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Mapping and development of shredding product stream(s):

Four shredding plants in Sweden

(What should be done for better performance of the plants?)

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Shredding plant, steel recycling, energy, material balance, optimum recycling scheme

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Contents

Synopsis:

In order to develop the shredding product streams for better recycling and having sustainable development and in connection with the pervious report on shredding plant facilities titled "*Looking at shredding plant configuration and its performance for developing shredding product stream- An overview*", four shredding plant facilities; i.e., *halmstad, halstahammar, huddinge* owned by Stena Gotthard AB, and *Skelleftehamn* owned by Kuusakoski, were visited and mapped. This report is prepared with to discuss about these shredding plants and the related issues.
Within first part of the report different aspects such as steel recycling and energy, recycled material for iron and steel production, material construction for different obsoletes, etc., are reviewed and studied in details in order to define their roles in recycling schema. In addition a general perspective for the recycling costs is presented and it is shown how recycling cost is affected by a factor named "Product factor", which is a function of product complexity and product size.
In the second part, the flow-sheet for the visited recycling plants are drawn and discussed in details in order to see their similarities and discrepancies as well as their functions for recycling different metals.
Within third part, two main strategic scenarios are addressed for optimum recycling of ELVs, obsolete appliances, and other wastes. Accordingly, improvements in dismantling, shredding, and separation stages are needed to increase the quality and quantity of recycled materials, especially in order to obtain the needs for iron and steel industries when concerning environmental issues. The recycling scheme must be then provided by considering the interrelationship among dismantling, shredding, and separation facilities and the material characteristics of the wastes.

Introduction:

Our society, nowadays, is characterized by production and use of complex multi-component products that are manufactured by using of wide range of different raw materials to meet all requirements. Although, the construction and manufacturing of these goods and products must be carried out in an energy efficient and environmentally friendly way, the product themselves and their use or operation should also contribute to the overall sustainability. For example, light weight materials are used to manufacture cars and appliances in order to save energy, however, it is important to have environmentally safe and economically viable methods to discard these products at their end lives to be used and converted into products once more. Examples are complex multi-component end of life vehicles and appliances that must be recycled after the reach their end of lives.
To have a sustainable development, it is vital that maximum percentage of materials and/or energy coming from the end of use products and scrap find their way back as the resources for industrial and consumer cycle. High costs for damping and land-filling of wastes as well as other environmental and economical concerns due to new legislations are strong forces and motivations behind reuse and recycling.
As shown in Fig.1, according to van Schaik et al., (2002, 2004) there are three main disciplines, i.e., life cycle, technology cycle, and resource cycle, must be linked in order to achieve sustainable development of the society.
Technology Cycle: In order to describe and understand recycling systems it is needed to look carefully at the combination of recycling technology (technology cycle) and material flows (resource cycle) within this recycling system being presented by the recycling flow-sheet for a specific product or material. Recycling of obsolete cars, appliances, and other end of life products consists of a combination of various processes, including de-pollution and dismantling, shredding, physical separation, to metallurgy and the processing of in-organic

components, in combination with thermal treatment of intermediate products, like shredding residue, for energy recovery. Even incinerating and land filling of the residuals must be considered as a part of recycling scenario although such actions without energy recovery are not considered as recycling according to European legislation for life cycle. The later is important especially when determining and controlling losses in the system.

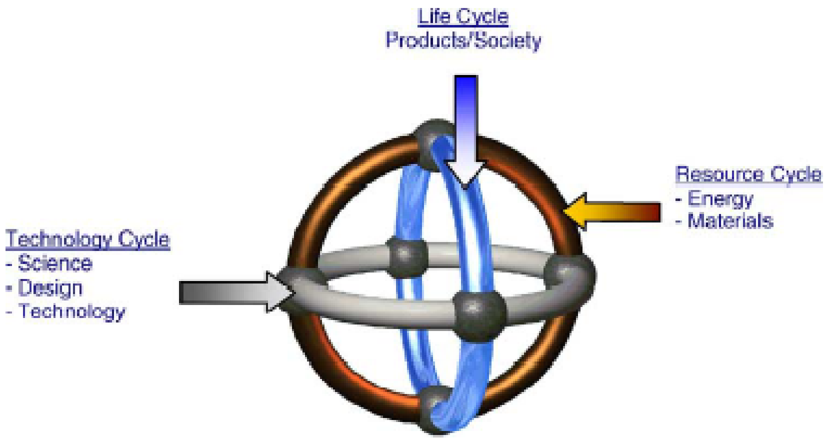

Fig.1- Links among three interconnected cycles for sustainable recycling (van Schaik 2002)

Each separation and processing steps, except land filling and incineration, contributes to the recycling and recovery of the various materials composing the end of life products. The contribution can be due to producing a product stream or an intermediate recycling stream that will be the feed for subsequent separation or recovery processes. Therefore, in recycling chain there is no divisible relation between the different processes and material flows. The product quality, particle size, and composition of the input for any processing stage is determined by its preceding processes, such as dismantling, size reduction and liberation (shredding), and physical separation. The design for product, however, plays a vital role in recycling schema. Furthermore, the recovery of recycled material and its recycling rate are significantly influenced by various aspects like the separation and metallurgical efficiency of different process steps within recycling system as well as the optimal interconnection among different processes in the recycling schema. The quality of recycling products and thereby the recycling rate for any specific product will be affected by the combination of materials being used for its manufacturing.

Based on the compositions for different materials the separation and recycling routes may differ. Since nowadays more complex products are produced and manufactured, a combination of different unit operations is needed and used for recycling of different components.

Within the recycling chain there is always loss of materials for each of the process steps. However, due to the interrelation between quality and recovery for the physical separation processes a 100% recovery cannot be achieved if recycling for high quality product is aimed.

To ensure the economic production of high quality metal products after smelting by the recycled material it is vital that metallurgical unit is supplied with a high quality feed. This indicates that high recycling rates is indispensable to achieve.

Resource Recycling: In fact the material and energy flows within the resource cycle for different obsolete manufactured products are defined by the product design and recycling. Various materials are combined and connected in many different ways, either simple or complex, to make up the composition of different products. These materials and their combinations are changed over the time. Due to their specifications these different

manufactured goods that can be recycled after reaching their end-life have different degree of recyclability. In addition the life time for the manufactured product differ individually over the time.
According to van Schaik, dynamic material and energy flows of the resource cycle system are a function of the various involved statistically distributed and time varying parameters such as life time, weight and composition of the recycled material, etc.

Life Cycle: Recycling has become an important approach in designing cars, appliances, and other manufactured products. Nowadays it is important to predict and calculate the recycling rate for different products. This must be done mainly in design phase. Recycling becomes complicated because of emerging new materials and rapidly changing in materials constructing products, the complexity of materials being used in new products, etc. The recycling, therefore, must be optimized in order to be able to follow the new legislation on recycling and type-approval.

According to what mentioned above in order to have a sustainable development efforts must be made to combine the resource cycle, the technology cycle, and the life cycle of the manufactured goods. Recycling greatly contributes to a more sustainable development of the society by conserving raw materials within the resource cycle and saving energy and minimizes the amount of waste streams to land fill.
Understanding the technological basis from shredding and fragmentation to separation stage(s) and assessing the parameters affecting these processes in plants, recognizing the bottle-necks in processing, and to see how the recycling system within shredding plants can be optimized are the key factors to be studied. When all aforementioned steps were studied the possibilities for developing new techniques for physical or metallurgical process may be taken into consideration. Finally, procedure for calculating and predicting of the recycling rate of present and future products must be certified if sustainable development and optimal use of resources are sought.
Optimization of recycling system can be realized from a system engineering approach. From engineering approach, the total recycling system is a dynamic feedback system. Economics, legislation, separation equipment characteristics, product design and its liberation during shredding, mass flow, mass balance, etc., must be taken into account and linked by this engineering system.

