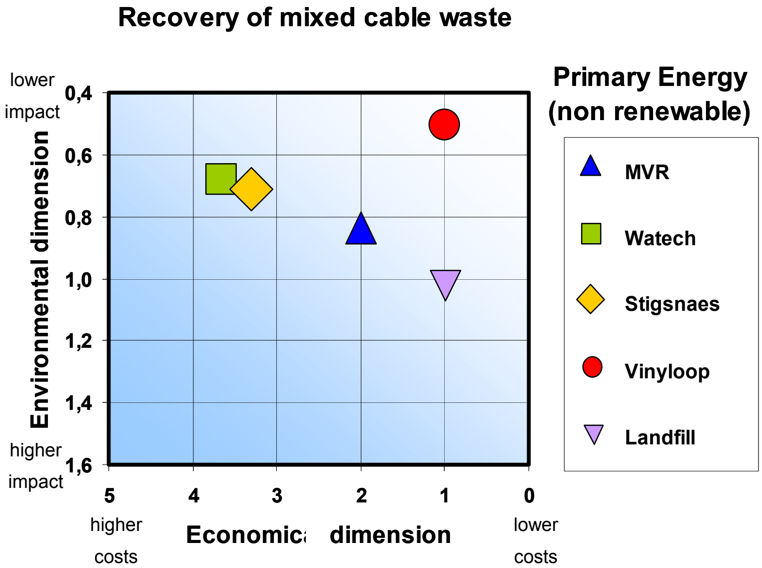
Some of these processes form trace amounts of **dioxins**, whilst with the Vinyloop process no formation of dioxins was detected. The Watech process showed trace amounts of formed dioxins, which are released via the stack. The MVR process directs the formed dioxins, together with other hazardous substances, into the hazardous waste stream (mainly filter ashes), which is securely disposed off in special underground facilities. The Stigsnæs process shows traces of dioxins in the oil product and in solid residue.

All recovery processes investigated recover **chlorine** from PVC - although in different ways - for industrial reuse. The recovery yields are highest for Stigsnæs, Watech and Vinyloop (all between 94 % and 99 %). The yield of chlorine recovery in the MVR waste incineration is around 53 %.

Eco-Efficiency

In order to illustrate the relation between the environmental effects and the costs of the investigated recovery options, economic and environmental aspects are presented in an Eco-efficiency diagram.

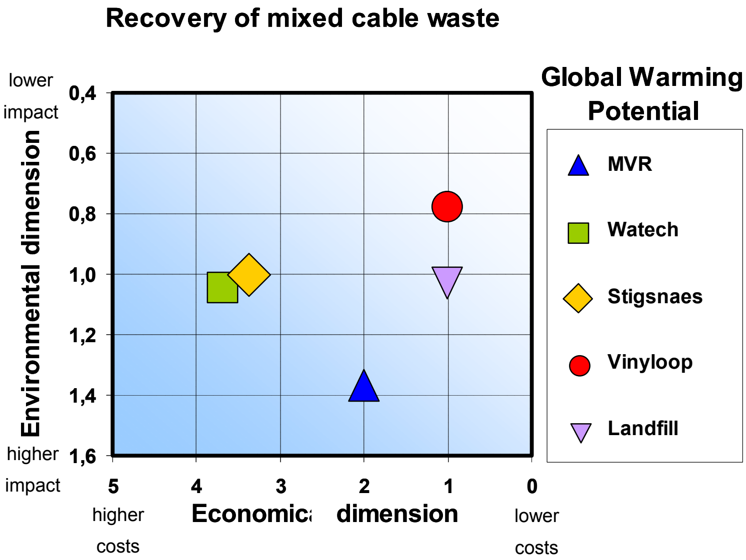
On the horizontal axis, the economic, and on the vertical axis the environmental assessment of the technology is displayed (high values = higher impact or costs, low values = lower impact or costs). The values are normalised with reference to the base case of landfilling (designated as 1 on each axis).



