PROJECT PERIODIC REPORT

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Work package 0
Coordination

Final report (D.0.4)

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1 Final publishable summary report

This section must be of suitable quality to enable direct publication by the Commission and should preferably not exceed 40 pages. This report should address a wide audience, including the general public.

The publishable summary has to include **5 distinct parts** described below:

- An executive summary (not exceeding 1 page).
- A summary description of project context and objectives (not exceeding 4 pages).
- A description of the main S&T results/foregrounds (not exceeding 25 pages),
- The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages).
- The address of the project public website, if applicable as well as relevant contact details.

Furthermore, project logo, diagrams or photographs illustrating and promoting the work of the project (including videos, etc…), as well as the list of all beneficiaries with the corresponding contact names can be submitted without any restriction.

1.1 An executive summary (not exceeding 1 page)

The concept of SORT IT was the development of new and improved sensor and measurement technologies for recovered paper sorting.

The main objective was to enable sustainable and cost effective paper recovery at higher than 95% yield of all recyclable paper and board grades and purity of 98% of deinking grade qualities.

The classification and quantification methods developed are the basis of the application of new NIR sensor based sorting technologies for recovered paper. Furthermore, significant improvement of actuators (in particular air blowing nozzles) and mechanical sorting equipments (Paperspike 2G) have been made. In addition to blow-ejection based technologies, the project also concentrated on the development on NIR detection sorting robots, in which significant progress was made.

In parallel, an intensive intellectual work was carried out in life-cycle assessments, where environmental, economic and social benefits were demonstrated. The environmental and economical sustainability performance of the newsprint paper and the packaging paper life cycles were optimized due to improved quality of the recovered paper grades 1.11 and 1.04. The savings were achieved by lower consumption of the improved quality recovered paper, raw materials and energy economy; and more efficient logistics due to transportation of sorted paper with lower amount of impurities in it. The manual and automatic sorting plants have little environmental impact from the total life cycle perspective, while the impact of the paper mills is the dominant. Energy consumption is the major environmental contributor. Waste management of rejects is an important issue. Incineration of the sorting rejects with energy recovery is more attractive environmental option than landfill or incineration without energy recovery. The technological switch to the automatic sorting resulted in enhanced environmental performance of the pulp and paper mills through increased pulp yield, lower amount of rejects and paper machines runnability, etc.

Economical aspects of sustainability were investigated in terms of the operational costs. Better economical performance automatic sorting plant was observed due to lower recovered paper consumption, labour and transportation costs. The social implications of higher efficiency together with production of improved quality of recovered paper at the sorting plants were observed through working conditions, health and safety, employment structure and education among others. New group of higher educated sorters instead of higher number of manual sorters is expected with less stressful job, less contact with contamination, less production stops and homogeneous quality of products.

These technologies were implemented into a new green field, full-scale industrial automatic sorting plant in Linz, Austria, with a capacity of 2000 tonnes per month. The full scale production runs which were monitored in detailed demonstrated the soundness of the concepts developed in the project, also on the long term.

The operation of the Linz sorting plant demonstrates the viability of the paradigm change in the industry, which can now forsake manual sorting and shift to fully automatic sorting plants. It also demonstrates that medium sized, tailored sorting plants to the need of municipalities, are viable.

Therefore, the project addresses important societal issues such as substitution of particularly stressful jobs, waste management and valorisation, sustainable supply of raw materials to industry, logistics and energy.

1.2 A summary description of project context and objectives (not exceeding 4 pages)

Recovered Paper SORTing with Innovative Technologies

Project overview

FP7 Call – Environment: SORT IT addresses the following research areas in the Call ENV.2007. 3.1.3.2. – New Technologies for Waste Sorting:

- environmentally and economically important waste material flows,
- new/improved automatic identification units,
- quality assessment related to utilization,
- LCA, LC social analysis, externality/LC costing,
- improve quality and homogeneity of materials,
- increase in energy efficiency,

These issues are also targeted in the Strategic Research Agenda of the Forest Based Sector Technology Platform, which includes thematic priorities such as: the development of intelligent and efficient manufacturing processes, including reduced energy consumption; reengineering the fibre-based value chain; more performance from less inputs in paper products; reducing energy consumption in pulp and paper mills; streamlined paper recycling.

Background: Rising prices for raw materials and energy put pressure on the paper industry. Virgin pulp production is strongly affected by increasing raw material prices as wood demand is subject to competition between several product uses and energy use. At global level, a higher demand for recovered paper as raw material for paper production will increase the competition in recovered paper utilization. Besides shortage of raw materials, the market trend also puts pressure on quality. Unwanted materials significantly disturb production and final product quality and reject handling is an important environmental and expense factor in papermaking. At the same time, tightening legal requirements and therefore increasing costs for the treatment and disposal of waste in general and especially, of residues from recovered paper treatment will require new, effective technologies for optimal recovering and utilization of used products. For increased usage of recovered paper and thus a more environmentally and economically sound paper production appropriate raw materials for high quality papers as well as increased amounts of recovered paper have to be provided. Homogeneity of recovered paper raw materials has to be improved as their composition varies depending on origin and sorting. In the past intense sorting was not economically reasonable due to low raw material prices. The project SORT IT developed the key technology to provide both, increased quality as well as increased quantities of recovered paper.

Project Concept: The concept of this project is the development of new and improved sensor and measurement technologies for recovered paper sorting. Automatic identification units were developed and integrated into the sorting processes that provide optimal measurement conditions matching the demands for separation. With respect to initial composition of recovered papers to be sorted and specifications of the customers (recycled paper producers), new concepts for the sorting process were be developed. The developed technology and concepts have undergone evaluation and optimisation in industrial paper sorting. Extensive life cycle studies have delivered detailed information on the impacts of the new sorting strategies and quantify the improvement achieved. This information is important for a successful dissemination of the developed technology.

Main Objectives:

- Enable sustainable and cost effective paper recovery with a yield higher than 95% of all recyclable paper and board grades.
- Obtain a purity of 98% of deinking grades.

Scope / Targets: The improvement of the recovery and increasing the collection rate of used paper products: analyzing European collection systems in terms of quantitative, qualitative and cost potentials, considering typical social and geographic conditions of the EU member states; determining the collection rates of recovered paper sources (office, household, industry & trade); providing optimized sorting technologies and collection systems with great acceptance and high separation ratio. The exploration of technological processes for optimum recovery of used paper and board: optimum sorting technologies for recovered paper; dry separation of non-paper components from recovered paper and their optimum use as secondary raw material or fuel. The reduction of specific energy demand for recovered paper processing: evaluating the influence of collection and sorting systems of recovered paper on the specific energy demand/costs of secondary fiber production.

Project Structure

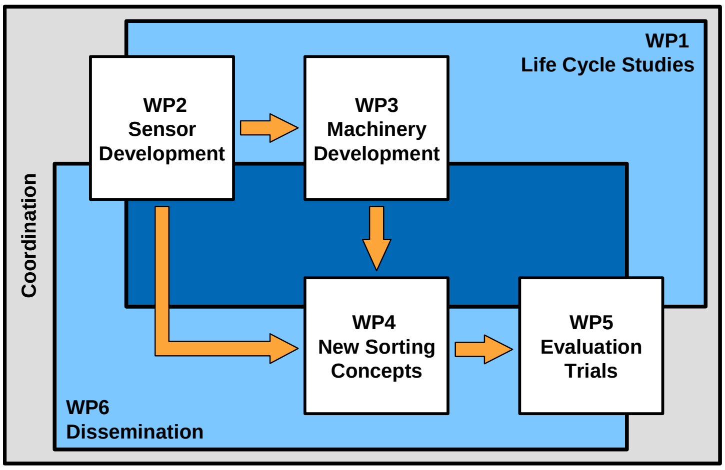


Figure 1: SORT IT Pert chart

- Life cycles studies for evaluation of sorting techniques: Life Cycle Assessment –LCA, Life Cycle Costs –LCC and Life Social Cycle –LSC
- Technology development: sensor technology, sorting machinery and technological concepts for sorting processes.
- Implementation into sorting process: testing sorting equipment on a pilot/industrial scale, sort different RP to defined grades/composition and refusal processing.
- Validation of sorting efficiency: assess RP composition and processing and log all energy aspects.
- Dissemination and communication: knowledge & technology, marketing promotion, environmental policy-related results
- Coordination of the project: consortium management and communication with the European Commission. Project activities are grouped in six work packages as it is shown in the Pert Chart.

Project Partners:

Participant organisation name	Country	Partner type
PTS (coordinator)	Germany	Institute
CTP	France	Institute
STFI-Packforsk	Sweden	Institute
UTI	Romania	Institute
ITENE	Spain	Institute
Bumaga	Netherlands	Industry SME
Bollegraaf	Netherlands	Industry SME
EVK	Austria	Industry SME
Rauch GmbH	Austria	Industry SME
Vrancart	Romania	Industry
Europac	Spain	Industry
RTT	Norway	Industry SME
Norske Skog	Germany	Industry

Figure 2: SORT IT consortium

Description of work packages

WP1 – Life cycle studies: The evaluation of the impacts for implementing of new sorting techniques was based on life cycle models of reference test cases, including sorted at source material, which were used as simulation tools. The results constitute a database for developing "new sorting concept". Databases contain valued indicators related to LCA, LCC and LSC of project cases and concepts. Finally, the evaluation trials provided data for life cycle impact studies of new sorting technology and quantifying changes on the impact, compared with references by using developed models (LCA, LCC and LSC) for sorted at source recovered paper. This study investigated the technological feasibility and economic viability of sorting to a purity of at least 98% of unsorted paper. The life cycle studies represent key feedback information for other WPs within the project: impact simulation of sorting techniques, developed in WP2 and WP3; new sorting concepts in WP4; knowledge dissemination between partners and producing the sustainability policy-related results, in WP6. Life cycle sustainability assessments of reference and new technology involved: Environmental impact; using Life Cycle Assessment (LCA) study (ISO 14040 conform); Social impact; using Life Cycle Social analysis (LSC) and Economic impact; using externality/Life Cycle Costing analyses (LCC). In the assessments the LCA data were provided according to data format and quality requirements set up by the European Platform for LCA. Environmental, economic and social data were collected mainly from industrial partners involved in the project. The LCAs of the current situation (reference from Vrancart Sorting and Paper mill as well as Norske Skog Reparco and Parenco and Reparco) and new sorting technology were subjected to an external review before reporting.

WP2 – Sensor Development: The aim of this work package was to enable the improvement of sorting efficiency and the use of new sorting criteria by developing a new NIR spectral imaging sensor, applying additional spectroscopic techniques and introducing new methods for identification and quantification of paper and board components.

The work package was divided into four major tasks. A new NIR spectral imaging sensor combined with a colour camera was developed. The NIR sensor allows measurements in an extended spectral range from 1350 nm to 2000 nm giving new possibilities for identification and quantitative analysis of recovered paper. In preliminary lab-scale studies the feasibility to develop stable qualitative and quantitative online NIR methods with a high accuracy was studied with a multiplex diode array spectrometer. Additionally to the NIR measurements the application of other spectroscopic methods were tested (e.g. fluorescence, microwaves). According to the test results of the preliminary study, the component parameters were chosen for which the final identification and quantification methods can be developed with the new spectroscopic techniques. All the work for the application of the measurement systems also included extensive software developments. The new developed technologies have undergone performance benchmark with former state-of-the-art technology.

WP3 – Machinery Development: Research and development on sorting machinery investigated optimal preparation of the incoming material entering the sensor based sorting step. Also options for more efficient separation of the flow respective the removal of detrimental substances were assessed and developed. State-of-the-art options for dosage, screening or other pre-treatment were assessed in detail and the most effective installations checked for further improvement. Aim was an optimal singling, providing maximum but monolayer load of the conveyor belts of the sensor device. In that context the effects of shredding of the input was assessed and its integration in sorting lines was evaluated. The separation techniques have undergone detailed analysis and optimisation for recovered paper sorting. Newly developed robot systems were tested for paper recovery.

WP4 – New sorting concepts: This work package developed concepts to enable optimised sorting processes with respect to specific prerequisites and final application of the recovered paper. System solutions were developed to perform sorting of sorted at source input streams. Sorting concepts were developed in a way to enable separation “white” and “brown” raw materials and the non-paper fraction. In general terms the new sorting concepts for pre-sorted/sorted at source input streams were developed in a way to enable paper recovery with a yield of sorting higher then 95% and purity of the output of 98%. Depending on the final application of the produced raw materials the elements of treatment can be combined in an optimal way. Deinking raw material production was the main focus but providing improved fibre sources for packaging production was also included. The raw materials produced were controlled regarding utilisation of relevant parameters and sorting processes adaptable to influence the composition and thus provide tailor-made raw materials.

WP5 – Evaluation Trials: This work package assessed the industrial application of the developed sorting technology. The results from WP 2, 3 and 4 were applied in combination. The sensor based sorting unit was integrated in an industrial scale recovered paper sorting line. The developed machinery, partly integrated in sensor-based unit already, was tested in full scale industrial production. The aim in this work package is to produce recovered paper that fulfils the paper industry requirements, including packaging applications. Papermakers delivered a certificate of compliance after a quality control of the sorted RP done according to their internal procedures.

WP6 - Dissemination and Communication: Having in view the multidisciplinary character of the project and diversity of partners’ background, information exchange were permanent activities. Training activities followed the sensors and sorting technology development and implementation. Communication with the Community Institutions and Bodies on the project results related to the environmental policy in the area of waste management, as well as on the recommendations for extending quality description of EN643 grades, were achieved with the help of a dedicated stakeholder group. The group includes experts from the consortium and from professional associations like CEPI and INGEDE.

The SORT IT website (http://www.sortit.eu) has been on line since 1st September 2008.

1.3 A description of the main S&T results/foregrounds (not exceeding 25 pages)

1.3.1 WP1 – Life cycle studies:

The pulp and paper industry has an important part to play in the future of sustainable development in Europe, because (CEPI 2009, Hall 2007, CEPI 2006):

- **Environmentally**: Paper is produced with more than 50% of renewable energies; paper products can then be recycled, extending their life cycle and minimizing the use of landfill; when they can no longer be used or recycled, it is possible to convert them into a renewable energy source.
- **Economically**: the industry generates wealth with €80 billion for the economy and adds €21 billion in value and wealth creation; it also employs more than 250,000 people and provides indirect employment to 1.8 million people.
- **Socially:** paper plays an important role in society, providing essential, everyday products that contribute to our quality of life; it is also an important driver for education, knowledge, democracy and culture.

These assets are all part of the virtuous eco-cycle that contributes to the sustainability of the paper industry.

In the SORT IT project, Work Package 1 was responsible for carrying out extensive life cycle studies with aim to assess the sustainability performance of the innovative technologies for recovered paper sorting developed within the project. The entire sustainability perspective of the project that consists of environmental, economical and social pillars was in focus when investigating manual and new sorting techniques and their impact on paper-making process.

The triple bottom line or three-pillar approach (environment, economy and society), the Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), as well as Social Life Cycle Assessment (SLCA) supports sustainability assessment under the following scheme:

$$LCSA = LCA + LCC + SLCA$$

Where:

- LCSA = Life Cycle Sustainability Assessment
- LCA = Life Cycle Assessment
- LCC = Life Cycle Costing
- SLCA = Social Life Cycle Assessment

By combining industrial and scientific perspectives in the SORT IT project, it was possible to develop the sustainability tools that were easy to apply by industrial partners, and that could generate reliable results.

Two test cases were identified in the overview-study on current situation with sorting technologies: production of standard newsprint paper from RP grade 1.11 and production of packaging paper (testliner) from RP grade 1.04. In the life cycle studies, the impact of the sorting technologies has been evaluated within each selected test case (see Figure 3).