<u>Steel Recycling and Energy</u>

Scrap steel or old steel is used to make new steel products by either basic oxygen furnace (BOF) and/or electric arc furnace (EAF). Statistically about 25 to 35% of feed for BOF is from old steel scrap; however, almost 100% of the feed for EAFs can be covered by steel scrap. According to recent statistics, the total recycled content to produce liquid steel in USA by BOF was 30.4% for 2004. However, the share of scrap consumption for EAF process for the same year was 95.3%.
BOF furnaces produce products such as automotive fenders, encasements of refrigerators, and packaging like soup cans, five-gallon pails, and 55-galon drums whose major required characteristic is draw-ability. The EAF process, however, virtually uses 100% old steel to make new. Products such as structural beams, steel plates, and reinforcement bars whose major required characteristic is strength are produces by EAF process.
From energy viewpoint recycling of iron and steel conserves 5450 BTU (~1373 kcal) per pound of steel production. In addition recycling conserves 1400 lbs coal, 2500 lbs of iron ore, and 120 lbs of limestone per ton of steel.
According to study done by Michaelis and Lackson (2000), there has been a twofold reduction in both the annual energy consumption and the energy consumption per tonne of

steel in UK steel sector in the period 1954-1994. This reduction is due to a complex inter-relationship between production technologies, consumption patterns, and the domestic and global infrastructure of the iron and steel sector. For example, the transition away from open heart furnace (OHF) towards BOF and EAF, and thereby use of scrap in production, has given rise to a reduction in the specific energy consumption of iron and steel production process. Further study revealed that there is considerable potential for reducing the energy consumption associated with the UK steel sector until 2019, through three specific types of measures, i.e., increasing technological efficiency in steel production, substitution of EAF for BOF and increasing the recovery of scrap steel, and reducing the overall demand for steel.

Assuming that demand remains constant and the production mix remains similar to the present one, the possible reduction in energy consumption varies between 15 and 23% over 1994 level by technological efficiency improvements.

Changing the production mix to incorporate a higher percentage of EAF technology in combination with the efficiency improvements envisaged above could reduce energy consumption in UK steel sector by almost 40% over 1994 levels. This must be noted that the extent of the increase in EAF production capacity is physically limited by the steel scrap availability.

Finally, the largest reduction in energy consumption realises for the scenarios in which lower demand for steel is considered in conjunction with increased recycling rate and penetration of EAF and improvements in technological efficiency. A maximum 72% reduction in energy consumption over level of 1994 can be conceived.

Table1 depicts the predicted reduction of energy consumption for steel production in UK for a period of 1994 to 2019 based on the 1994 level for energy consumption for UK steel sector. Numbers 1 to 8 indicate different production conditions with respect to demands for goods, increasing the use of EAF for steel production and thereby increasing in consuming scrap, and the improvements for technological efficiency. Accordingly, between 14.7% and 71.8% saving can be realized with respect to the energy consumption level for 1994.

Table 1 – Energy consumption (PJ) in UK steel sector for 1994-2019
(Michaelis and Jackson 2000)

Year / Condition	1¤	2¤	3¤	4¤	5¤	6¤	7¤	8¤
1994	381	381	381	381	381	381	381	381
1999	367	361	353	347	324	319	312	307
2004	363	349	336	322	285	274	265	254
2009	338	318	298	279	232	219	206	193
2014	331	306	278	255	189	174	159	146
2019	325	294	259	232	153	138	121	107
Reduction %	***14,7***	***22,6***	***32,0***	***39,1***	***59,9***	***63,8***	***68,3***	***71,8***

1¤= constant demand, constant EAF, and slow technical change, 2¤= constant demand, constant EAF, and fast technical change, 3¤= constant demand, increasing EAF take up, and slow technical change, 4¤= constant demand, increasing EAF take up, and fast technical change, 5¤= reducing demand, constant EAF, and slow technical change, 6¤= reducing demand, constant EAF, and fast technical change, 7¤= reducing demand, increasing EAF take up, and slow technical change, 8¤= reducing demand, increasing EAF take up, and fast technical change

In fact advanced steelmaking technology has contributed substantially to reduce energy consumption and CO_2 emission during last decade(s); however, it is not impossible to speculate additional cutback possible in future. This additional reduction in energy consumption and CO_2 emission would be gain due to optimizing and integrating existing steelmaking processes, implementing emerging technologies, better scrap utilization, and developing eco-steel products while hot metal production via BF and conversion via BOF and EAF remain as the basis of the steelmaking in a projected future.

Recycled Material for Iron and Steel Production:

In 2004 the world production of steel surpassed 1000 Mt. The total raw material requirement to produce 1 ton of steel is about 5.1 tonnes. Scrap is obviously the second source of iron units for the steel industry. Scrap is a commodity, traded on the world market, with price posted on the Web, however, the issue of scrap quality has not received that much attention. Obviously, scrap is a less energy intensive iron source since the heat of iron ore reduction is unnecessary when it is used for steel production. In addition the emission of CO_2 per ton of steel is considerably reduced when scrap is used for steel production (Emi, 2005).
Major problems for the use of scrap among others have been well depicted, i.e., organized collection system, logistics and contamination by tramp elements, and finally scrap density.
In order to have quality scrap for iron and steel making more sensible ways to classify scrap should be developed. For ELVs, separation of non-ferrous components from steel has been elaborated in two ways. One is to thoroughly dismantle the components before scraping cars, and the other is to separate non-ferrous materials from shreds after preliminary dismantling and shredding cars. The same can be done for other scrap sources, e.g., scrap coming from home electrical appliances.
It is claimed that the Cu-containing parts for ELVs are thoroughly dismantled and the remains are pressed into a block without causing shredder dust in new dismantling and shredding plant installed in Japan. The shredding has been subject to improvement by implementing advanced devices for sensing and separating the non-ferrous components from the shreds, although it remains as yet labour intensive.
Recently a new process has been developed to deal with the shreds that contain non-ferrous components. To separate non-ferrous components from steel and plastics the thermo-bath process has been developed and was successful in pilot plant scale operation. By this process non-ferrous components are separated from steel and plastics by flotation (Takaoka et al., 2003).

Material Construction for Different Obsoletes:

For successful recycling of material, especially iron and steel recycling, from old and out of use products such as ELVs and obsolete appliances, etc., it is needed to have a perspective of their compositions.
Automobile is one of the most resource intensive and influential consumer products whose interactions with the environment motivate frequent attention from regulatory authorities. This results in the formulation of policies that are aimed at including continuous improvement in the automobile environmental performance (Amaral et al., 2003).
In addition to the impacts from polluting, the material flows associated with the life cycle of the automobile have become increasingly relevant at EU level. The annual waste flow due to ELVs in EU is estimated to be around 9 million tones. Given the perspective that number of automobiles in use has been considerably increased, this is reasonably expected that the flow of ELVs in the EU and its related waste stream become a major issue. An estimation done by in1999 indicated an increase of 21% in the number of ELV in European Union between 1995 and 2010 (EEA, 1999).
Table 2 depicts the data in details for car and truck production in EU, Japan, and United States and number of cars that are registered, deregistered and shredded, however, the average material composition for different models for cars is shown in Fig 2.

With this respect a glance at the statistics indicates that total car production for automobiles and trucks in EU, Japan, and United States is annually about 45 million. However, the number of total cars in use is about ten times of the production, i.e., 450 millions.