Primary Energy (non renew.) with system expansion view

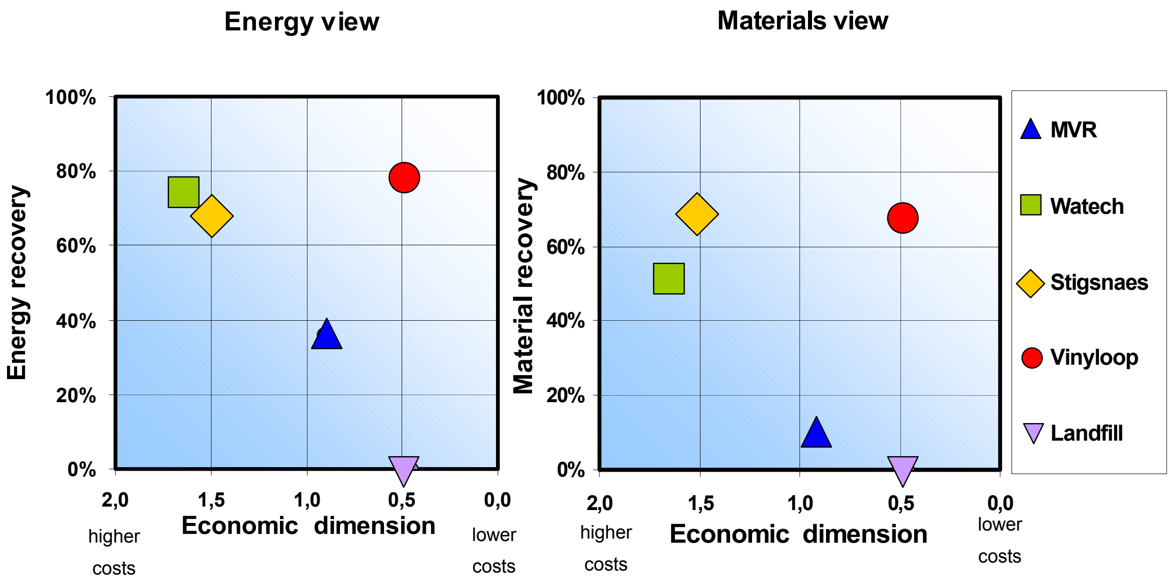
As already discussed above, regarding the primary energy demand, all recovery options perform better than landfilling from an environmental perspective. However, with the exception of the Vinyloop process, all recovery options are more expensive than landfilling. The Vinyloop process shows the lowest primary energy impact in combination with a gate fee that is comparable with the reference option of landfilling.

Concerning the GWP, the Vinyloop process shows an environmental advantage while the economic dimension is comparable with landfilling. The Stigsnæs and Watech processes show a comparable GWP to landfilling but higher gate fees. The MVR incineration process increases both the costs and the GWP load in relation to landfilling, since carbon from the cable waste is converted into greenhouse-relevant exhaust gases.



Global Warming Potential with system expansion view

The results can also be presented from an energy and materials recovery perspective. The energy recovery diagram shows the energy content of all products recovered by the technology in relation to the energy content of the input cable waste. The materials recovery diagram shows the recovered share of mass in relation to the input cable waste on an elementary level.



Energy and Material Recovery without system expansion view[1]

It indicates that all recovery options save material in comparison with landfilling. However, while the Stigsnæs, Vinyloop, and Watech processes achieve material recovery rates of 50–70 %, the MVR process turns almost all input into energy products and thus provides only

[1] 1,0 on the economic scale represents in this case the average of all processes

about 10 % material recovery. The economic valuations remain the same as above, of course. Note that it is not correct to combine the values of the energy and material recovery rates, respectively, because double counting would occur (e.g. oil counts for mass and energy). Therefore, the charts can only be interpreted independently from each other.

Conclusions

The results of the environmental and economic system analysis from this study are only valid for mixed cable waste with the described composition and for the specific conditions of the investigated recovery plants. The environmental assessment was conducted according to the applicable standards ISO 14040 ff. Differences in national environmental policies may also effect the conclusions from this study. In general, the following conclusions can be drawn:

1. When considering recovery options for an integrated waste management concept, an Eco-efficiency approach provides valuable insights in the environmental and the economic aspects of the investigated processes.

2. Compared with the reference option landfilling, all of the investigated recovery options have a positive effect on the demand of primary energy, due to the recovery of either energy or materials. The Vinyloop mechanical recycling process shows the best performance in this respect, followed by the Watech and Stigsnæs feedstock recycling processes, on a similar level, and with the MVR incineration process at 3rd place.

3. In addition to this criterion, the results for the other impact categories – global warming potential (GWP) and acidification potential (AP) – as well as the management of substance flows (lead and dioxin) also need to be considered. For example, the Watech and Stigsnæs processes are the only ones allowing to separate and recover lead.

4. The management of the polymer as a resource plays a decisive role for the environmental assessment. In landfills, the carbon content of the waste product is "stored", although a long-term fixation is uncertain. Furthermore, landfilling incurs long-term risks and liabilities, which cannot be represented in the Eco-efficiency diagram. At least in Europe, landfilling of plastic waste does not represent a long-term disposal option from a legal point of view. Incineration processes such as MVR use the embodied energy of the polymer, while recycling processes such as Vinyloop, Watech, and Stigsnæs recover the material itself or its feedstock.

5. When taking the economic dimension (gate fees) into consideration, the Vinyloop process is shown to be competitive with landfilling, while all other recovery options entail higher costs – MVR, Stigsnæs and Watech in order of increasing gate-fees – mainly because of their low revenues for the recovered products.

The task for the decision-makers remains to arrive at an evaluation of the Eco-efficiency profile of each recovery option under consideration. This final evaluation will have to be based upon the system boundaries, conditions and specific demands of the technology, but will also need to take local and regional aspects into consideration.

We can herewith confirm after an in-depth critical review conducted according to EN ISO 14'040, chapter 7 that the compilation and valuation of environmental aspects of several end-of-life options for PVC cable waste in the report

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presented by PE Europe GmbH and dated 10th of April 2003 is in conformity with the actual series of standards EN ISO 14'040ff on environmental life cycle assessment (LCA). This part of the study is in line with the required structure of an LCA and fulfils the requirements on data quality, transparency, consistency, completeness and methodological soundness in dependency of the goal of the study.

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