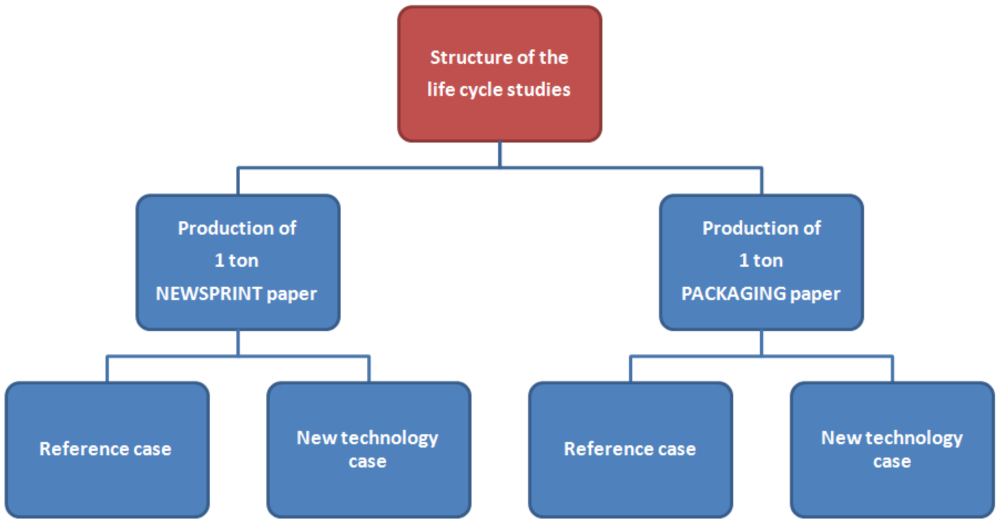


Figure 3 Structure of the life cycle studies in the SORT IT project.

In the sustainability assessment, the accounting for the environmental benefits of the innovative sorting was made by performing the comparative LCA studies according to the international LCA standard ISO 14044. The environmental impact categories (environmental problems) that are relevant to paper industry have been assessed. The environmental impact categories related to natural resources use are: abiotic depletion potentials (ADP), both ADP elements and ADP fossil. The environmental impact categories related to non-toxicological impacts are: acidification, eutrophication, climate change in terms of global warming potential (GWP), ozone layer depletion potential (ODP) and photochemical ozone creation potential (POCP). The environmental impact category related to toxicological impact is human toxicity potential. An external critical review of the LCA studies was performed.

The economical analysis has been carried out by developing and performing the comparative LCC study that analysed the costs occurred during the test cases (life cycles of the newsprint paper and the packaging paper). The LCC study of the packaging paper and the newsprint paper has been simplified by the reason of partial unavailability of the economical data from the industrial partners in the SORT IT project due to confidentiality issues. Therefore, the LCC study included the assessment of the internal costs in the test cases (i.e. production, use or end-of-life expenses). The internal costs that were possible to obtain from the project partners and partly from the reliable statistical sources belong to: direct costs borne by the company when manufacturing a product (i.e.: raw materials, electricity, transport, etc.) and hidden costs that are general costs related to license expenses, waste management costs, etc.

Social aspects of sustainability for the manual and automatic sorting plants and the paper mills have been evaluated by following the SETAC recommendations on carrying put social life cycle studies. The social aspects appeared to be limited mainly due to physical working conditions, especially stress related, to lower number of employees dealing directly with manual sorting, and new group of employees with higher education that might substitute low-educated sorters.

Newsprint paper sustainability assessment

The newsprint paper life cycle starts at the sorting plant with sorting of recovered paper from household collection, continues with newsprint paper manufacturing at the paper mill, production of newspaper in printing process, consumption of newspaper, newspaper waste collection and ends with waste management of newspaper in terms of material recycling, incineration and landfill. The transportations between the processes have also been included in the studied newsprint paper life cycle.

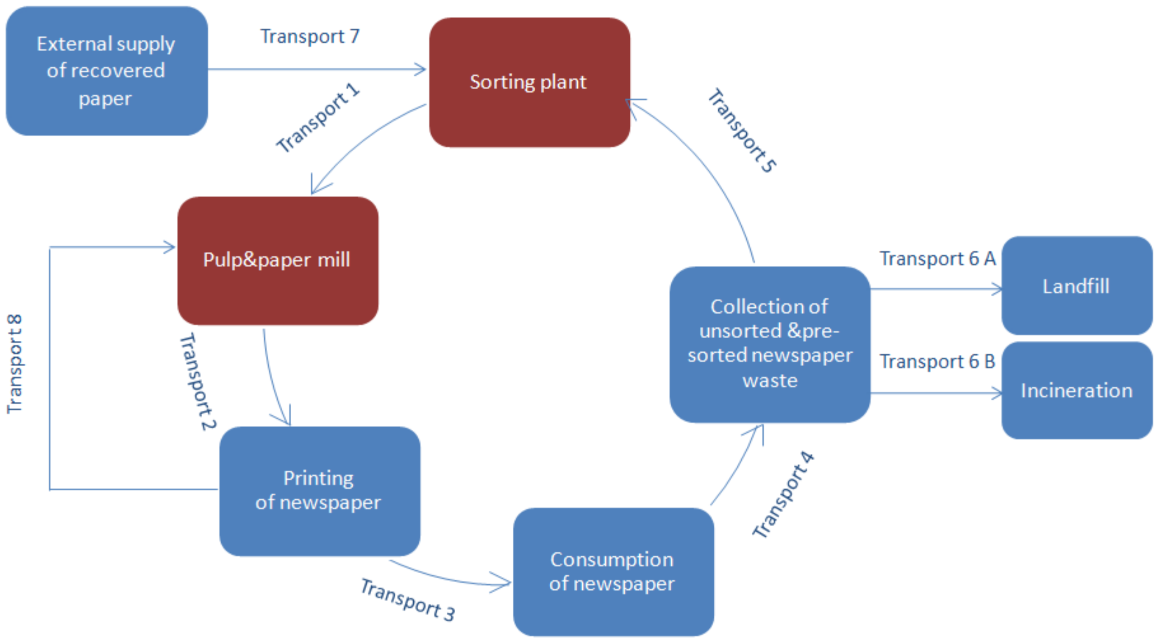


Figure 4 The overall newsprint paper product system (the studied life cycle). The sorting and pulp and paper mill processes are the main focus of the study.

The results of the environmental and economical sustainability assessment are estimated per functional unit, which is production of 1 ton paper (newsprint paper or packaging paper depending on the test case), with the paper produced from 100% recovered paper.

LCA study of newsprint paper

The overall LCA results of the studied newsprint paper life cycle have shown that the pulp and paper mill, printing of newspapers and environmental burden of recovered paper are the life cycle stages that have the largest environmental impact in all environmental impact categories, from the total life cycle perspective. Use of energy and fuels was the dominant contributor to the environmental impacts.

There are two cases in the newsprint paper life cycle that have been compared with each other: the reference case and the new technology case. The difference between the cases is in the manual sorting plant in the reference case and the innovative sorting plant in the new technology case. The other processes in the newsprint paper life cycle remained unchanged.

The overall LCA results of the reference case and new technology case in the newsprint paper life cycle were comparable from the total life cycle perspective.

The table shows that the new technology case has performed somewhat better in eutrophication potential (-3.3%), global warming potential (-2.1%) and abiotic depletion potential (ADP fossil) (-1.3%). The reference case has showed better result for acidification potential, abiotic depletion potential (ADP elements), while other environmental impact categories resulted in similar level of environmental impacts:

Furthermore, the environmental impacts of the manual and innovative automatic sorting plants and their impact on the pulp and paper mill have been analysed in detail for the reference case and new technology case. The environmental impact of the sorting plants occurred due to energy consumption and waste management of the rejects sorted out, whereas the innovative sorting plant demanded more energy and generated more rejects.

Life Cycle Impact Assessment (LCIA) categories	Comparison of NEW TECHNOLOGY CASE to REFERENCE CASE
Abiotic Depletion (ADP elements) [kg Sb-Equiv.]	**1.8 %**
Abiotic Depletion (ADP fossil) [MJ]	**-1.3 %**
Acidification Potential (AP) [kg SO2-Equiv.]	**1.8 %**
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	**-3.3 %**
Global Warming Potential (GWP 100 years)	**-2.1 %**
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	**0.03 %**
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	**0.5 %**
Human toxicity [cases]	**-0.03 %**

The environmental impact of the sorting plant on the paper-making process showed that the environmental performance of the pulp and paper mill in the new technology case has been improved thanks to the improved quality of RP grade 1.11. The result is less on-site emissions from the paper-making process, less consumption of raw materials and energy required for production of 1 ton newsprint paper at the mill. The environmental impacts are mostly linked to production of electricity, natural gas, both consumed at the mill and the mills on-site emissions to air and water.

Altogether, the innovative sorting technology is a more energy demanding technology and generates more sorting rejects. At the same time, more rejects are sorted out and higher quality recovered paper products are produced at the sorting plant. As a result:

- Less unwanted materials are transported inside the RP grade 1.11 to the pulp and paper mill for manufacturing of newsprint paper
- Less ancillary materials are needed at the mill due to improved quality of incoming RP grade 1.11
- Less energy is needed in paper production process
- Less amount of RP grade 1.11 is needed to produce 1 ton of newsprint paper at the mill

The description of the main environmental impacts between the reference case and the new technology case with more focus on the sorting plant and the paper mill processes can be seen in Table 1. The impacts are caused by better quality of recovered paper grade 1.11 that is sorted more efficiently at the sorting plant in the new technology case.

Table 1. Main environmental impacts in each environmental impact categories in the comparison between reference and new case within newsprint paper product system. RP- recovered paper.

Impact Assessment categories	Description of environmental impact by each impact assessment category
Abiotic Depletion (ADP elements) [kg Sb-Equiv.]	The major environmental impact is caused by recovered paper (RP) consumption, pulp and paper mill and printing of newspaper. In the printing process, manufacturing of printing colour that is consumed in the printing of newspapers is the largest environmental contributor. Additional stream of RP is supplied to the studied newsprint paper life cycle since some RP is being lost in incineration and landfill in the life cycle. It is modelled as a system expansion (consumption of recycled paper produces a reduction in paper produced from recycled fiber, and increase in production of paper produced from virgin fiber). The new case consumes lower

Impact Assessment categories	Description of environmental impact by each impact assessment category
	amount of RP and for this reason its abiotic depletion (elements) is lower. The additional stream of RP is called RP consumption further on. Sorting plants have little environmental impact: the impact comes from electricity consumption and incineration of sorted out rejects at the incineration plant located nearby the sorting plants. The innovative sorting plant has higher impact since more electricity is consumed and more rejects are incinerated. At the mill, manufacturing of sodium silicate (bleaching chemical in RP processing) and natural gas (for steam and gas turbine) contribute most to the ADP elements impact category. In the new technology case, the mill has lower impact since fewer raw materials and energy are needed in paper production.
Abiotic Depletion (ADP fossil) [MJ]	The major environmental impact is caused by the processes: pulp and paper mill, printing of newspaper and RP consumption. The environmental impact in the respective processes is due to electric and thermal energy consumption when energy is produced from fossil resources (e.g. crude oil, hard coal, natural gas). The impact is also caused by consumption of raw materials whose production is fossil-energy-consuming such as production of printing colour, offset plates during printing of newspaper and production of diesel fuel used in the transportation processes. Sorting plants have little environmental impact, whereas the innovative sorting plant is performing better from the perspective of waste management of sorting rejects: the larger amount of rejects incinerated generates more electricity and heat in the new technology case, thus reducing the environmental impact of electricity and heat production in Europe. In the new technology case, the mill has lower impact, mainly due to reduced consumption of electricity and natural gas.
Acidification Potential (AP) [kg SO2-Equiv.]	The major impact is caused by RP consumption, printing of newspaper and pulp and paper mill. Sorting plants have little environmental impact from the total life cycle perspective, whereas electricity production impact is higher in the new technology case due to higher demand of electricity at the innovative sorting plant. The same trend is for incineration of the rejects sorted out. At the mill, the new technology case has lower environmental impact. This is because fewer raw materials are required in production. Most of the environmental impact is caused by production of electricity and natural gas consumed at the mill. In the printing of newspaper, most of the environmental impact is caused by production of electricity that is consumed in the process.
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	The major environmental impact is related to emissions to water and is caused by the pulp and paper mill, and landfill of paper waste from the total life cycle perspective, whereas RP consumption has decreased the impact (due to the avoided emissions of phosphor when landfilling ash). Sorting plants have little environmental impact, whereas most of it is caused by incineration of sorting rejects at the incineration plant (mainly emissions of nitrogen oxides to air). Higher electricity consumption and higher amount of incinerated rejects gives higher environmental impact to the sorting plant in the new technology case. At the mill, the new technology case has lower environmental impact. Most of the environmental impact is caused by ash disposal and production of natural gas that are consumed at the mill.
Global Warming Potential (GWP 100 years)	The most of the environmental impact is caused by the pulp and paper mill, printing of newspapers and landfill of paper waste. The GWP impact category is highly influenced by energy intensive processes. The impact is caused by production of electricity and natural gas fuel that is consumed at the mill, direct emissions from newsprint paper production at the mill and production of electricity and offset plates (produced from aluminium) that are utilized at the printing of newspapers. The RP consumption modelled as system expansion has decreased the overall impact. It includes the production of paper from virgin fiber, where the carbon uptake from trees is considered and produces an environmental credit (environmental savings). As a consequence of the methodology, the consumption of recovered paper is considered to produce a reduction in the GWP impact. Sorting plants have little environmental impact and most of it is caused by incineration of the sorted out rejects at the incineration plant located nearby. The impact of the sorting plant is higher in the new technology case and the impact of the mill is lower in the new technology case.

Impact Assessment categories	Description of environmental impact by each impact assessment category
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	Major environmental impact is related to the activities at the printing, the pulp and paper mill, and RP consumption, from the total studied life cycle perspective. The impact is related to energy production consumed in the processes. This is the electric energy at the printing and the mill and natural gas fuel at the mill. Sorting plants have little environmental impact. The impact of the sorting plant is lower in the new technology case because of incineration of sorting rejects with electricity and heat recovery at the incineration plant. The impact of the mill in the new technology case is also lower in the new technology case.
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	Major environmental impact is related to the printing of newspaper, the pulp and paper mill, and environmental burden of RP, from the total studied life cycle perspective. The impact in is caused by emissions of organic compounds to air. At printing of newspapers and the environmental burden of RP, these are caused by on-site emissions of volatile organic compounds (VOC) to air. In the RP consumption, the impact occurs in the production of paper from virgin fibers. Sorting plants have little environmental impact and caused by emissions from electricity production that is consumed at the sorting plants. The impact of the sorting plant is higher in the new technology case since the innovative sorting plant consumption more electricity. At the mill, the impact is caused by production of natural gas and electricity that are consumed. The new technology case has showed lower impact due to lower consumption of those.
Human toxicity [cases]	Major environmental impact is related to the pulp and paper mill, the printing of newspaper and RP consumption, from the total studied life cycle perspective. The dominant impact is caused by VOC emissions to air during production of raw materials and energy that are consumed and direct emissions from the processes in the studied newsprint paper life cycle. In the printing of newspapers, production of the printing colour and electricity are the major contributors. Sorting plants have little environmental impact and most of it is caused by incineration of the sorted out rejects at the incineration plant located nearby. The sorting plant in the new technology case show reduced impact. This is due to co-generation of higher amount of electricity and heat from incineration of the sorting rejects since larger amount of rejects is generated. At the mill, production of electricity and soap consumed, contribute most to the impact. The new technology case has showed less environmental impact due to less consumption of raw materials and energy.

In the SORT IT project, the innovative sorting plant has not been working in full operation during the full-scale trials. In order to perform the LCA study, the full potential of the innovative sorting plant has been defined, estimated based on expert judgment and served as a baseline for the new technology case assessed in the current study. This of course has an impact on the environmental results of the study but the results can be interpreted as an indication of the potential of this innovative sorting technology. The sorting plant continues to run in industrial scale outside the project scope and is being optimized continuously towards better performance in terms of quality of the product and energy consumptions.