Table 2 – Statistics on ELVs for main countries (ICSG, 2004)

Country statistics	**EU**	**Japan**	**USA**
Car production	16 - 18 millions	9 - 10 millions	16 -18 millions
Car in use	200 millions	~50 millions	200 - 210 Millions
New cars registered	14 -14.5 millions	5 - 5.5 millions	15 - 15.5 millions
Deregistered cars	11 - 12 millions	~5 millions	13.5 - 14.5 millions
Shredded/recycled cars	7 - 8 millions	4 - 4.5 millions	12.5 – 13.5 millions
Abandoned/stored cars	~5-7 %	~1 %	~6 %
Exported used cars	3 – 3.5 millions	0.5 - 1 millions	Not available
Average car's weight	1000 – 1200 kg	1000 – 1200 kg	1200 – 1400 kg
Copper & alloy content	1 – 2.2 %	Not available	1.4 – 1.5 %

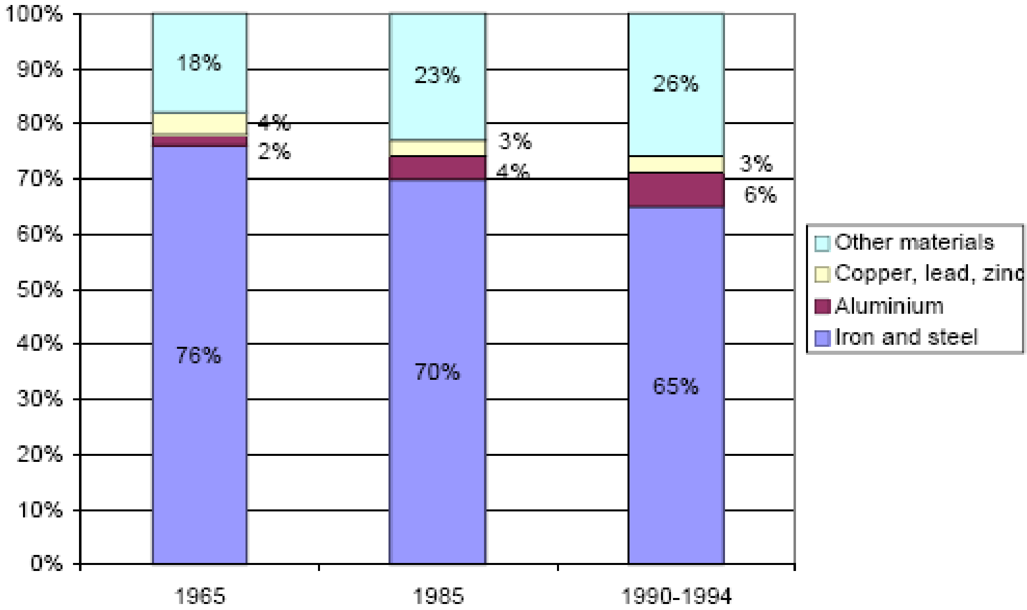

Fig.2 – Average composition of different models of cars (ICSG, 2004)

Table 3 shows the average material composition for three different models of cars manufactured in Japan, Europe and the United State that have almost same average weight.
It can be seen from the above tables and figure about 70% of the materials to be used for car manufacturing consists of ferrous metals. The share of ferrous metal in car manufacturing has declined slowly over the decades. Instead, the consumption of non-ferrous metals, especially aluminium, and plastics has increased. The trend in decreasing of ferrous metal consumption and increasing the consumption of aluminium and plastics in car manufacturing made it difficult to achieve the EU goals for ELVs recycling according to the new legislation.
Except ELVs, there are other sources for metal recycling. Industrial wastes, obsolete home appliances, electric and electronic scrap, etc., are other sources in recycling chain. The obsolete appliances and electronic wastes are processed by manual dismantling, shredding, and separation to recycle ferrous and non-ferrous metals, as well as plastics.

Table 3 – Typical composition for three different generic cars in Japan, USA, and Europe that have almost same average weight of 1020 kg (Amaral et al., 2003)

Materials	Japanese 1992	US 1994	Europe 1998

Ferrous metals	68,8%	67,7%	65,4%
Non-ferrous metals	9,9%	7,5%	10%
Rubber	3,4%	4,2%	5,6%
Plastics	8,2%	7,8%	9,3%
Glass	3,1%	2,8%	2,9%
Others	2,64%	4%	2,72%
Fluids	3,96%	6%	4,08%

In recycling obsolete appliances it is important to know the accumulation of heavy metals in recovered components, especially for metal fractions, since the iron and steel industry has restrictions in using scrap for producing new metals. In addition, it is important to reduce the possible emissions to heavy metals and other wastes to the environment by better recycling. A comprehensive study was done by Matsuto et al., (2004) in order to determine the composition of recovered components during recycling of the home electrical appliances in Japan in order to increase the rate of recycling and to reduce the emission of hazardous material to the environment by choosing the best possible recycling system.
Results of material balance survey for TV, washing machine, refrigerator, and air conditioner are shown in Figs3-6.

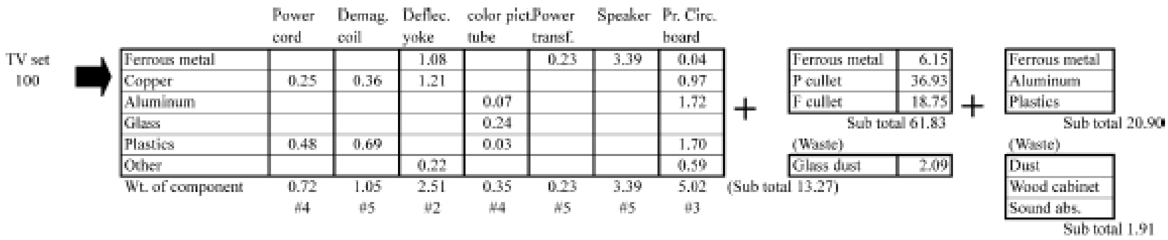

Fig.3 – Material composition for obsolete TVs

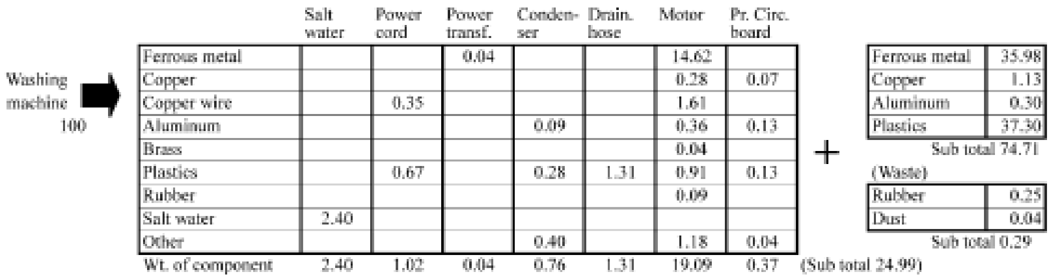

Fig.4 – Material composition for obsolete washing machines

Since reducing of the volume of waste and increase material recycling rate are intended primarily by recycling of obsoletes, it is important to characterize the material by which these absolute are constructed. Metallurgical industries are the main consumers of the recycled materials obtained from different waste resources. Furthermore, because of high content of impurities, such as heavy metals, tramp elements, etc., in some components of products, it is expected that recycled materials cannot meet the requirements for metallurgical application and also recycling may lessen adverse impacts on the environment. In order to evaluate these effects and try to find the best solution for better and more recycling it is important to do the material balance and heavy metal balance in a recycling facility. Using material balance model, which can be made up by data collection from products manufacturers and recycling plants, help recyclers to define what would be changed in manufacturing of different products and what should be the optimum recycling flow-sheet. These understandings lead for optimum recycling of raw materials with less environmental impact.

Refrigerator 100 →

	CFCs/ oil	Power cord	Packing	Power unit	Compr.
Ferrous metal				0.09	10.89
Copper					0.10
Copper wire		0.06		0.03	0.59
Aluminum					0.14
Brass					0.01
Plastics		0.04	2.80	0.05	0.35
Rubber					0.04
Urethane					
CFC	0.15				
Oil	0.25				
Other					0.44
Wt. of component	0.40	0.10	2.80	0.17	12.56

(Sub total 16.03)

+

Ferrous metal	43.50
Copper	2.58
Aluminum	0.11
Plastics	25.87
Urethane	10.70

Sub total 82.76

(Waste)

CFC	0.35
Drain water	0.85
Dust	0.01

Sub total 1.21

Fig.5 – Material composition for obsolete refrigerators

Air conditioner 100 →

	CFCs/ oil	Power cord	Copper pipe	Heat exchang.	Pr. Circ. board	Power transf.	Condense	Motor/ compr.
Ferrous metal					0.01	0.78		28.25
Copper			4.77	7.45	0.14			1.68
Copper wire		0.78						1.37
Aluminum				7.92	0.25		0.14	0.59
Brass								0.03
Plastics		0.34			0.24		0.44	0.78
Rubber								0.08
CFC	0.49							
Oil	0.11							
Other				0.13	0.04		0.63	1.18
Wt. of component	0.6	1.12	4.77	15.50	0.68	0.78	1.20	33.96

(Sub total 58.61)

+

Ferrous metal	25.36
Copper	0.28
Aluminum	0.50
Plastics	14.08

Sub total 40.22

(Waste)

Dust	0.19
Sound abs.	0.95

Sub total 1.22

Fig.6 – Material composition for obsolete air conditioners

Shredding Process:

Most shredding plants worldwide process ELVs alongside other consumer products including white appliances, light iron and metallic manufacturing and construction waste. General configuration and processes at a typical shredding facility for ELVs is shown as the Fig.7.
In more comprehensive manner the following route must be followed by an object to be shredded and then separated into different product and waste streams (Manouchehri 2005):

(a) weighing of the income old scrap
(b) inspection prior to shredding to remove hazardous, dangerous, and explosive substances, like radioactive materials, air bags, LPG and LNG in tanks, ammonia and CFCs in air conditioner, inflation capsules, etc.
(c) introducing scrap to the housing of the shredder (normally input roll system is used which squashes the feed which facilitates the action of hammers)
(d) by introducing the scrap raw material to the shredder the hammers first rip up the flattened scrap against the breaker bar or anvil that are positioned at the month of the shredder
(e) scrap is dragged deeper into the rotor housing by the motion of hammers and hammers reduce it further against the rotor housing wall and the cast steel grates until the scrap is small enough to be knocked through the holes in the grates
(f) light fractions are sucked by the heavy duty suction system installed at the top of shredder
(g) the chopped heavy fractions are screened and subjected to magnetic separation section
(h) the magnetic part will be purified further by either hand sorting or other separation techniques if requires
(i) non-magnetic part will send to eddy current separator for separating aluminium fraction (Al and Al alloys) from other non-ferrous metals and other non metallic fractions, such as stone, wood, plastics, and rubbers.

(j) heavy fraction is usually sent to sink-float separation and then after to other separation techniques, like eddy current for further separation,
(k) in modern shredding and recycling plants different fractions of non-ferrous metals, i.e., fractions containing aluminium, copper, zinc, and magnesium metals are further treated by other separation techniques, like optical sorting, electromagnetic sorting, image analysis, etc., for having different products made from different aluminium alloys, copper and its alloys, magnesium alloys, etc.
(l) for non-metallic fraction(s) further separation of different plastics, or rubber-plastic, etc., can be carried out by sorting techniques and/or electrostatic separation techniques.

This must be noted that for further separation of non-ferrous materials the non-ferrous fraction is usually screened into two but up to four different sizes, e.g., minus 12mm, 12-40mm, 40-100mm, and over 100mm.
Finally there is the shredder residue or waste fraction, i.e., fluff, which is generated at the de-dusting unit at the discharge from the shredder housing, also above the conveyor belt just before the separation drum, and also at the non-ferrous sorting stage, that will be land filled. There are issues to be challenged in order to decrease the amount of generated fluff as much as possible and also to treat the generated for some special applications.

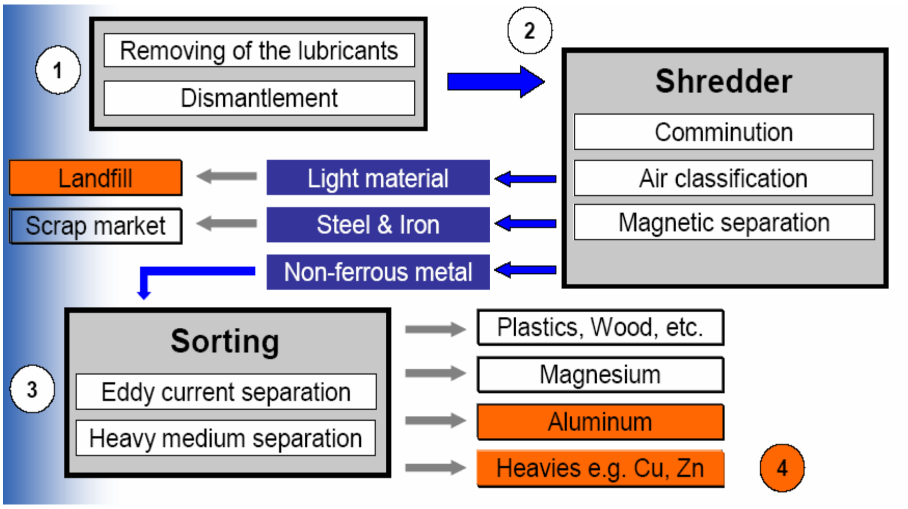

Fig.7- Schema of processes at a typical shredding facility

It must be noted that the dust collection system is driven by fairly powerful electric motor. Considerable amount of energy is consumed by whole de-dusting system; in some cases up to 500hp motor is installed. In fact thousands of tones of light fraction must be sucked away over a considerable distance and the ultimate aim is to leave no more than 20-30mg of dust per cubic meter of air after separation. Damp or semi-dry shredder is favourable for having better environmental condition and less dusty particles per cubic meter of air. Most problems with respect to dust and dust collection disappear by installing semi-wet shredder.

Mapping and Description of Four Shredding Plants in Sweden:

One aim for this study, i.e., Mapping and Development of Shredding Stream, was to look at the shredding facilities in Sweden in order to define the performance of the shredding plants and to find the bottle-necks in plants' flow-sheet. Finding and understanding the problems with respect the existence shredding plant will help to increase the rate of recycling and to improve the product quality for metallurgical and other industries and to reduce the amount of wastes to be land-filled.

It is important to note that both the economics for producing raw materials as well as waste land-filling and the environmental concerns play vital role in recycling schema. Costs for recycling can be roughly divided into logistic costs, i.e., collection, transportation, etc., and processing costs, i.e., dismantling, shredding and size reduction, liberation, separation, etc. The processing costs, however, depend heavily on the complexity of the recycled object. The required recycling installations become more sophisticated and, therefore, more expensive with increasing product complexity. Fig.8 indicates the relationship between recycling costs and product factor (Norgate, 2004). Within this figure, the product factor is defined as product complexity divided by product size where the product complexity reflects the number of materials applied in the product and their size in a given component.
This must be noted that processing costs are not essentially in relation to the value of the recycled materials. For example, logistic costs are primarily determined by the collected amount of discarded products and transport distance. Various contributing costs concerned for base metals recycling are discussed by Theo and Magnus (2002) as shown in Table 4.