A sensitivity analysis of the environmental results has been carried out. The important aspects have been identified and these are related to geographical location of the newsprint paper product system. Thus, the placement of the newsprint paper product system to different European regions will have a significant influence on the aspects such as electricity production sources and waste management infrastructure available.

The new technology base scenario has been simulated for different regions in Europe: South-West Europe, Central-North Europe, East Europe and European average. The sensitivity analysis showed that the East Europe scenario has resulted in higher environmental impact in almost all of the impact categories reported in Table 1. This is due to a large share of paper waste landfilling and the type of electricity mix in this region. The North-Central scenario was the best scenario in the new technology case. This is due to the low landfilling ratio for waste paper and lower emissions from electricity production that is consumed in the processes in this region. The landiflling ratio in the Central-North

Europe scenario was 1%, while in the East Europe scenario it was equal to 54%. The recycling rate in the North-Central scenario is the highest of all scenarios included in the study, being 73%.

LCC study of newsprint paper

The aim of the LCC study of the newsprint paper was also to compare the performance of the new technology case with the reference case, but from the economical point of view. The comparison unit used in the LCC study is also a production of 1 ton newsprint paper. The LCC study results have shown that the new technology case that includes the automated sorting plant is more economically sound than the reference case with the manual sorting technology. The overall cost reduction achieved in the new technology case is 1.2%. The main cost contributors to the newsprint paper life cycle are the pulp and paper mill and printing of newspapers, from the total life cycle perspective. The processes are responsible for the 77% of the total costs studied.

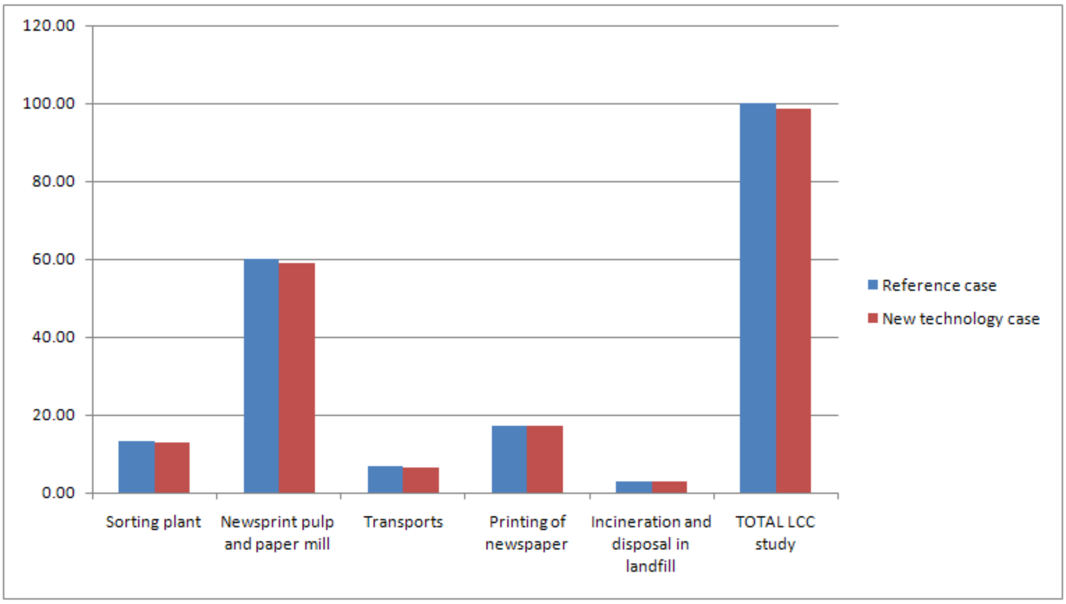


Figure 5 Costs in each stage of the newsprint paper life: in the reference case and new technology case. The costs of the reference case are set to 100%.

The economical analysis of the automatic sorting plant alone showed that it performed economically better than the manual sorting plant. The main cost contributor is the recovered paper consumption followed by the labour cost. The labour costs have resulted in major change due to switch from the manual to the innovative sorting technology. The change has occurred due to reduction in the working personnel and less working shifts per day. The increase in cost for electricity consumption due to automatisation of the sorting plant, and the increase in cost of incineration of the rejects sorted out due to better sorting efficiency of the sorting plant have been observed. Only slight decrease of the recovered paper consumption has been achieved at the automatic sorting plant.

The cost of the newsprint paper production in the new technology case is slightly lower (1.5%) than it is in the reference case. The cost optimization is achieved due to better quality of RP grade 1.11 supplied to the mill in the new technology case, and is allocated to decrease in the operating costs, raw material costs and labour costs at the mill. Only natural gas consumption (thermal energy) cost is higher at the mill in the new technology. This is due to the fact that the improved quality of RP grade 1.11 generates less waste at the mill, which is in turn incinerated in the steam and gas turbines. Consequently, the remaining demand for thermal energy (fuel) in the new technology case shall be satisfied by the additional supply of the natural gas.

The total transportation costs have been analysed in the LCC study of the newsprint paper. The processes in the new technology case show slightly better economical performance if compared to the reference situation. This is due to lower load of collected recovered paper supplied to the automatic sorting plant and also lower load of RP grade 1.11 supplied from the automatic sorting plant to the newsprint paper mill.

Sensitivity analysis of the economical results in the LCC study has been performed. The aim of the analysis was to assess the economical performance of the new (automated) sorting plant, from the European perspective. The focus of the sensitivity analysis laid on the automated sorting plant, production of newsprint paper at the pulp and paper mill, and also transportations of: collected recovered paper (RP grade 1.01) to the sorting plant and sorted recovered paper to the mill (RP grade 1.11). Labour, fuel and electricity cost have been analysed in the scenarios with different European regions and compared to the European average scenario. The results have shown that the investigated costs are the highest in the scenario with North-Central Europe. The Eastern European scenario is the most economic scenario among all scenarios being 8% less expensive, while the cost of the North-Central European scenario is 20% higher than that of the European Average scenario. The cost breakdown into electricity and labour costs in the analysed processes demonstrated that the electricity and labour costs occurred at the paper mill are dominant.

Packaging paper sustainability assessment

The packaging paper life cycle starts with the sorting of the recovered packaging paper coming from household collection, as well as the production of packaging paper at the paper mill, followed by the assembly of boxes and their consumption, and ending with the packaging paper waste collection and management, considering the recycling, incineration and landfill alternatives. The transports between the processes have also been included in the life cycle of the packaging paper case study.

Two cases described below were considered for the life cycle assessment of the packaging paper:

- Reference case: Recovered paper coming from household collection is sorted manually.
- New technology case: Recovered paper coming from household collection is sorted using the automatic sorting technology developed in the SORT IT project.

Additionally, the Informative case with recovered paper originating from supermarket and being sorted at source (as in nowadays situation at Vrancart Adjud paper mill) has been assessed.

Table 2. Description of the different case studies considered.

Cases	Sorting technology	Source of recovered paper
Reference case	Manual sorting	Household collection
New technology case	Automatic sorting	Household collection
Informative case	Sorted at source	Sorted at source (from supermarket)

The results of the environmental and economical sustainability assessment are estimated per functional unit, which is production of 1 ton packaging paper with a quality of testliner. In all the three cases the recovered paper feed in the packaging paper mill is a mix of RP 1.04 and RP 4.01 (with an higher amount of RP 1.04). In accordance with the definitions from EN 643 standard, grade 1.04 is defined as *"used paper and board packaging, containing a minimum of 70% of corrugated board, the rest being solid board and wrapping papers"*. Therefore by adding shavings of corrugated board (RP 4.01) to RP 1.04, a RP 1.04 with higher quality will be obtained. Consequently the mix of RP 1.04 and RP 4.01 was assumed as RP 1.04 with higher quality.

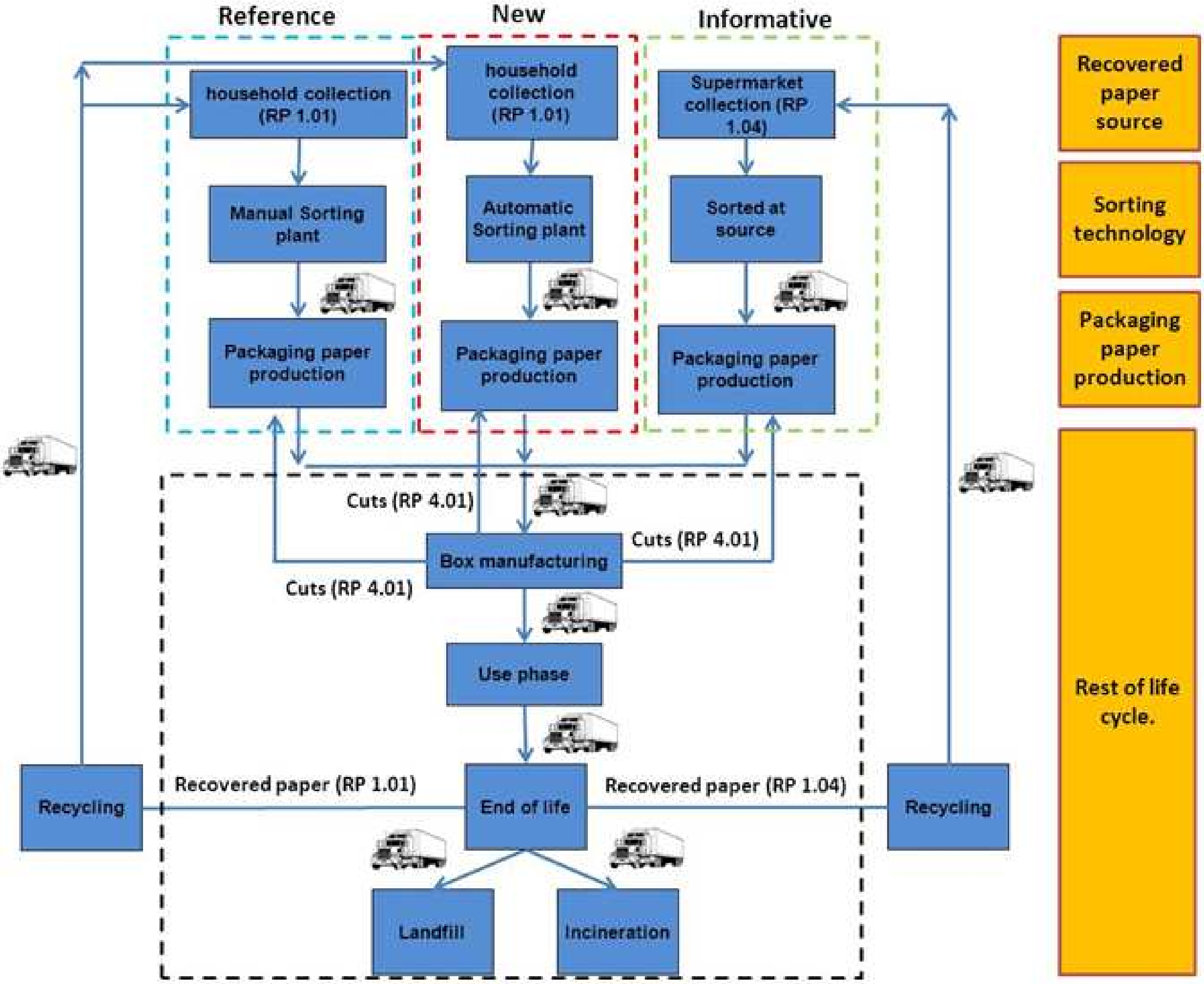


Figure 6 The overall packaging paper product system (the studied life cycle). The sorting and pulp and paper mill processes are the main focus of the study.

LCA study of packaging paper

The packaging paper LCA study has shown that the packaging paper production and corrugated board box assembly, as well as the environmental burden of the recovered paper cause the largest environmental impacts in all environmental impact categories. On the contrary the environmental impact of the sorting process is almost negligible except in eutrophication potential. The transport processes have a limited environmental impact in the life cycle, except for the global warming potential.

Next table summarizes the relative LCA results obtained for the new technology case and the informative case in comparison to the reference case of packaging paper in every of the environmental impact categories considered in the study. A relative reduction can be observed in all environmental impact categories except for global warming potential, where an increase of the environmental impacts was identified.

Table 3 Comparison of the new technology case and informative case in relation to the reference case.

Life Cycle Impact Assessment (LCIA) categories	**Comparison of NEW TECHNOLOGY CASE**	**Comparison of INFORMATIVE CASE**
Abiotic Depletion (ADP elements) [kg Sb-Equiv.]	-18.35%	-5.28%
Abiotic Depletion (ADP fossil) [MJ]	-5.49%	-0.04%
Acidification Potential (AP) [kg SO2-Equiv.]	-2.45%	-0.34%
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	-13.46%	-10.50%
Global Warming Potential (GWP 100 years)	10.60%	4.67%
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	-2.35%	-1.20%
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	-4.32%	-0.96%
Human toxicity [cases]	-11.25%	-5.03%

The main impacts associated to the reference and new technology case are described in the following table:

Table 4. Comparison of the main environmental impacts of the reference and new technology case for each impact categories. RP – recovered paper.

Impact category	**Description**
Abiotic Depletion (ADP elements) [kg Sb-Equiv.]	The main differences in this impact category are linked to the recovered paper (RP) consumption, which is modelled like a system expansion. Only a slight difference is observed in case of the paper mill stage where less electricity and ancillary materials for paper production are used in the new technology case.
Abiotic Depletion (ADP fossil) [MJ]	The main difference in this impact category is also linked to RP consumption. The new technology case consumes less RP, so its abiotic depletion (fossil) is the lowest. Futhermore less environmental impact is observed in transport and paper mill processing, since less electricity is consumed in the latter case.
Acidification Potential (AP) [kg SO2-Equiv.]	The main contribution to the environmental impact is caused by the packaging paper production due to the decrease of sulphur dioxide emissions since the energy consumption is lower in the new technology case.
Eutrophication Potential (EP) [kg Phosphate-Equiv.]	The main contributions to this impact category are: a) At the sorting plant: Disposal of rejects in a landfill. b) At the packaging paper mill: i. Disposal of rejects to landfill. ii. Emissions of nitrogen oxides to air. iii. Emissions as Chemical Oxygen Demand (COD) to water c) At the manufacturing of corrugated board boxes: Disposal in a landfill of wastes and the ink consumption to print the box. d) Disposal in a landfill of waste paper. Results obtained showed that the automatic sorting technology produced less impact in this category since fewer emissions are produced mainly at the packaging paper mill.
Global Warming Potential (GWP 100 years)	On the contrary to other impact categories, an increase in GWP is observed for the new technology case. This is mainly caused by all the stages considered in the life cycle. The highest contribution is caused by processing at the paper mill,

Impact category	Description
	followed by the manufacturing of corrugated board boxes. In contrast to other impact categories, in GWP the transportation and end-of-life processes have relevant contribution to the environmental impact, whereas the avoided impact of consumption of recovered paper has a environmental credit. The increase in the use of natural gas in the new technology case and specifically that less use of RP from background (less environmental credits by avoided impact) resulted in higher contributions in this impact category for the new technology case.
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]	The electricity and natural gas consumption are the main contributors to the increase of the ozone layer depletion potential. The new technology case consumes less electricity that leads to a lower impact to ozone layer depletion.
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]	The release of sulphur dioxide due to the burning of fuels in the packaging paper manufacturing and ink use in the manufacturing of corrugated board boxes assembly are the main contributions to this impact category. The new technology case consumes less energy. As a result of that its impact is lower than the reference case.
Human toxicity [cases]	The impact on human toxicity is mainly related to the electricity production and the release of pollutants during the production and use of various materials at different life cycle stages: • At corrugated board box manufacturing: the printing inks, and rosin size. • At packaging paper production: maize starch, and rosin size. The new technology case consumes lower amount of raw materials and electricity resulting in lower impact on human toxicity.

The benefit of the automatic sorting technology (new technology case) in comparison to the manual sorting (reference case) is due to a better quality of the recovered paper obtained at the sorting plant and therefore introduced at the paper mill, as well as in reduction in the electricity and raw materials consumption (including recovered paper).

A sensitivity analysis of the environmental results was also carried out. The most important factors were identified and the key aspects were those related to geographical location of the packaging paper product system with the automatic technology. The geography of the packaging paper production system in different European regions had a significant influence on some aspects such as electricity production sources and waste management infrastructure available.

The results of the sensivity analysis showed clearly that the geographic location have a significant influence in the results specially in East Europe, due to the different electricity mix and the higher use of landfilling as waste management route. The avoided impact for the recovered paper consumption was also analysed in the sensitivity analysis, although the influence of avoided impact on the LCA results is small.

LCC study of packaging paper

In accordance with the results from the LCC study of the packaging paper, several conclusions have been obtained and presented below.

The LCC study results have shown that the most influencing stages in the packaging paper life cycle are the manufacturing of the corrugated board boxes followed by the costs of the packaging paper mill. On an average both processes represents around 83% of the whole costs of the life cycle (Figure 7). This follows the same trend as in the majority of the impact categories in the LCA study, where the manufacturing of the corrugated board boxes and the packaging paper mill represented the main contribution to environmental impact.

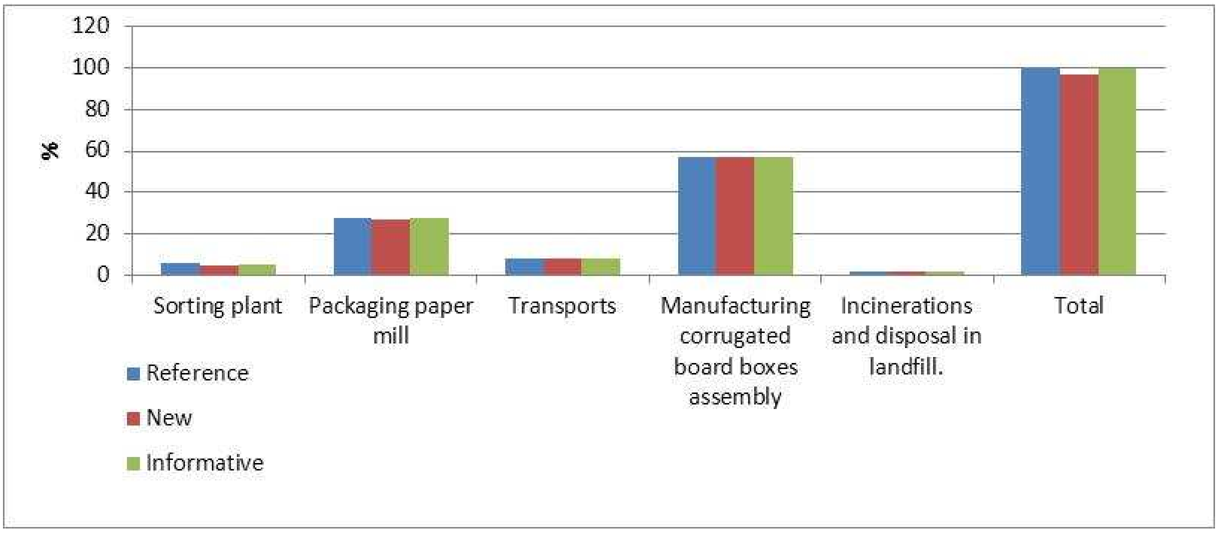


Figure 7. Cost in each packaging paper life cycle steps for reference, new and informative case. Costs in each stage of the newsprint paper life cycle: in the reference, new and informative cases. The costs of the reference case are set to 100%.

The automatic sorting technology developed within the SORT IT project (new technology case), resulted in less costs during the whole life cycle than the manual paper sorting from household collection (reference case) or the recovered paper from supermarket collection and sorted-at-source (informative case). The comparison between the reference and new technology case shows savings of 3%. The comparison between the new technology case and the informative case produces savings in the costs higher than 2%.

The greater difference in the costs is produced at the sorting plant level, whereas the difference in the packaging paper mill and transports is lower.

Looking at the sorting plant, the savings in the costs at the automatic sorting plant (new technology case) is higher than 20% with regard to the former manual sorting technology (reference case). Such cost savings are consequence of the lower amount of recovered paper required for the production of one ton of packaging paper. In the case of the comparison with regard to the supermarket collection sorted at source (informative case), the cost savings are around 20%, since lower amount of RP is required to produce 1 ton of packaging paper.

The cost savings at the packaging paper mill in the new technology case are higher than 3% in relation to the packaging paper in the reference and informative case. The savings are linked to the reduction in the raw materials consumption, including recovered paper but chemical materials as well. The energy costs, operational costs, and labour costs are slightly lower than in the reference and informative cases. The saving in costs as a consequence of the reduction in the amount of energy, raw materials, and increase in production capacity at the packaging paper mill.

The cost savings in the transport are less than in the packaging paper mill and the sorting plant. The differences in the transport are limited to the transportation load of recovered paper supplied from the additional source, and the transportation load between the sorting plant and the mill. The cost savings between the new technology case and the reference case are higher than 4% with regard to the reference case. The savings in the costs between the new technology and informative case are higher than 3%.

In relation to the types of the analysed LCC costs, the main contributor is the labour cost.

The sensitivity analysis has demonstrated that the LCC results are sensitive to influence of the geographical location. The different scenarios in the analysis show that the automatic sorting technology (new technology case) is the best case in all geographic locations. However, the highest

LCC cost is reached when the scenario of North-Central Europe is considered due to the higher labour cost in the region if compared to the respective cost in the other regions.

LSC study of packaging paper and newsprint paper as part of sustainability assessment

Social aspect of sustainability has been investigated in relation to different social areas of interest and related Impact subcategories such as e.g. technological innovations that are represented by demonstrators and end-of-life company responsibility.

Stakeholders involved in the LSC study have been divided into two groups: sorting plants and paper mills. Sorting plants group includes Vrancart Sorting and Rauch Recycling. Paper mills group includes Norske Skog Paper Mill and Vrancart Paper Mill. Based on The Society of Environmental Toxicology and Chemistry (SETAC) guidelines, following stakeholders' categories have been used: Workers, Consumers, Local community, Society and Value chain actors (not including consumers).

Following the definition of stakeholder categories and subcategories of the respective social impacts, the inventory indicators have been defined in order to carry out the inventory. The inventory indicators used in the analysis were qualitative or quantitative and have been related to improvements in kind such as for example higher efficiency and higher quality of recovered paper. Paper mills as well as sorting plant involved in data collection had chosen those indicators that data was possible to collect and important from the progress perspective. For this purpose, the LSC questionnaires have been developed.

One of the major conclusions after the first survey part in the project is that the industrial partners had difficulties in recognizing important indicators and providing reliable data, even for the improved questionnaires. The latest version of the LSC questionnaires, which was developed from the industrial perspective, was much simplified and narrowed but it fulfilled its purpose (Table 5):

Table 5 New questionnaire concerning implications in social aspects that are directly related to new sorting technology.

Improvement in kind	**Stakeholder category**	**Implication field (social) within the Stakeholder category**
Higher efficiency	Workers	Working conditions
		Education
		Employment structure
	Local community	Safe & healthy living conditions
Higher quality of recycled paper Higher amount of refuses	Customers	Feedback mechanism
	Society	Technology development

The major focus in collected answers was on working conditions inclusive salary, working hours, equal opportunities, health and safety, employment structure, and education. Another focus was on health and safety of consumers as well as safe and healthy living conditions in local community. The short summary of the results is given below:

Sorting plant – higher efficiency

The most significant positive changes in working conditions are fewer contaminations that workers have contact with, since the new sorting line handles them automatically.

Companies expect lower number of employees dealing directly with manual sorting, and new group of employees with higher education might substitute low-educated sorters.

One of the sorting plants expects to increase the amount of raw material by collecting from the bigger area and by accepting worse quality recovered paper.

Sorting plant – higher quality of recovered paper

Companies expect that new sorting technology will lead to lower consumption of recovered paper at paper mills and respectively higher quality of final paper.

Paper mill – higher efficiency

The most significant positive changes are less production stops that cause less stress for employees. Employees can concentrate and focus on different parts of manufacturing process instead of breaks on paper machines.

Paper mill - higher quality of recovered paper

Higher and constant level of quality can positively influence working conditions in terms of less dust and less moisture. Employees get very stressed when quality of paper varies.

Since the recovered paper changes continuously, sorting technology should follow changes and adapt to them.

The most general conclusion from the second part of survey process is that social related indicators should be created in cooperation with industry partners in order to secure industry involvement in data providing, better motivation and clear communication.

Implementation of the automatic sorting technique at the sorting plant minimized employees stress at both sorting plants and paper mills. Higher quality of recovered paper has also positive impact on paper manufacturing process in terms of less process breaks.

Remarks

- In the SORT IT project, the innovative sorting plant has not been working in full operation during the trials and the trials at the paper mills could not be performed. Therefore, in order to carry out the life cycle studies, the potential influence of the innovative sorting plant on the performance of the paper mills has been defined, estimated on expert judgment and served as a baseline for the new technology case assessed in the current study. This of course has an impact on the results and therefore the results can be interpreted as a potential indication of the potential of the innovative sorting technology. Nowadays, outside the project scope, the innovative sorting plant is running in industrial scale and is being optimized continuously towards better performance in terms of quality of the product and energy consumptions.
- It shall be noted that the performed LCC and LSC studies of the packaging paper and newsprint paper are simplified. The reason for simplification is the partial unavailability of the data from the industrial partners in the SORT IT project due to the confidentiality issues inside and outside the project consortium. Paper business is facing hard economical situation and therefore the sensitive economical data is not revealed in the project. For instance, in the opposite situation in the project, it would be necessary to include the sensitive economical data such as investment cost and maintenance cost of the manual sorting plant, the automated sorting plant and the paper mill since such costs are significant economical factor. The current LCC results do not include the analysis of the investment cost and the maintenance cost, whereas the results are presented from the perspective of the costs defined in the current LCC study.
- The LSC study has been improved, simplified and fitted to companies' requirements. However collecting social data is a difficult task for some of the industrial partners involved in the project. Some data is confidential and not available for analysis. The social aspects appeared to be limited mainly due to physical working conditions, especially stress related, to lower number of employees dealing directly with manual sorting, and new group of employees with higher education that might substitute low-educated sorters. However, the major goal of data collection was to identify social areas that could be improved as a result of implanting new sorting technique.

Final words

The performance of the life cycle studies in the SORT IT project generated two main kinds of conclusions:

- general, related to combining scientific and industrial perspectives in one
- specific, related to gathering data, analyzing and interpretation of data, and creating results

General conclusion

Combining scientific and industrial perspectives in one requires very close cooperation between academia and industry. Communication should be “face-to-face” in order to avoid misunderstanding and secure correct flow of information.

Specific conclusion

Process for gathering data, analyzing and interpretation of data, and for creation of results should be easy to run and clearly motivated, since requested data and consequently, created results might be sensitive for industries.

1.3.2 WP2 – Sensor Development:

The aim of Work Package 2 was to enable the improvement of sorting efficiency and the use of new sorting criteria by developing a new Near Infra-Red (NIR) spectral imaging sensor, by applying additional sensing techniques and by introducing new methods for identification and quantification of paper and board components.

The work package was divided into four major tasks.

- The feasibility of the basic hypothesis – use of first-of-a-kind extended NIR (SWIR) spectroscopic measurement methods would enable unprecedented high accuracy and stable classification of various recovered paper types – was verified in a preliminary lab-scale study with a diode array spectrometer and a FT-NIR laboratory spectrometer.
- Additionally to the NIR measurements the application of other spectroscopic methods were tested for feasibility within this project (e.g. fluorescence, microwaves).
- The development of a new NIR spectral imaging sensor. The NIR sensor was intended to enable measurements in the extended spectral range from 1300 nm to 2300 nm giving new possibilities for identification and quantitative analysis of different types of recovered paper.
- According to the test results of the preliminary study, the component parameters were chosen for which the final identification and quantification methods would be developed with the new spectroscopic techniques. All the work for the application of the measurement systems would also include software developments.

The new developed technologies were designed to undergo performance benchmarks with former state-of-the-art technologies in real field-tests and production environment application.

The result of the preliminary feasibility study showed that the extended spectral range from 1300 to 2300 nm of the new NIR sensor would give new possibilities for improving the accuracy of the detection of paper components and their quantitative contents. The following materials and paper types would be detected with a high accuracy:

Papers for deinking	**Unwanted papers**	**Non-paper components**
Newspapers **Magazines** **Brochures & flyers** **Office papers** **Catalogues**	Corrugated board (brown, laminated paper, coated) Folding boxes (brown, grey, coated) Packaging papers (brown, grey) Wall papers and wet strengthened papers Papers with plastics (coated or attached) Flexo printed newspapers	Plastics Textiles (synthetics, natural fibres) Wood Organic waste

The investigative study on additional technologies showed no additional methods that could be more effective besides the chosen NIR-spectroscopic and colour based camera systems. Within this study also food contact and sorting possibilities were investigated. With respect to this aim the conclusion was that the actual assessment of purity criteria in accordance with these recommendations necessitates sophisticated analytical equipment that has to be operated in a suitable laboratory environment. This is not possible with the sensor equipment developed by SORT IT.

Final result of the subsequent development activities was then the new **FusioSort™ Sensor System** containing one NIR / SWIR 1300 - 2300 and two VIS cameras per “Unisort SORT IT” machine and pneumatic ejection row.

The SWIR-camera **Helios 2300 Complete** developed by EVK can be used to perform spectral imaging measurements. This technique makes it possible to obtain spatial and chemical information characterising recovered paper samples with high speed and high spatial resolution. It also offers new possibilities for classification and sorting. The spatial resolution of the camera (240 pixels) and the measuring frequency (90 Hz) allows a spatial measurement resolution of 1 cm x 3 cm by covering a 2.4 m broad conveyor belt at a belt speed of 2.7 m/s.

PTS contributed to this development by supplying classification models and algorithms. For the development of the classification methods representative samples of recovered papers were collected and separated into different fractions, categories and sub-categories. The main fractions were chosen according to the European List of Standard Grades of Recovered Paper and Board EN 643. The SWIR sensor Helios 2.3 was used to measure the SWIR reference spectra of all recovered paper samples. The calculation of the classification methods for each fraction of recovered paper were carried out on the basis of the recorded NIR spectra of the reference samples using the Discriminant PLS method (PLS - Partial Least Squares Regression). The new sensor improves the standard sorting of recovered paper for deinking (1.11) that is currently being used. It is also possible to introduce new quantitative sorting criteria like the ash and mechanical pulp content.

The individual classification models were combined to a classification algorithm similar to that shown in Figure 8.

Additionally the available EVK VIS-line scanning cameras **EOS** were integrated into the "UNISORT SORT IT“ as an additional fall-back solution to enable basic colour sorting.

These methods were verified and fine-tuned in intensive real-operation field-tests over more than 9 months and finally validated April 2011 in a comprehensive monitoring process at the Rauch sorting plant in Linz, Austria.