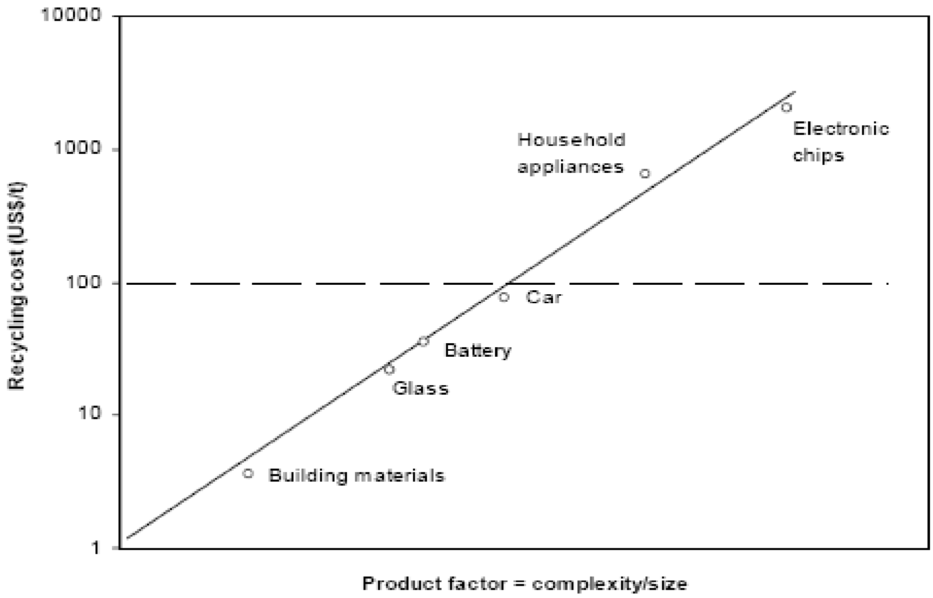

Fig.8- Relationship between recycling costs and product factor (Norgate, 2004)

According to what are listed in Table 4 it can be concluded that the quality of given material available for recycling is a vital determinant for the feasibility of recycling. This is due to the fact that the recycling and processing costs decrease more and more with increasing throughput due to economies of scale.
Landfill and dumping costs are increased, both because of the shortage of sites and increasing distance from cities. Although, this increasing costs for landfill facilitates the treatment of otherwise sub-economic residues. Such materials will normally be delivered to the processing plant free of charge, or their owner will pay a treatment charge levied somewhat lower than the cost of disposal. Land fill costs for automobile shredder residue (ASR) in various countries have been reported by Kanari et al., (2003) that are listed in Table 5.

Table 4 - Comparison of various recycling cost contributors for base metals (Theo and Magnus 2002)

Contributing Cost	***Skr/t***
Collection cost	-6000 to +5000
Transportation costs (truck/rail/sea)	800/600/200
Legal costs (taxes, fees, lost business)	hide
Permitting costs (fees, bank guarantee)	50 to 200

Paperwork costs (preparatory, travels, reporting etc.)	200?
Handling costs (sorting, crushing, separation, moving, de-hazardizing)	1000 to 10000
Sampling costs	1000
Extraction costs (smelting and refining)	1000 to 4000
Environmental costs (deposits, effluent care, filtering, water treatment, monitoring, etc.)	> 100
Safety costs	10
Inventory costs, etc.	-10 to +100

Table 5 - ASR landfill costs in various countries (Kanari, 2003)

Country	***Cost (US$/t)***
EU Countries	
Austria	140
Belgium	55
Denmark	70 -140
France	40 - 60
Germany	60 - 170
Italy	75 - 80
Netherlands	70 - 90
Spain	20 - 60
Sweden	90 - 100
UK	30 - 35
Eastern European Countries	
Poland	25 - 30
Czech Republic	30
Non- EU Countries	
Australia	20
Japan	135 - 160
Norway	50
USA	50 - 60
South Africa	25 - 40
Switzerland	120

In Sweden, shredding and recycling of ELVs alongside other consumer products including white appliances, light iron and metallic manufacturing, construction waste, and also municipal wastes are carried out in shredding and recycling plants owned by two companies, STENA and KUUSAKOSKI. However, STENA is the main recycler and supplier of recycled products in Sweden.

High costs for land-filling of the waste as well as costs for transportation of these wastes to a proper location are motivations to encourage recyclers to look for new processes to recycle more material and to reduce the total wastes produced in recycling plants.

General schema of processes at a typical shredding facility for ELVs is shown as the Fig.9. This must be noted that the presented data in the figure are the approximate and may change case by case for different shredding plants. The same flow-sheet can be used for other obsoletes to some degree or another.

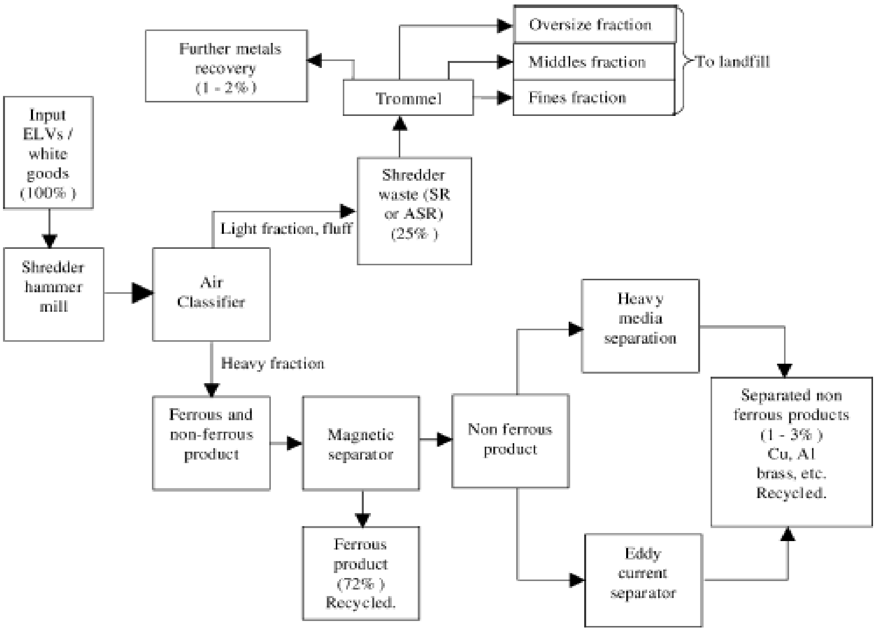

Fig.9- Configuration for recycling of ELVs

Stena's Shredding Plants (Halmstad, Hallstahammar, and Huddinge)

Although Stena has several recycling plants for different kinds of wastes but the company owns four shredding and processing plants for crushing, classification, and separation of ferrous and non-ferrous metals to supply the metallurgical industry. These shredding plants are located in Malmo, Halmstad, Hallstahammar, and Hudinge.

It is estimated that almost 80% of materials to be recycled, especially recycled ferrous metals for iron and steel industry, is shredded and processed by Stena.

Three different Stena's plants were visited, Halmstad, Hallstahammar, and Hudinge plants. The main shredding and processing facilities is located in Halmstad where the processing plants, including both dry magnetic and eddy current separation, is in combination with wet heavy media separation to process different fractions of shredding products. Even other gravity based separation techniques, i.e., shaking table and pneumatic jigs, are in use for processing of the electric and electronic wastes.

In both Hallstahammar and plant the raw material is shredded and classified by in light and heavy and magnetic and eddy current separators are used for separating ferrous metals and aluminium from heavy and light fractions respectively. However, in Hudingee just a magnet is used for collecting ferrous materials from heavy fractions coming out from shredder. The remains from heavy fraction from both sites is send to Halmstad plant for further separation.

Details for the plants are as the following:

a- Halmstad Plant:

The raw material containing different kinds of obsoletes is sent to the plant for metal recycling. It is roughly estimated that the raw material contains of 49% industrial wastes, 30% of household waste, and 21% ELVs.

Both dry and wet processing stages exist in Halmstad plant. In dry separation stage magnetic, eddy current and hand sorting are used to separate iron and ferrous metals from heavy fractions and also aluminium from other light materials, such as wood and plastics exist in light fraction. In fact two different products are produced, high iron content and high aluminium content.