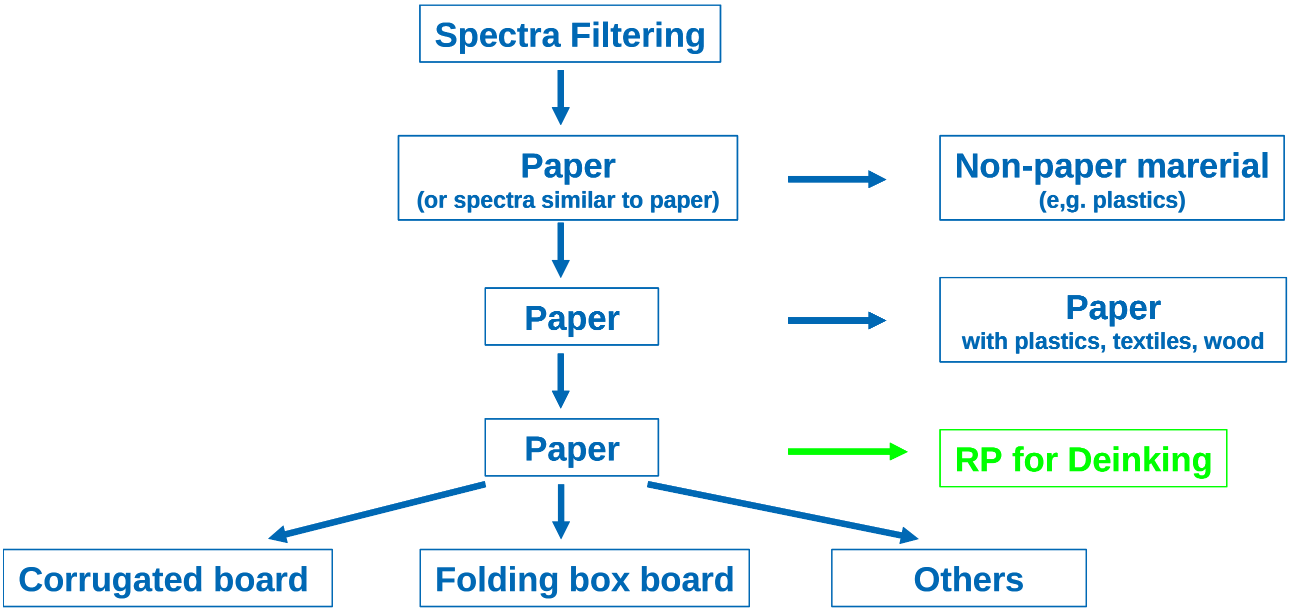


Figure 8: Classification algorithm

The sensor-based sorting machine unit was developed and assembled by RTT Steinert GmbH and is called "**UNISORT SORT-IT**". RTT decided on a 2,400 mm basic width system with an adjustable conveyor speed up to 3.5 m/s.

The basic building blocks of the new **FusioSort™ Sensor System**

HELIOS 2300 Complete is an integrated opto-electronic measuring and classification system, incorporating the complete hyperspectral processing chain that can sort different materials and products using parallel recorded SWIR (shortwave infrared radiation up to 2.3 µm) spectral data.

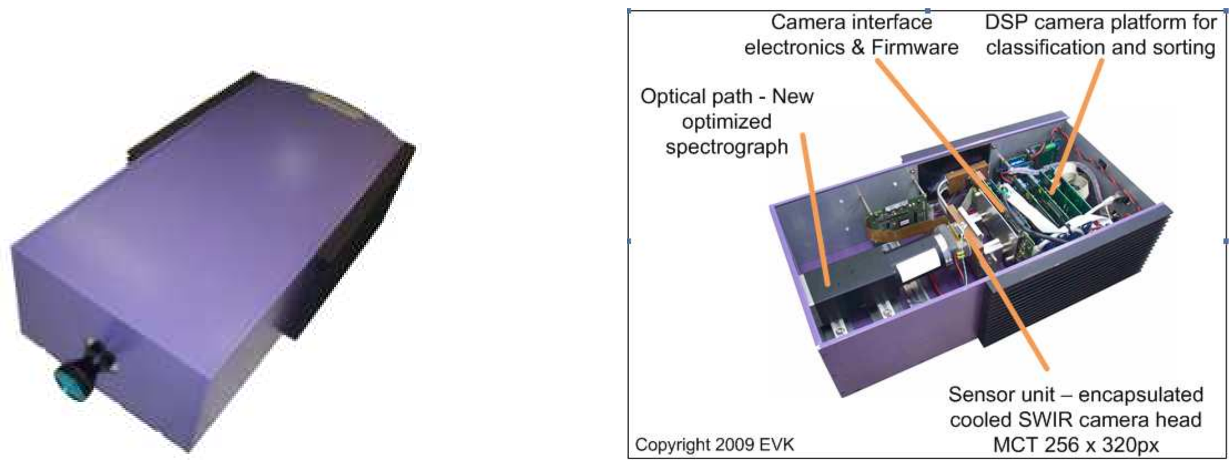


Figure 9: NIR camera

Figure 10: FusioSort™ mounted on the UNISORT

It consists of an optical assembly with lenses and spectroscope for spatial and spectral resolution of the scanned line, a 2D-SWIR sensor and a proprietary FPGA and DSP (FPGA – Field Programmable Gate Array; DSP – Digital Signal Processors) based computing unit for fast (limited by sensor read-out scan rates) processing and reduction of data and subsequent in-line classification of materials. The generated information can directly control pressurized air nozzle banks or can be handed over to a computer system.

HELIOS 2300 COMPLETE is a standalone system that requires a PC only for parameterization and visualization of sorting statistics.

The distinctive capability of the new sensor unit HELIOS 2300 is that it is optimized for a first-of-a-kind extended spectral range from 1300 to 2300 nm. The range 2200-2300 nm – not covered by any available sensor technologies on the market today – does, based on desk research and verification studies performed by PTS, all within the SORT-IT project, reveal interesting spectral differences from CH3 and CH2 hydrocarbon combinations. The hypothesis was that this may improve sorting quality in automated sorting machines.

Fields of application

HELIOS 2300 COMPLETE is designed for :

- In-line sorting for paper recycling plants;
- in-line quality monitoring for pulp makers;

with some slight adaptations in optics and classification algorithms the sensor unit can be adapted for in-line mineral sorting

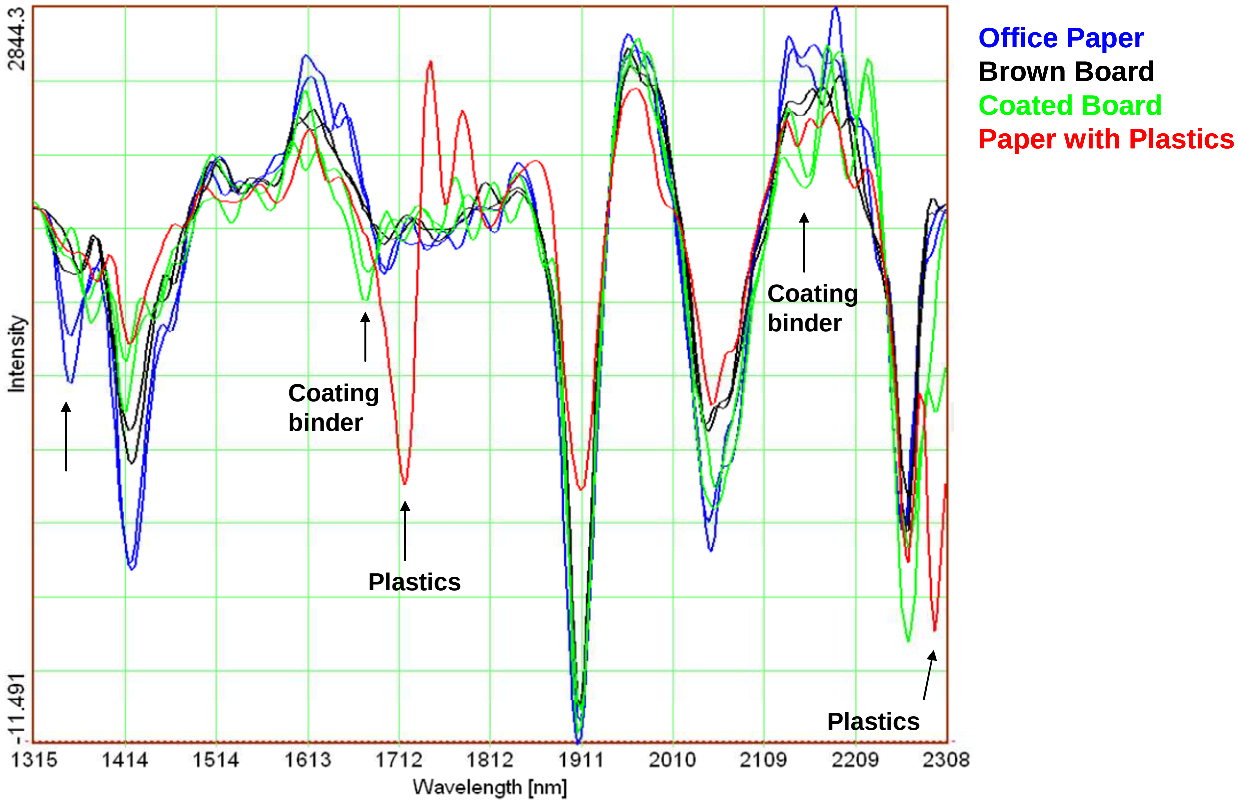


Figure 11, First derivatives of NIR spectra of paper samples

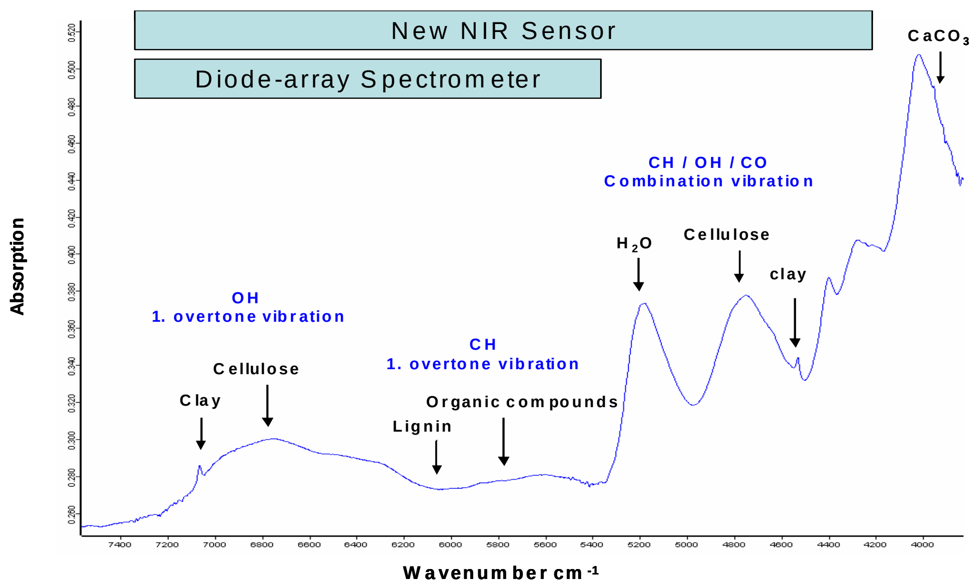


Figure 12: extended spectral range

The EOS colour camera sensor system is designed for the sorting of bulk materials and operates with reflective halogen light. The sensor is able to distinguish up to 8 different colour classes trained beforehand. Particles starting from 4 mm in diameter can be easily detected and hence fully automated removed from the bulk stream. The sensors directly control the valves that blow out detected and classified objects. The EOS sensor units are networked with the help of an RS485 interface and are interfaced via a 100MB-Ethernet connection with a PC based man-machine-interface control panel. Within the SORTIT configuration EOS cameras perform the fusion of data between colour and SWIR based classification.

Figure 13: EOS Complete V.SORTIT

Software tools

The new **FusioSort™ Sensor System** has the whole internal software pre-installed and configured. The user needs no direct access to this real-time software. The user only communicates with the system over PC based programmes (based on Windows XP).

FUSIOSORT™ MMI – Man Machine Interface Software

Figure 14: screenshots of Fusiosort MMI

The programme is a very comprehensive and complete package for operating entire sorting systems. This programme package has been developed by EVK for different applications in many years' work. Presently it is used in different versions for various sorting systems and machines (glass, paper, plastics, metal). The package enables the user and service personnel to perform all the steps necessary for operating the system. For example, the following tasks are taken over by the software package:
♦ acquiring and presenting different sorting statistics; ♦ acquiring and presenting different machine parameters; ♦ managing and presenting system internal error messages; ♦ setting of sorting states and sorting parameters; ♦ configuring the system parameters; ♦ automatically carrying out machine calibrations; ♦ performing automated analyzing routines (e.g. valve test).

These programmes are supplemented by additional helpful tools provided by EVK, such as scanners and protocol simulation. These tools offer still other advantages to trained personnel when it comes to analyzing and optimizing the system settings.

Conclusions

The classification and quantification methods developed are the basis of the application of new NIR sensor based sorting technologies for recovered paper in the SORT IT project. The results show that the new NIR camera Helios 2.3 gives the possibility to classify recovered papers with a high accuracy. In connection with the other new mechanical sorting technologies developed within the project this will enable to produce a high quality recovered paper for deinking (EN 643 grade 1.11).

1.3.3 WP3 – Machinery Development:

Pre-treatment research
In order to have an optimal functioning sorting line, the material will have to be dosed in a constant, loosened single layer. Therefore research has been done on the optimal preparation of the material entering the sorting line. This preparation step is called pre-treatment.
There are a lot of factors influencing the material quality entering the sorting line:

- collection system
- Storage systems
- Loosening of material
- Feeding of the material
- Fine and Coarse separation
- Paper immobilization
- shredding

All these steps are investigated and the effects on the sorting line (and part wise the effect on the paper mills). Every collection system has it own set of machines that are required to sort the material in the most effective way, therefore there is no single sorting line that works for every possible collection system. The quality of the sorted paper that is produced by the sorting line is the biggest influence on the required energy by the papermills.

Shredding
In a separate test the effect of shredding all the material on the total required energy has been researched for graphic paper and for packaging paper.

The conclusion of the investigation was that shredding is not recommended since it results in higher energy costs and losses in optical quality for the graphic paper.

50 % ONP / 50 % OMG				
	Overall energy consumption, %	Brightness (after flotation), %	ERIC (after hyperwashing), ppm	Ink speck (after flotation), n/ m²
Unshredded + 15 min pulping	100	58.84	248.2	13 481
Low shredded + 15 min pulping +	137	56.85	309.4	14 726
High shredded + 15 min pulping	139	56.57	303.6	12 759

For the packaging paper an energy reduction can be obtained, but only if the pulping time is reduced by 30%. The effect on the fibre strength and fibre length will still have to be investigated by using industrial scale pulpers and shredders.

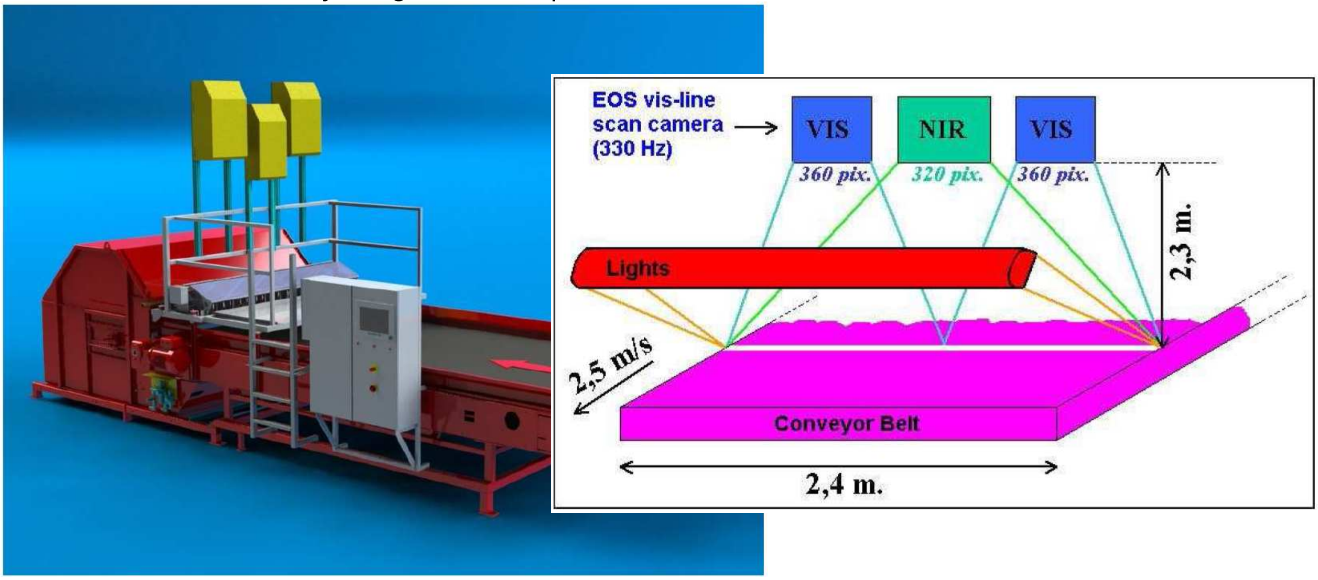
Shredding the material has a negative effect on the sorting quality and effectiveness since there is a huge increase in objects that will have to be sorted. This is a bigger load on the optical sorting equipment and the paperspike and the sorting robot only function on objects bigger then 100mm. For these reasons the development of new shredding machinery was cancelled.