However, in wet stage the process that is based on a heavy media separation, the plant has two stages of heavy media separation where particles are separated based on their specific

gravity. Eddy current separator(s) and hand sorting, as well as magnetic separator techniques are also employed for having better quality of the products, i.e., aluminium, copper and zinc, stainless steel, etc.
The plant can be explained in details as the followings:

a-1- The old scrap is fed into the shredding machine where the raw material is ground to different particle sizes. A heavy duty cyclone is installed on top of shredder to vacuum the light and fine fractions, i.e., plastics, wood, aluminium, etc. The amount of light fraction that is goes through the cyclone varies between 5 to 15% of input. This light fraction from the air system is run through a metal separation plant, where light metal fragments, especially aluminium and its alloys, are separated with eddy current separator(s), leaving a fines fraction to landfill and a fuel fraction suitable to combustion or just for land-filling.

a-2- The heavy fraction is gone though magnetic separation to separate iron and ferrous metals from the other heavy materials. The heavy and coarser fractions that have been ground by shredder are passed through magnetic field where iron and ferrous particles are separated from non-ferrous heavy metals and other impurities. Therefore, a product of ferrous metals is produced for iron and steel industry.
It must be noted that in some plants for having better quality of ferrous fractions the ferrous fraction from first separation step may be fed to another magnetic field.
The magnetic fraction obtained by magnetic separation of raw material is sent for hand sorting where the unwanted impurities, such as copper wires, cloths, any contaminated aluminium or other non-ferrous metals are picked up by workers.
The non-magnetic fraction from this stage goes to the heavy media separation plant in order to de separated into different metal fractions as well as waste fraction.

a-3- The non-magnetic part from heavy fraction is classified and a material with size fraction between 10 to 100 mm is processed in heavy media plant.
There are different rules for classification. The classification must be done properly with respect to the separation techniques used for separating different metals and non-metals. Especially for eddy current separator it is important to set the machine variables, such as rotor speed and pole size for the magnets in a manner that the optimal separation is achieved.
In Halmstad plant heavy media plant, the heavy media fraction is passed through two stages of media separation. In first step a heavy media with specific gravity of 2.2 is used and in second step a heavy media with specific gravity of 3.4 is used. Materials that are sunk in second stage of media separation are ten classified into 10-20mm and 20-100mm. These two fractions are then passed through magnetic separator.

a-4- The light fraction from shredding step is classified by screening into -8mm, 8 to 40mm, and +40mm. The +40mm fraction is back to the shredder to be further ground. However, the 0 to 8mm is directly sent for land filling. The size fraction between 8mm and 40mm is passed through the eddy current separator to have a product of high aluminium content.

It is said that in the wet heavy media separation plant annually 50000 tonnes of raw material is processed. The out put for the heavy media plant is about 21000 tonnes of different metals, including steel, aluminium, magnesium, and their alloys, as well as copper and zinc and their alloys. Generally, particles within size range of 10 to 100 mm are processed by wet heavy media separation process.

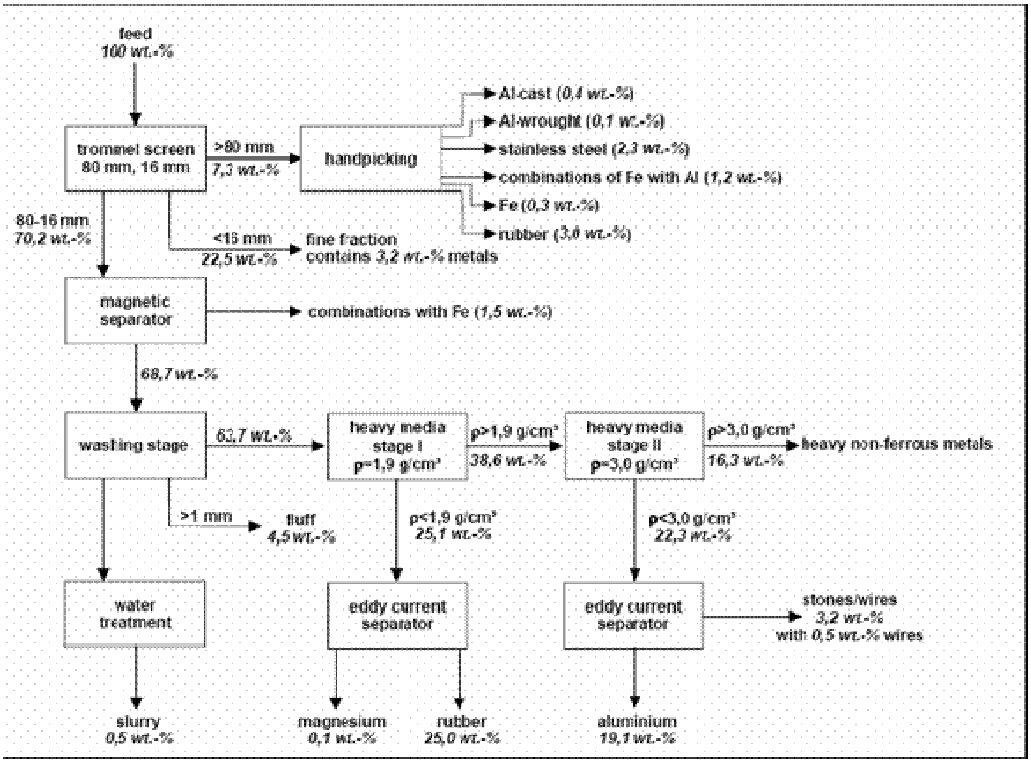

Fig.10 – General configuration for heavy media plant to separate aluminium and other metals

Within the heavy media plant, first of all the raw material is washed to remove dusts and other fines. Then, media separation is done in two different steps, first the media is fixed with a specific gravity of 2.2. The light materials recovered from this step are fed into eddy current separator to recover aluminium. Hand sorting may also be employed after eddy current separation in order to have high quality product. The remaining is mainly made of plastics, woods, etc., that must be sent for land-filling.

The heavy fraction is processed further where a media with specific gravity of 3.4 is used. The light fraction which contains of steel and some other lighter non-ferrous metals is passed through eddy current separator for purification. However, the heavy fraction is divided into two different size fractions, i.e., 10<p<20 and 20<p<100 mm. these two fractions are passed through magnetic separators to remove magnetic particles. The non-ferrous part may be passed through eddy current separator for further separation of different non-ferrous metals.

It must be noted that Halmstad plant was a wet shredding plant before the time that the Stena owned the plant. The fellow-sheet of the previous plant is shown in Fig.11.

A glance at the flow-sheet depicted in Fig.11, it can be confirmed that there was different classification for the light fraction comes from shredding stage. In addition the separation processes for light and heavy fractions are rather different. Therefore a comprehensive study must be donated to find the optimum flow-sheet in order to obtain the optimum recovery for iron and steel, other non-ferrous metals, and the combustive materials.

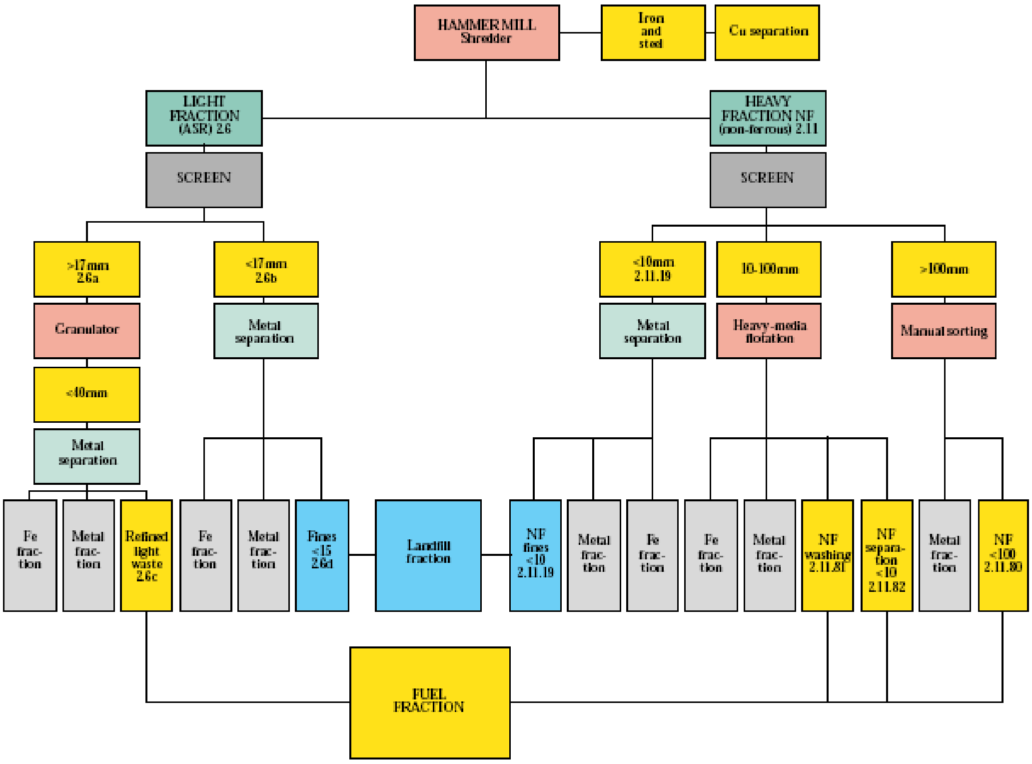

Fig.11 – Previous flow-sheet for Stena Bilfragmentering in Halmstad (ECRIS, 1998)

General configuration for the current processes in Halmstad plant is shown in Fig 12. To summarize the whole processes the following can be stated:

- After thorough pre sorting the material is fed into the shredder. From the shredder, where the scrap is fragmentised, is the material transported with a conveyor belt to the sorting and separating plant where it at first is rinsed from waste with an air separation system. In order to make the material damp, water is injected in the shredder. This prevents emissions of dust and reduces the risk of explosions.
- The magnetic material (ferrous scrap) is sorted out by using magnetic drums. The ferrous material is manually checked for copper and waste prior it is delivered to steel plants. Maximum copper content allowed is 0.25%.
- Heavy non ferrous material such as glass, stones, rubber, concrete, aluminium, zinc, copper, brass etc, falls down under the magnets. This type of material is sent to the heavy media plant, where the different metals are sorted out from the waste, two stages of heavy media are employed.
- The light waste fraction from the vacuum system, is run through a metal separation plant, where light metal fragments are separated by make use of eddy current separator(s), leaving a fines fraction to landfill and a fuel fraction suitable to combustion.
- Ferrous material is also recovered from both the light and the heavy waste fraction either by hand picking or magnetic separation.

It must be added that in Halmstad plant there are facilities for processing of the electric and electronic scraps where pneumatic jigs and shaking tables are used in combination with other separation techniques, such as magnetic separator, to separate different metal fractions. These facilities process raw material within size fractions up to 12 mm.

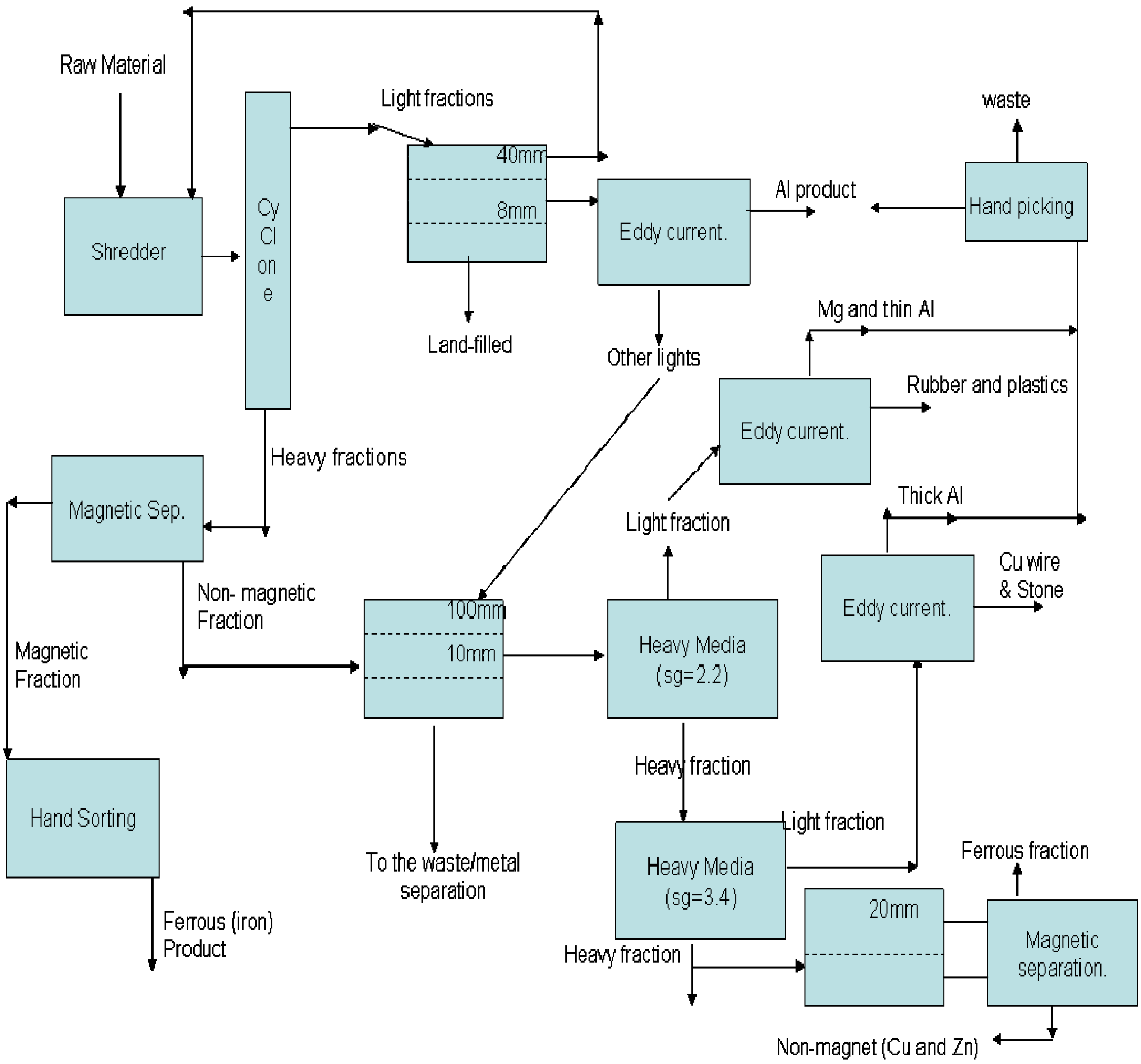

Fig.12- General configuration for current Halmstad shredding and separating plant

b- *Hallstahammar Plant:*

In hallstahammar plant the ELVs, obsolete appliances, industrial wastes, and other materials to be recycled are fed into a shredder which works by a motor of 2.5 MW. The capacity of the plant is about 100t/h for shredding.

b-1- After shredding of the feed, as like as Halmstad plant, the heavy fraction is passed through the magnetic separation where ferrous material are separated and collected for sending to the metallurgical plants. The non-ferrous from heavy fraction is then send to the Halmstad heavy media plant for further separation of non-ferrous metals.

b-2- The light fraction that is vacuumed from top of the shredder is classified by screening into three different fractions, i.e., -12mm, +12 -40mm, and +40mm. The -12 is land-filled without further processing however, the fraction within the size of +12 -40mm is passed through eddy current separator in order to have a high alumina recycled product. The over size of 40mm is send back to the shredder.
The plant's configuration is rather simple since there is no heavy media separation.