New sorting machinery

During the sort-it project new sorting machinery was developed for an optimal sorting of the paper. The Machines are all produced and transported to the testing facility where they were tested during industrial scale trials.

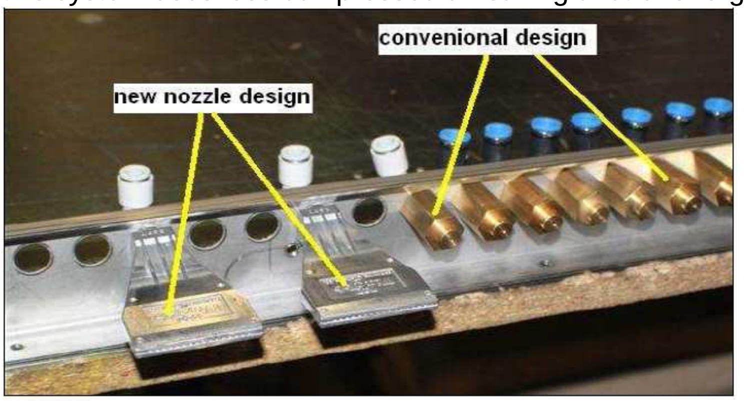
Optical sorting unit

The unisort is an optical sorting machine that uses a three camera cluster system for identifying the material and afterwards ejecting it with compressed air.



Drawing of the unisort machine with the three-camera cluster

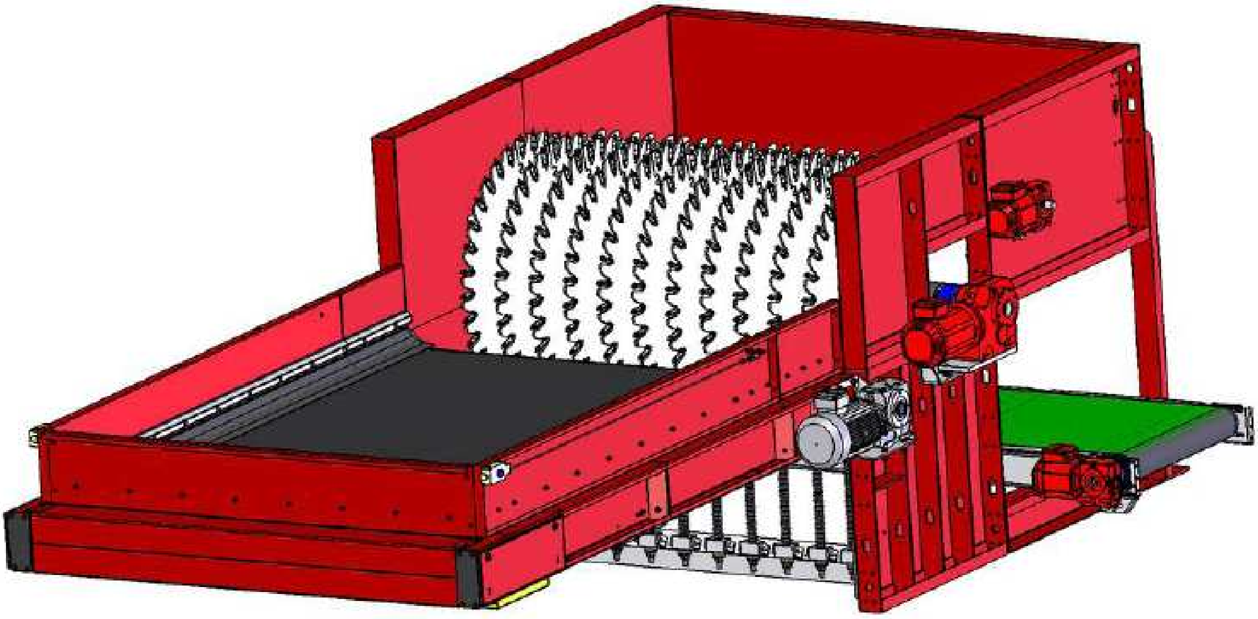
The Unisort machine uses compressed air to separate the materials from on another with the use of a nozzle bar. The most innovative solution was developped for the nozzle bar. Normally every injector is activated by 1 valve. In the new Unisort machine one valve activates 16 small injectors that create a more stable airflow for a better ejection of the material. Another big advantage of this system is that this system uses less compressed air saving a lot of energy.



During the trials this system showed to be a useful improvement to the machine.

Paperspike 2G

For the removal of big cardboard pieces a new machine has been developed without the drawbacks of the standard paperspike. The new system consists out of a big rotating drum filled with flexible spikes. The material is fed by a conveyor and afterwards sliding over the slide-gutter. While sliding over this gutter the material is spiked by the paperspike and the cardboard remains pierced to the spikes and the paper falls off. This system works very well and the machine has significantly less wear than the standard machine.



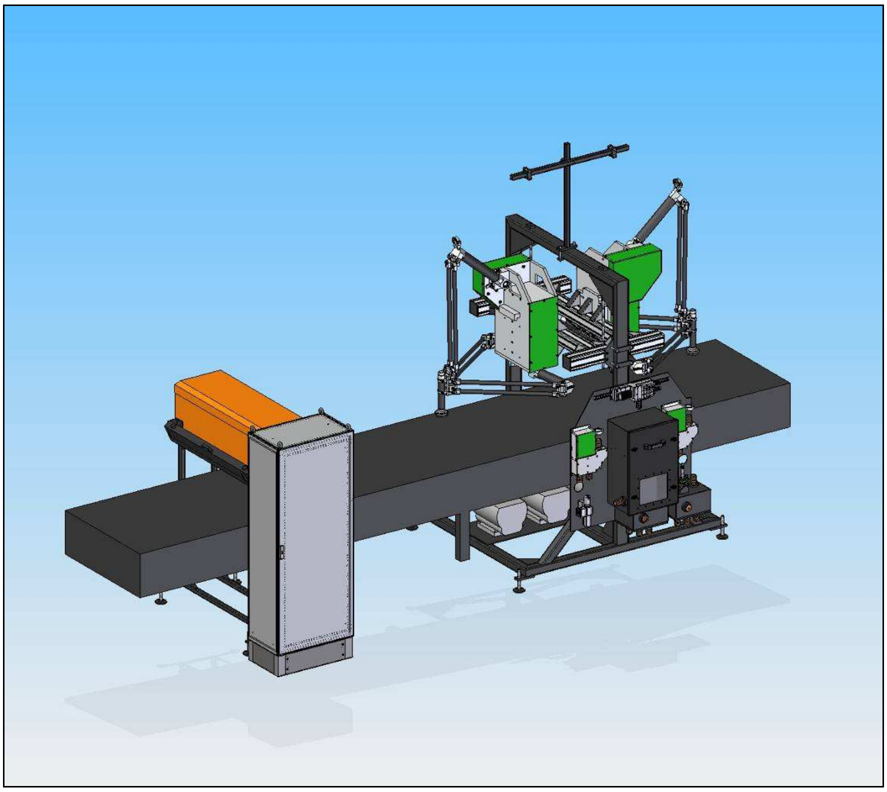
Since the new machine has more spikes and a flexible slide gutter that can move aside when a big piece goes under the drum there are less blockings, so a higher throughput of the sorting line is achieved.

Advantages:
- More robust through flexible spikes
- Easy to operate and service
- Higher spike resolution (more spikes per area)
- Stiffer support of the spikes, leading to better spike quality
- Better results on single layer and lower quality board

During the sorting trials there were no problems with the paperspike and the machine removed the foreseen quantity of cardboard.

Sorting robot

The Bollegraaf robot sorting system was designed to separate materials out of a material flow completely automatically, quickly and very precisely. The system can be employed to replace manual Quality Control, in material flows that have already passed through the primary mechanical separation process. A maximum of ten robots can be installed in line behind a single vision system. The last point is the biggest advantage compared to standard optical units. Every robot can get there own sorting task, or all of them can do the same task. This system gives the user a big flexibility for adjusting to material deviation.



Developments
Resulting out of the research work on implementation possibilities of the robots in paper sorting installations and the semi-industrial tests, the below mentioned developments have been specially done for the Sort It project:

- Because of the fact that the robots will be implemented for negatieve sorting instead of positive sorting, the end-effectors have to be able to handle as much as possible different materials and object shapes. This ability has therefore been improved. Among other things, this has been done by lowering the vacuum level at the vacuum cup and increasing of the air flow by optimising the side channel blower specifications, reducing the air traject resistance, including filters, valves and hoses.
- The vacuum cups are improved by increasing the radial stiffness of the cups while remaining the axial flexibility to adjust the cup to the object shape. The valves have been re-engineered to enable quicker switching and thereby faster build-up of the vacuum level at the vacuum cup. The robots are being made suitable for handling films.
- A new system has been developed for measuring the height of objects during the downward stroke, to associate with the improved robot speed.
- The control software has been optimised for the new drives and air system characteristics.
- A human machine interface has been created for controlling the robots in the application at the Rauch test plant.

Full scale industrial testing

The robots were transported to the sorting line in Linz and tested during normal working conditions. The material was correctly identified by the camera system and this information was given to the control software. The software divides the sorting tasks over both robots.

The sorting procedure goes as follows: Robot gets the task to sort an object and goes to the corresponding belt position while accelerating to current belt speed. While moving with the belt speed the and actuator goes down and grabs the object by means of a vacuum and goes up again. When the robot has picked the object it goes to the side of the belt and switches the vacuum of and blows the object in the sorting bin. The accelerating to belt speed, following the belt, and gripping and throwing away of the objects worked very good.

The new sorting principle works:

- Recognition
- Picking up the objects
- Throwing the objects away

During the full scale industrial testing the robots proved to be to slow to make a big influence on the sorting quality. With the current speed (40 picks/minute) 1 robot can maximally remove 0,4% of the input (calculated with 20 grams object weight and 12 T/hr troughput) . Therefore more and faster robots are required to make a significant influence on the final quality.

Therefore a faster design will have to be developed. This can however not been achieved with the current mechanical design and therefore a completely new design is needed. The robots will have to be faster in order to keep up with the belt speed. The robot design works with a belt-speed of 0,4m/sec. and in order to work in the sorting plant a speed of 1m/sec. is necessary.

1.3.4 WP4 – New sorting concepts:

The main objective of Work Package 4 is to develop concepts for a sorting line which performs an optimal sorting with respect to specific requirements for material before sorting as well as quality requirements of recovered paper to be recycled. To develop the most optimal sorting line, every step of the sorted paper is investigated, from collection to new paper product.
For the SORT IT project, several new sorting units and sorting sensors have been developed. The new developed sorting sensors are used for the development of the concept for the new sorting line.

Collection of recovered paper

Recovered paper can be collected from industrial and commercial sources, from offices or from households and small businesses. Paper originating from industrial and commercial sources and from offices is normally clean and homogeneous. Recovered paper from households and small businesses can be collected through different methods including selective collection, door-to-door collection, co-mingled collection (collection of dry recyclable materials like paper, metals and plastic) or mixed with other non-recyclable components. Selective collection, sorted at source, gives the highest quality to recovered paper. This high quality of recovered paper has a strong positive effect on sustainable recycling in the production of different paper grades. The processing yield of the sorting line will increase and the solid waste will decrease, resulting in positive economic and environmental impacts, having a positive effect on paper machine productivity and on the properties of the paper that is produced from recovered paper.
The average recycling rate in CEPI countries in 2008 was 66.6%[2]. The different countries had collection rates varying from 35% to more than 70%. The paper that is not recycled is either landfilled or incinerated. Recycling must be given priority.

Paper grades

Recovered paper from households and small businesses will be sorted into different paper grades. These paper grades are described in the European Standard EN643:2001, or in short EN643. The grades which are produced and tested in the SORT IT project are grade 1.11 (Sorted graphic paper for deinking), grade 1.04 (supermarket corrugated paper and board) and grade 1.02 (Mixed papers and boards (sorted)). The amounts of permitted contamination within these grades are presented in EN643.
Besides the grades present in EN643, paper makers also miss grades in this standard, like white wood-free papers. Also, most of the grades described in EN643 are not traded at all. Because EN643 is a guideline, paper makers and suppliers have to make bilateral contracts to determine the quality of the recovered paper.

Contamination of recovered paper

Possible contaminants in recovered paper are plastics, glass, metal and wood. These contaminations need to be removed to meet at least minimal requirements in EN643. Laboratory tests in the SORT IT project demonstrated that removing contaminants will result in an increase of the mechanical properties of the paper produced from this cleaner recovered paper. If contaminants are still present in the sorted paper that is used for paper production, the contaminants can form a burden for the papermaking process and negatively influence the efficiency of the process as well as the quality of the end product.
The contaminations will usually be removed with screening and cleaning devices. These devices are not completely selective for contaminant removal and will, though unintended, also remove highly wanted materials based on long fibres. This can result in reduced quality and increased costs involved with removal of waste streams.

[2] CEPI, European Declaration on Paper Recycling, Monitoring Report 2008
Amsterdam, 11 September 2009

Sorting of recovered paper

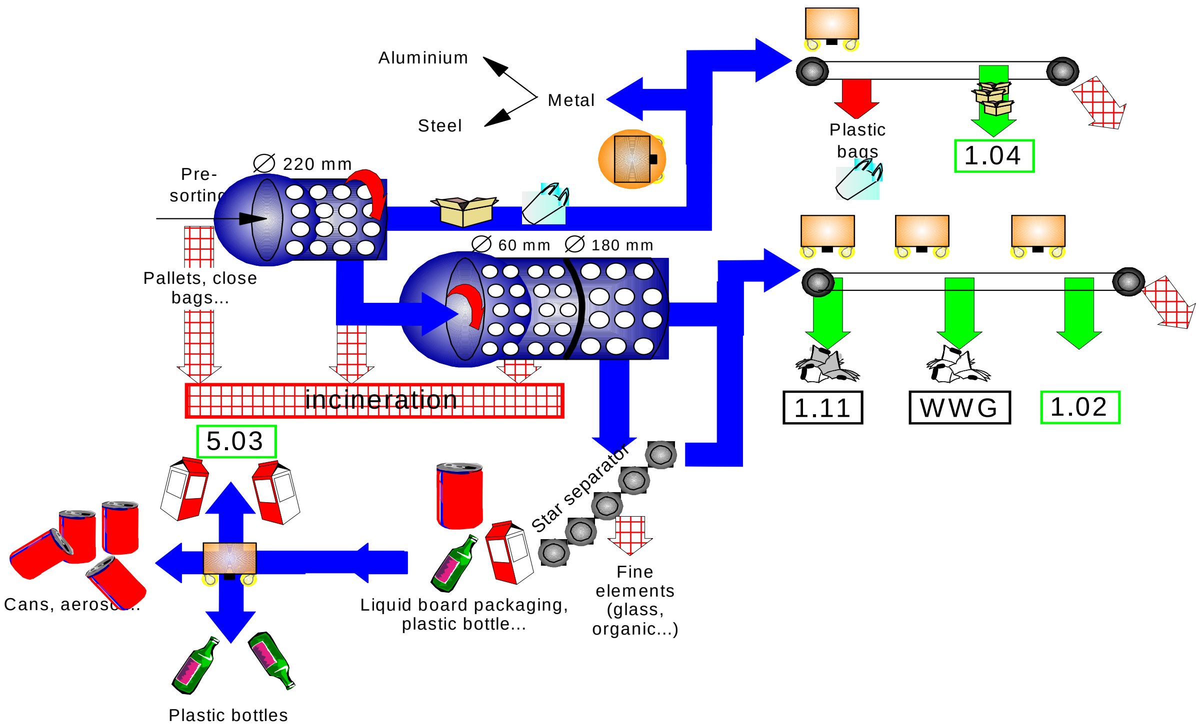
The sorting of recovered paper is done with several sorting units and sorting sensors. The sorting sensors are connected to the sorting units, so the sensor communicates with the sorting unit what needs to be sorted. Mechanical sorting units, like magnets for the removal of metallic objects, do not need sorting sensors.

Results on the properties of paper being produced from recovered paper

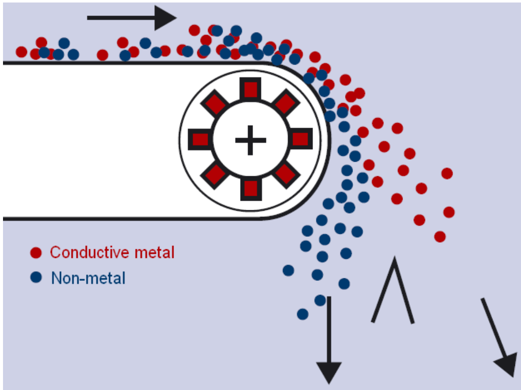
Recovered paper cannot be used for making paper again if it is not cleaned. The paper can contain toxic or hazardous materials. If these materials get into food packaging, they can harm people and animals. To determine if paper grades 1.11, 1.04 and 1.02 can be used for packaging of dry and non-fatty foodstuff, the grades have been tested for the presence of DIPNs (diisopropyl naphthalenes, supporting chemicals for paper) and Bisphenol A.

Sorting design

The flow sheet below features a theoretically optimal sorting line:



In this design, the possible contaminants will be removed successively. With the help of ballistic separators, holed drums, star separators or paperspikes (or in combination), 2D material (graphic papers) can be sorted from 3D material (packaging papers). In the designed sorting line, two of these holed drums are placed. The 2D material, mostly containing paper sheets, will be present after the last holed drum between 2D and 3D material. This can now be sorted in paper grade 1.11, WWG (white wood-free paper grade) and grade 1.02 with the help of sensors developed in work package 2. After the first separation of between 2D and 3D material, a flow with corrugated board (boxes), plastic bags and metal will occur. The ferrous metal can be removed with a magnet. The non-ferrous metal can be removed with help of the Eddy current. Here, a continuing change in the magnetic field will drop the non-ferrous metals at a different location then the non-metals. With the help of a sorting robot, plastics can be removed from the corrugated board, resulting in a grade 1.04. The 3D material leaving the second separation between 2D and 3D materials will be sorted with a star separator, removing all the fine elements. At last, this stream will be separated with a sorting robot into different recyclable materials, along with grade 5.03, liquid packaging board.



Eddy current separator

End-Of-Waste

After the sorting line, different materials besides paper grades are collected, like metals and plastic bottles. In order to conduct and facilitate the expected increase in paper recycling in rates and in volume, Directive 2008/98/EC introduced a new procedure for defining end-of-waste criteria, which a given waste stream has to fulfil in order to cease to be a waste, without endangering the environment. This methodology is a tool to help improve recycling by determining when waste ceases to be a waste, independently from the waste management option chosen. The end-of-waste criteria do not exclude materials from recycling. If a material does not meet the end-of-waste requirements, this does not imply that the material cannot be recycled and needs to be disposed. Materials not fulfilling the end-of-waste requirements can be recycled and reused under the waste regime.

Other prospects for the future

The price of recovered paper is a function of availability, quality, demand, and availability of effective and economically viable technologies for their processing as well as the possibilities and regulations governing the management of waste generated during the production of recycled pulp. Therefore and considering the future rise of paper demand, an increase of recovered paper prices is expected. In the medium and long term, marginally higher prices of recovered paper could force development of new sorting technologies that are able to provide a better quality of recovered paper for paper mills. Furthermore, a marginal energy saving would also result by avoiding unnecessary transport of this waste fraction. Finally, a reduced export of impurities hidden in recovered paper is expected, implying the avoidance of a case of camouflaging waste export and the disposal of this fraction in the country of destination.

1.3.5 WP5 – Evaluation Trials:

Generalities

The monitoring phase was performed thank to the participation of several partners at the end of April 2011 and has consisted in determining the composition of the input raw materials and the output raw materials after being run in the sorting line. The determination of the composition of the input and outputs were made according to the official reference EN643 which gives the following definitions:

- Grade 1.01 (Input): Mixed paper and board, unsorted, but unusable materials removed. A mixture of various grades of paper and board, without restriction on short fibre content
- Grade 1.04 (Output): Supermarket corrugated paper and board. Used paper and board packaging, containing a minimum of 70% of corrugated board, the rest being solid board and wrapping papers.
- Grade 1.11 (Output): Sorted graphic paper for deinking. Sorted graphic paper from households, newspapers and magazines, each at a minimum of 40%. The percentage of non-deinkable paper

and board should be reduced over time to a maximum level of 1.5%. The actual percentage is to be negotiated between buyer and seller.

The monitoring phase was performed according to a procedure proposed by CTP and PTS and validated by the other partners:

- The sorting line was considered as a black box with one inlet corresponding to the input material (1.01) and two outlets being the output materials (1.11 and 1.04).
- The 3 grades 1.01, 1.04 and 1.11 were characterised in terms of composition (type of papers and boards)
- Note: Grade 1.11 was split into two outputs; the first sorting line after UniSort 1 including the rejects from manual sorting, and the second sorting line after UniSort2, also with rejects.
- Conformity: based on characterisations, the products were determined conform or not according to EN643 standard and a certificate of conformity was proposed.

Characterisation of raw materials

Input raw material

The characterisation of the input and outputs was performed according to a statistical method in order to obtain averages representative of the production. Thus, 8 samples of around more or less 200 kilograms were sorted manually in various types of papers and boards.

Using this procedure, we could note the quality of the input raw material was relatively stable with a composition close to:

- 76 % graphic paper with
    - 57 % old magazines
    - 32 % old newspaper
    - 11 % old graphic papers
- 22 % packaging materials with
    - 72 % corrugated boards
    - 28 % other packagings
- 2 % undesirable materials (non-fibrous components)

Within this characterisation of the input raw materials, in theory, the sorting line can be liable to produce the two expected raw materials which are conform to the EN653: 1.11 and 1.04

Output raw materials

Grade 1.11

Output deinking grade was characterised several times for a good statistical study approach. Fortunately, the produced grade 1.11 showed a large portion of graphic materials (old newspaper ONP, old magazines OMG and old graphic papers OGP). Nevertheless, a significant amount of packaging boards was found (more than 5 % in weight) and is detrimental to deinking because of a decrease in the brightness value. The amount of non-fibrous materials is acceptable.
As a consequence, the produced 1.11 cannot be considered as acceptable in reference to the EN643.

Grade 1.04

As expected, the ratio of packaging materials is largely higher as the amount of graphic papers but a detailed analysis of the composition showed that the produced grade is not free of graphic papers which should be normally the case according to the EN643 standard. Concerning the packaging fraction, the ratio between corrugated boards and other packaging boards is 82 / 18. This is conforming to the EN643 for the packaging part.
The amount of unwanted materials is inferior to 2 % which is largely acceptable for recycling line specially dedicated to the recycling of packaging raw materials.

The produced grade 1.04 cannot be considered as conform to the EN643 standard but is most of the time accepted by papermakers. In reality and mainly in Germany, the amount of graphic papers in the 1.04 grade can be higher.

Rejects

The quantity of rejects in the input raw materials is low and even unwanted materials are found in the output grades, a significant part is removed by the sorting line.

Characterisation of the sorting line

Stability of the running conditions

Analyses performed during two consecutive days have shown a relative stability of the sorting line:

- firstly the stability of the initial raw material (1.01) to be treated (with shows a regularity in the separate collection composition around Linz)
- secondly, even improvements are necessary to adapt the sorting line to the objectives of the project, a good stability in the sorting conditions of the line. The initial raw material is systematically sorted in the same conditions. In other words, the operating conditions given to the sensors and the sorting machines are well operated. Whatever the process, the first requirement is to stabilise the operating conditions. This is obtained in the sorting line. The last point to do is to be in a position to sort efficiently the initial input into two acceptable raw materials for the paper industry.

Purity & Yield

The calculations of yield and purity are based the obtained results of the monitoring phase. Yields were determined for the sorting line, the production of output materials and the removal of unwanted materials:

- sorting line yield: 98.6 % (ratio between accepts and input)
- Grade 1.11 yield: 95.4% with a purity of 94.4%
- Grade 1.04 yield: 82.5% with a purity of 82.8 %
- Unwanted material removal: 64.5%

Certificates of compliance

The certificates of compliance are documents certified by competent authorities that the supplied good or service meets the required specifications.
It defines if the sorted recovered papers produced in the new Rauch sorting plant located in Linz, meet the papermills quality requirements.
The different recovered paper grades related to EN 643 are:

- Unsorted house hold collection :1.01 used by Rauch
- Sorted packaging grade:1.04 used by Vrancart and Europac
- Sorted deinking grade:1.11 used by Norske Skog

In the certificates, the quality specifications (for deinkers and recyclers) are largely described in terms of quality characteristics (designation of grade according to EN643, moisture content, composition, unwanted materials…). Controls to monitor the grades at the entrance of the mills are described in order to notify the procedure applied to check the quality of the raw materials (to be approved by both seller and buyer).

Conclusion of monitoring results of sorting line and grades

New sorting plant in Linz was built and equipped with machines and sensors developed in the frame of the SORT IT project. Technological trials started one year ago and in spite of difficulties encountered, it has made constant progress.

The sorting plant performance was stabilised during last months: purity (content of wanted materials) reached and maintains around 95% in grade 1.11 and around 83% in grade 1.04; the content of non-paper materials was reduced continuously and stabilized up to 0.5% in grade 1.11 and up to 1.8% in grade 1.04. The two grades produced daily on the sorting line do not match exactly the definitions in EN 643 with respect to their composition (no packaging paper in 1.11 and no graphic papers in 1.04). However, their composition is in/or under maximum limits provided by paper mill specifications: Norske Skog – 4% packaging papers and 0.5% rejects in grade 1.11; Europac – 20% graphic papers in grade 1.04 and 3% rejects).
Within the SORT IT project, several improvements were made in terms of research and development and a sorting line was built equipped with machines and sensors developed in the frame of the project. Other improvements have to be done to reach the targets fixed in the objective. Presently, some solutions can be proposed:

- to commercialise the packaging grade as 1.02
- to implement sensor before the bale press of the "packaging fraction" in order to determine the composition and to propose to papermakers a grade with its pedigree

1.4 The potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and exploitation of results (not exceeding 10 pages)

From a strategic point of view, the primary goal of this project was to improve the quality and yield of the fractions sorted from recovered paper. In this respect, the main driver of the project was the paper industry. The rationale was that on the one hand the demand on quality and quantities of recovered paper as raw material for the paper industry was and is still constantly increasing, and on the other that profit margins for the same industry were and still are constantly shrinking.

The concept of the project was to develop automatic identification and sorting units, to integrate them into a sorting plant and to demonstrate their improved efficiency in full scale trials. This resulted in benefits not only for the paper industry, but also for the sorting machinery sector and for the society as a whole.

Improving dry sorting of recovered paper has many advantages, which are not all easily quantified.

1.4.1 Benefits in increasing yield

The most straightforward way to increase available recovered paper quantities to the paper industry is to increase collection. But the only possible sources provide recovered paper mixes, which makes sorting mandatory.

Increasing sorting yield makes more raw materials available for the paper industry. When 57 million tonnes of recovered paper were collected in the CEPI countries in 2010, 1 point increase in yield means an additional 570,000 tonnes of raw materials for the paper industry, i.e. enough raw materials to supply one modern paper machine.

Recovered paper is a global commodity, the prices of which on the market are not entirely driven by supply-demand considerations. The generation of recovered paper is limited in itself. Not more used paper can be collected than was put on the market. Furthermore, only a fraction of it, between 70 and 75% in average, can be collected and recycled. Indeed such products as hygiene papers are not collected after use and are not suitable for recycling in acceptable conditions. In addition, there are always losses when recycling paper. The yield ranges from 50% when using deinking grades in tissue paper production to 90% or more in packaging boards. Without the constant input of virgin fibres to the production loop, the paper industry would run out of fibres within two months. Therefore, a higher demand of recovered paper does not easily or necessarily lead to higher supply. Traditional sources for recovered paper, whether industrial (trimmings, unsold products, over issues, conversion waste…) or commercial (empty transport packages from stores), have long since been fully exploited and the only possible additional source is the population (offices and households).

Office waste is increasingly, for the sake of protecting information, collected and shredded at source. Shredded paper cannot be sorted. Non-shredded office paper has a somewhat constant composition, based on white or coloured printed grades, and can often be used without sorting.

Households are not part of the market. The “benefit” for consumers in collecting used paper for recycling is mainly intellectual: tranquillity of mind in the correct perception that recycling is beneficial to the environment. The economic benefit is only indirect: collection from households is mainly organised and carried out by municipalities at the tax payers’ costs and the operation is barely profitable. Economic benefit made by municipalities, if any, may in the best of cases lead to the reduction of local taxes.

This project has investigated economic aspects in detail. Looking at the demand for fibres in general, there are two factors putting pressure on their availability. The shift towards a bio-based economy and the increased demand from emerging economies are pulling on fibre resources. The latter seems to be in particular of influence on the availability of fibres needed to produce 1.04, i.e. mainly packaging. In 2009, China imported 40 million tonnes recovered paper, a close match to what Europe has collected. Our explanation for this is that when people have more money to spend, they will consume more and therefore need more packaging. The fact that the growth in demand of the Chinese market for fibres correlates stronger with 1.04 than 1.11 seems therefore not surprising. Presumably, new packages are made from the imported fibres in China.

Other important conclusions are that the markets for 1.04 and 1.11 are very different from each other. Packaging is characterized by a strong pattern that correlates with the state of the economy. Furthermore, a correlation is found between a growing population and the amount of 1.04 used. This conclusion does not come as a surprise. When a society counts more people, these people need more packaging materials and therefore more 1.04 to produce them. Although literature research suggested that the rise of e-commerce was having a great impact on the use of corrugated board, no significant correlation was found between the use of e-commerce and the price and consumption of 1.04. Thus, predictions on the price of 1.04 may be based on the developments in GDP, size of the population and the export of fibres to emerging markets, although other factors may also be of influence.

For 1.11, the conclusions are less compelling. There seems to be no correlation between price and production quantities as independent variables and GDP and the size of the population as independent variables. Also, the use of online news does not seem to be correlated with the use of 1.11. This is rather surprising, as intuition suggests that this trend would decrease the demand for traditional newspapers and therefore to 1.11. Another use of 1.11 than newsprint production, that of tissue paper, may be the reason that no significant (or statistically relevant) correlations were found in this research.

The financial performance of the new sorting technologies is highly dependent on the price premium that paper mills are willing to pay for paper sorted with new, enhanced technologies. This price premium should at least exceed the extra energy costs, the additional investment costs and according depreciation, and maintenance costs. Valorisation of reject streams and a decrease in number of staff are factors that add to the positive side of the equation. The decrease in labour costs is rather significant. Why paper makers should accept to pay a premium for better quality will be discussed below (Benefits in increasing purity).

The growth of production of paper and board is shifting outside the traditional supply areas. The share of North America and Western Europe of the World’s paper and board production is forecast to decline from the current 46% to 38% by 2020. At the same time, Asia’s share (including Japan) is expected to grow from 43% at present to 49%. For this reason and thanks to a sustained incitation effort from authorities and industry to increase collection, Europe has become a net exporter of recovered paper. The net trade amounted to more than 8 million tonnes in 2010, as compared to 49 million tonnes used. This is a real opportunity for Europe if the best and more profitable recovered paper qualities may be preserved for the internal market, while lower grades are exported and profit made from these sales. Improved sorting may provide Europe with the potential to get sufficient quantities of recovered paper in suitable qualities.

This situation covers important discrepancies across Europe. Eastern Europe’s development is seen as important for paper recycling in Europe. Paper consumption and production are expected to increase. Western neighbours are net importers of papers for recycling, while collection levels in the East are still relatively low and expected to increase. Quality levels there are still low, emphasising the need for even better sorting technologies.

Increased recourse to collection from households results in a decrease of quality. For practical and economic reasons, recovered papers are collected within mixtures. Single collection systems provide mixed papers and boards: newspapers, magazines, corrugated boards, folding boxes, etc. Co-mingled collection systems provide mixtures of paper and board of different grades with plastic and metal packaging. This leads to more impurities and contamination of the paper fraction and more difficult sorting. In many respects this project has confirmed these statements. Thanks to the Waste Directive, co-mingled collection systems should be phased out by 2015. However and technical recommendations not withstanding, consumers do not separate certain papers with specific challenges in recycling like flexographic or UV-cured or ink-jet prints. Therefore a sound and efficient sorting has become an essential requirement from the paper industry.

Increasing yield means increasing the amount of paper recovered from the mix, thereby decreasing the total amount of sorting residues, which are in general treated as final waste. Reducing amounts entails reducing elimination costs. Sorting residues from recovered paper mainly consist of plastics. It must be emphasised that whatever occurs, non-paper material must be eliminated. Optimally, this is done at the sorting plant, where rejects are produced in the dry state. Any remaining plastics in the recovered paper that is delivered to the paper mill will be eliminated as cleaning and screening waste, i.e. in a wet state. In both cases they will be considered for incineration with energy recovery. This is, nowadays, the scenario acknowledged as the more sustainable, from both environmental and economic points of view.

Incineration of dry waste has a much higher thermal yield. If not incinerated, being dry, waste flows from recovered paper sorting may be further handled in sorting centres adapted to plastic sorting.

1.4.2 Benefits in increasing purity

Recovered paper sorted fractions with lesser amounts of improper components are processed more efficiently in paper mills. The productivity of the paper machine is higher because there are less frequent web breaks. Less raw material and less ancillary materials are needed for the same amount of produced paper. A more efficient paper machine also consumes less energy: non-conform paper also needs to be dried. With cleaner raw materials, the wear of machinery is reduced. The generation of cleaning and screening waste from paper machines is minimised.

The supply of deinking grades with lower amounts of packaging paper allows the production of printing grades of better brightness and cleanliness. The intensity of cleaning stages may be reduced, thereby increasing the overall yield of the paper machine and the impact on the environment.

The supply of packaging grades with lower amounts of printed material allows the production of packaging boards with higher mechanical strength. The grammage and therefore production and transport costs may be reduced. Lower-grammage papers also need less drying energy.

Sorted fractions of higher purity are by definition more material-efficient. Lower amounts of raw materials need to be purchased, transported and processed, thereby reducing corresponding costs.

Here again, large regional differences are observed. In Western and Central Europe, paper machines run on the edge of technological progress. Productivity is high and competition is fierce. Quality improvements, even small, may prove invaluable to keep apace.

In contrast, the paper industry in Eastern Europe is struggling with immense availability and quality problems that put its very existence at stake. This part of Europe is still in the aftermath of the fall of planned economy. The emergence of free market has given rise to a large number of small enterprises in the recovered paper business, which do not have sorting facilities: Eastern Europe still has a strong recovery potential from households, but virtually no sorting capacity to go with. As a result, for example, Vrancart, the largest recovered paper consumer of Romania with 30% of national collection, has seen prices and contamination level double since 2007. Vrancart is currently setting up its own collection system, where the availability of innovative automatic sorting technologies plays an essential role.

1.4.3 High impact for the European Industry

Europe is characterised by its still large industry sector with a high dependence on resource availability, while a large proportion of its virgin resources must be imported. A notable exception is the strength of the forest sector, but the wood supply in general is highly coveted by other sectors, either traditional (wood construction, wood materials) or emerging (bioenergy, biorefineries). As a result, Europe has developed excellence in the economy of recovering, reusing and recycling.

As explained above, the project SORT IT has operated on the case study of recovered paper sorting and valorisation. As such, it has a direct impact of the entire paper and board sector, which produces 100 million tonnes per year on 1,400 paper machines and employs 225,000 people for a turnover of

80 billion Euros. A direct impact can also be counted with on its upstream suppliers, recovered paper sorters and dealers and sorting machinery suppliers.

Key technologies have been developed with the collaboration of and for the benefit of machinery suppliers: optical sensors, their software and operating actuators. They have been implemented and demonstrated at full industrial scale. At the outset of the project, 40% of the European recovered paper production was sorted, and 25% of this was done so manually. The success of SORT IT will allow a significant leap forward in these areas. Europe will maintain its world-leading position in environmental technologies.

The shift toward automatic sorting will bring reliability to sorting centres. There will be less demand on manpower. Manual sorters are difficult to recruit and to keep durably. This job is particularly ingratiating, with a standing position, noise, dust, offensive odours and constant air streams. These are last recourse jobs that are in general only provisionally accepted by instable populations. Their holders will change for better jobs at first opportunity. Even a trained sorter makes sorting mistakes and cannot hold a sustained rate for more than a few hours. Like in all manpower-intensive activities, planning is made difficult in vacation periods and by seasonal epidemics (e.g. flu). With automatic sorting, costs can be kept constant and predictable; quality can be easily adapted to customer needs.

1.4.4 Benefits for the environment and society

The environmental and economical sustainability performance of the newsprint paper and the packaging paper life cycles were improved due to better quality of the recovered paper grades 1.11 and 1.04. The savings were achieved by lower consumption of the improved quality recovered paper, raw materials and energy economy; and more efficient logistics due to transportation of sorted paper with lower amount of impurities in it. The manual and automatic sorting plants have little environmental impact from the total life cycle perspective, while the impact of the paper mills is the dominant. Energy consumption is the major environmental contributor. Waste management of rejects is an important issue. Incineration of the sorting rejects with energy recovery is a more attractive environmental option than landfilling or incineration without energy recovery. The technological switch to the automatic sorting resulted in enhanced environmental performance of the pulp and paper mills through increased pulp yield, lower amount of rejects and paper machines runnability etc.

Economical aspects of sustainability were investigated in terms of the operational costs. Better economical performance of the automatic sorting plant was observed due to lower recovered paper consumption and labour and transportation costs. The social implications of higher efficiency together with production of improved quality of recovered paper at the sorting plants were observed through working conditions, health and safety, employment structure and education among others. New group of higher educated sorters instead of higher number of manual sorters is expected with less stressful job, less contact with contamination, less production stops and homogeneous quality of products.

1.4.5 Input to the European institutions for policy development

The project demonstrated the need of advanced technology for waste paper sorting. Quality of recovered paper used in the production of recycled packaging paper has a strong influence on the resource efficiency (energy, fibre raw material and chemicals) and overall environmental impact of paper mill production system.

The full-scale trials of the automated sorting plant in the SORT IT project demonstrated how the optimization of the newsprint and packaging paper production system can be achieved by switching to the innovative technology for recovered paper sorting and how to measure the sustainable progress from the environmental, economical and social perspectives.

The sustainability performance of the innovative technology for recovered paper (RP) sorting has been demonstrated.

These results come as support to the enforcement and future improvement of a number of European Directives and Regulations, which have an impact on the availability, quality and cost of recovered paper, impacting therefore industry's opportunities in recycling. Waste Framework Directive (2008/98/EC) and Packaging and Packaging Waste Directive (94/62/EC) are main EU Directives impacting paper recycling chain. For specific final streams of paper recycling sector, other Directives and Regulations are important: Landfill Directive (1999/71/EC); Incineration Directive (2000/76/EC); REACH EC Regulation 1907/2006; Waste Shipment Regulation (EEC/259/93).

1.4.6 Dissemination and use

The project has had a strong audience with a dedicated website, 4 newsletters and 53 publications and contributions to conferences, trade fairs and exhibitions, of which 7 peer-reviewed papers and one doctoral thesis. It was featured as "success story" on several "Brokerage" events of National Contact Points.

SORT IT was the subject of a TV documentary co-produced by EuroNews and the European Commission. It has been aired for a whole week in October 2010 (22 times) in the award-winning program Futuris, on European science and research to 130 countries in EuroNews´ nine broadcasting languages (English, French, Russian, German, Spanish, Italian, Portuguese, Arabic and Turkish).

SORT IT was marked "Star Project" of the European Commission's Research & Innovation website on 6 April 2011.

In the last project month, October 2011, a one-day strategic workshop was organised with key experts and stakeholders in the field of recovered paper valorisation and in collaboration with another EU collaborative action: COST E48 "The limits of paper recycling". The aim of the workshop was to confront experiences and discuss strategic issues on paper recycling. All presentations were made available on the project website and its highlights substantiate the present chapter of the final report.

1.4.7 Paradigm change: waste-to-resource thinking

From a social perspective, waste is disgusting, dangerous, useless, worthless, in a word, waste is what we want it to be. However, from an economic perspective, waste has come to appear us as a resource: it is traded internationally; it generates turnover and jobs; it has prices that can be supply-demand driven or not. We are living in a "trash economy": we are a throwaway society, where some products have to be declared as waste to produce new products and where growth in our economy requires the generation of waste.

Waste management is an essential activity in our collaborative society. It follows two central targets: Protection (health, environment, basis of life, climate) and Resource (substitute rarefying raw materials). Waste management creates awareness and provides information for product and production design. It controls material flows, creates and prepares anthropogenic stocks for its use and strives for a steady state between the output currents of society and the absorption capacity of environmental media. It works for future generations.

Waste management undergoes various stages of development, which can be passed over different time periods but cannot be skipped.

In the first stages of "no attention" or "coverage and disordered disposal", awareness must be created towards the need to protect nature and maintain the landscape. The first laws on waste disposal lead to the closure of wild dumping sites and the construction of sanitary landfills and the emergence of technological innovations in order to keep any associated pollution under control. Regional waste management plans and concepts to bring rising waste generation under control are adopted. In the next phases, collection logistics are established. Waste information centres are created on waste prevention, collection of recyclables as well as prevention and recycling of hazardous materials. Telephone advice, media information and advice to schools and environmental organizations are provided. Public relations play an essential role in raising awareness and sensitising of population on the needs for behaviour changes: “Successful unmixed collection of recyclables requires the intensive cooperation of the population”.

Recycling solutions are set up. For instance the Packaging Directive has established an obligation to return on the side of end consumers as well as an obligation to take back on the side of the economy. The goal was to increase the product responsibility or stewardship. The economical use of packaging by industry and consumers required the construction of a nationwide collection system for packaging waste and the reuse or recycling of packaging waste through appropriate systems. Important factors for the success of material recycling was the control of costs of collection, transportation and processing, solving problems linked with the accumulation of pollutants of secondary raw materials and most of all the existence of a market for the created products: Recycling of waste is primarily a marketing problem.

In the “Industrial Cycle” phase, land filling is reconsidered to reduce the burden on future generations. Alternatives must be found and waste is redefined as a resource that can re-enter material cycles and therefore save primary resources and energy.

In the final stage “Raw Material Sourcing”, landfill sites are entirely replaced. New requirements are defined on resource management, closing of material cycles and the extension of value added chains. Waste management companies become resource suppliers and providers. Strong interdependencies are created between waste and raw material markets.

The transition from a young, dynamic sector to maturity takes place. This is characterised, as shown in Figure 15, by a soaring overcapacity in recycling plants and a strong correlation between the energy and raw materials markets, meaning a low elasticity of prices. This is obviously the case for the European paper and board industry, showing that it has reached this stage of maturity. On the contrary, a rather high elasticity is observed in China, which continues buying and storing when prices are low and relents when they soar. Considering the amounts of recovered paper at stake, this strongly amplifies price fluctuations.

Being in the state of maturity does not mean that life is easier, on the contrary. The non-elasticity of recovered prices is proven when paper mills go on buying even at high prices: The only other choice is to close capacities. This scenario also turns into reality, while in 2010 the industry in the CEPI countries had only 1413 paper machines left from its 1464 in 2009 and 1896 in 2000! Having to buy recovered paper at all costs or simply starve to death, the European Paper industry can survive only if high prices are met with high quality of recovered papers. Certain compensation is then brought by reduced operational costs and an advantage on product quality.

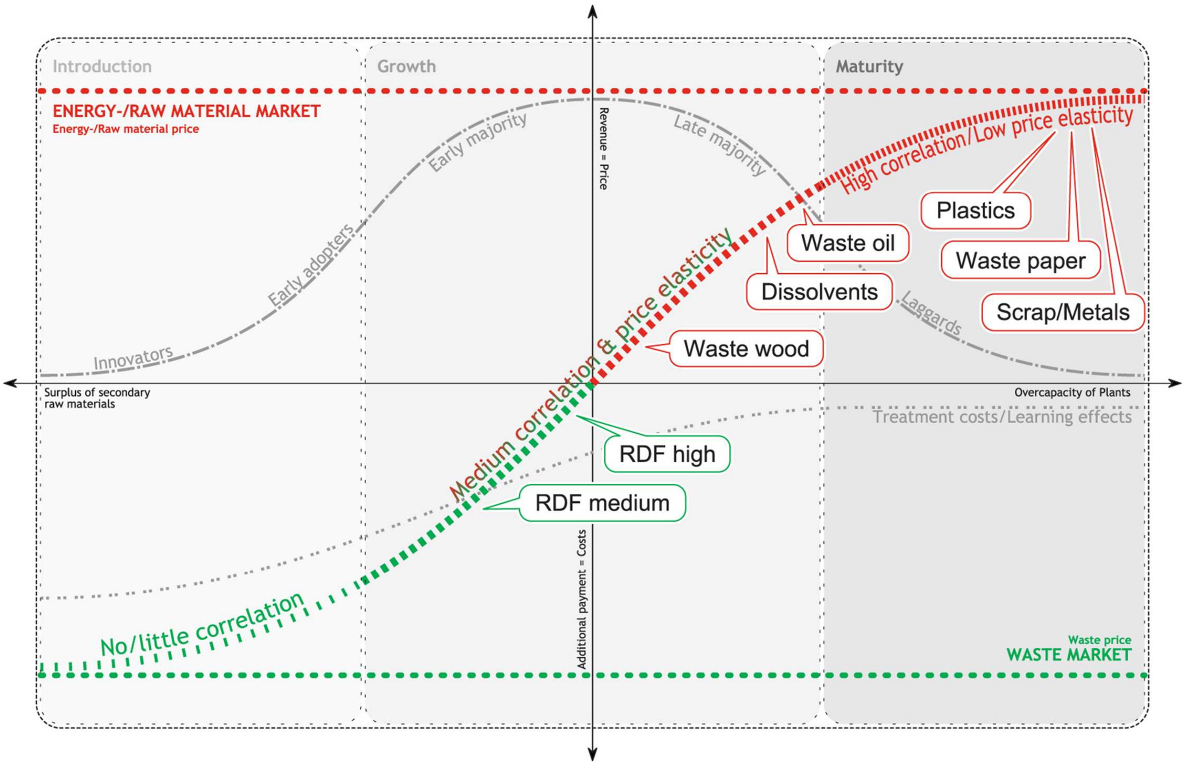


Figure 15: market evolution of waste management technologies

The SORT IT project, thanks to technological and conceptual developments and a solid contribution to European policy, has given the pulp and paper industry strong tools to remain competitive in the global economy.

1.5 The address of the project public website, if applicable as well as relevant contact details

The SORT IT website: **http://www.sortit.eu** has been on line since 1st September 2008.

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