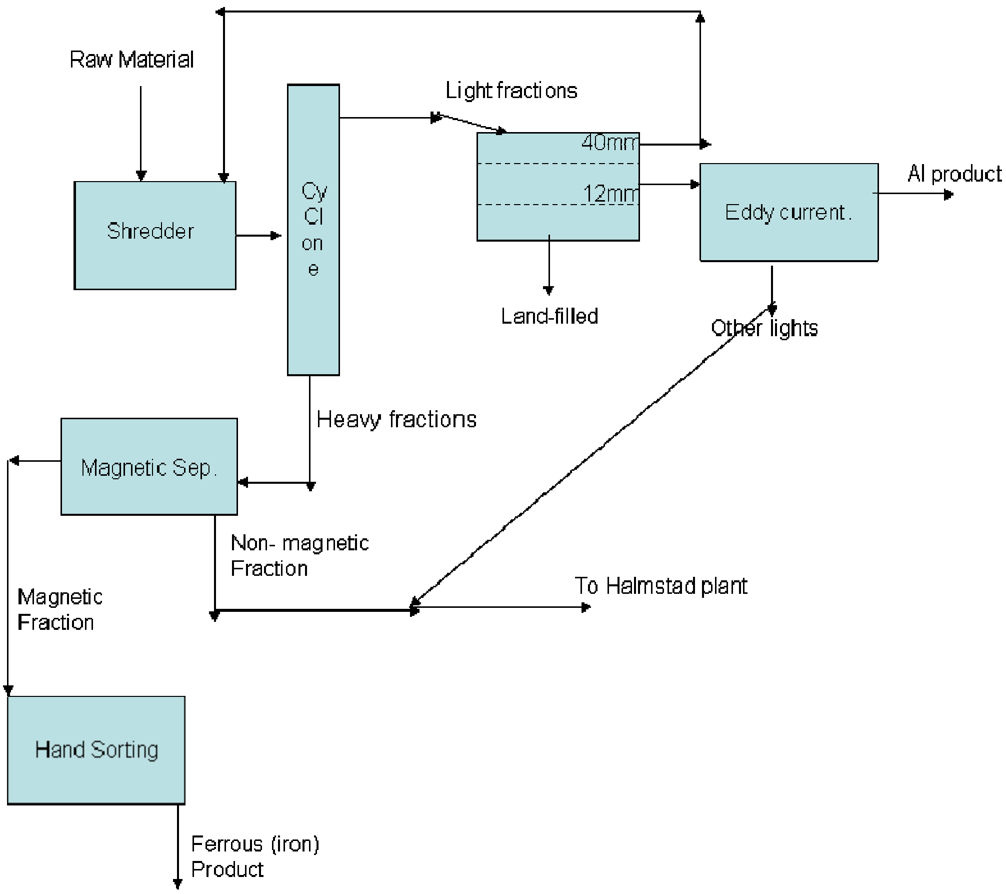

Fig.13- General configuration for Hallstahammar shredding and separating plant

c- Huddinge Plant:

Huddinge plant is even simpler than the Hallstahammar plant. According to the information achieved the feed material for the plant consists approximately of 30% ELVs, 30% MSW, and 40% of industrial wastes. The plant has a capacity of accepting 200000 t/y of obsoletes.

c-1- The raw material is fed to the shredder and the heavy fraction is passed through the magnetic separation to process high iron content material. The ferrous metal achieved from magnetic separation is further purified by hand picking to remove wires, cloths and other big impurities. The product is then sold to iron and steel industries as a raw material for steel making.
The non-ferrous fraction achieved from processing of heavy fraction after shredding is sent for further processing to the Halmstad plant. This fraction is added to the feed for heavy media separation in Halmstad.

c-2- The light fraction that is vacuumed from top of the shredder is sent for classification. In This plant there is just one screen to cut the light fraction into two different fractions, i.e., -8mm and +8mm.
Particles smaller than 8mm in size are not processed any more and they are land-filled. However, particles bigger than 8mm in size are sent to Halmstad plant for further separation where the aluminium content of this fraction is separated from other light materials by eddy current separator.

The plant flow-sheet is shown in Fig 14.

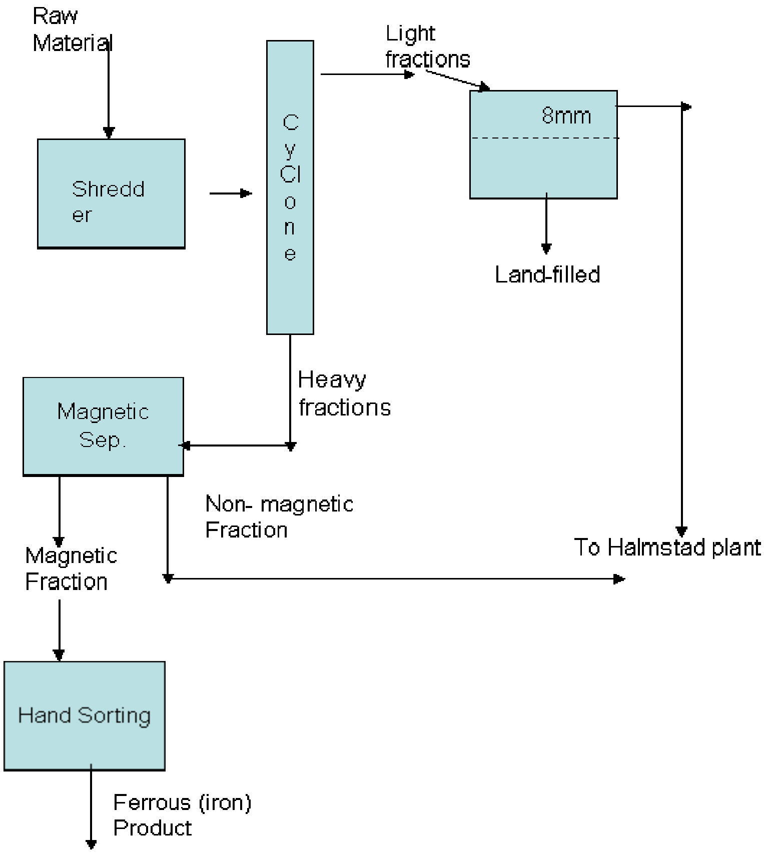

Fig.14- General configuration for Huddinge shredding and separating plant

d- KUUSAKOSKI Shredding Plant (Skelleftehamn):

Kuusakoski plant can process 150000 tonnes of scrap per year. However, at the moment they mainly process 100000 tonnes per year. The scrap comes from different sources, i.e., 15-20% ELVs, 5-10% appliances, municipally wastes up to 60%, and remaining is industrial waste.

The iron product contains less than 0.4% of copper based on request for different industries. The scrap for using in Swedish steel plants must contain < 0.25%, however, the shredded scrap that is sent for other countries may contain up to 0.4% copper.

The size fraction for ferrous final product from shredding facility ranges mainly from 100-200 m.

The shredder has a 3000 hp and consumes 40 kWh per ton of feed. It rotates at about 500 rpm with opening of 20 to 30 cm. The plant consists of 4 different sections:

d-1- *Main Shredding Facilities (Shredder, cyclone, magnet and eddy current separators, hand picking):* The main processing facility is set up to separate ferrous metals (especially iron) from non-ferrous metals and non-metals in first step and then to separate aluminium from non-ferrous stream by using magnetic and eddy current separators respectively.

After shredding there is a magnet separator to separate ferrous fraction from others. There are no screening facilities to screen the ground particles. However, the particle size for ground particles is controlled by adjusting the shredder.

After shredding, the light fraction is separated from heavy fraction (mainly ferrous and non-ferrous metals) by making use of a big cyclone. The light fraction which mainly contains of light metals, plastics, wood, etc., is then sent out either for further processing (in Finland) or as disposal.

Heavy fraction is processed further, firstly to remove the iron or ferrous fraction by magnetic separation. The ferrous fraction then is send for hand sorting where copper wires, cloths, some plastics, and other non-metals are sorted out from ferrous stream. The ferrous fraction having the copper content from 0.2 to 0.4% is prepared and sold to the metallurgical industry.
The non-magnetic part of heavy fraction is processed further by using an eddy current separator to separate aluminium and its alloys from the non-magnetic fraction. Therefore two more fractions of non-magnetic particles are prepared, the fraction containing of aluminium and its alloys, and the fraction in which other non-ferrous metals, like copper, zinc, brass, and even steel, are accumulated.
This aluminium fraction is sold to costumers and the other non-ferrous part is send to another plant in Finland for further processing.
Fig.15 depicts the flow-sheet for the main shredding facility

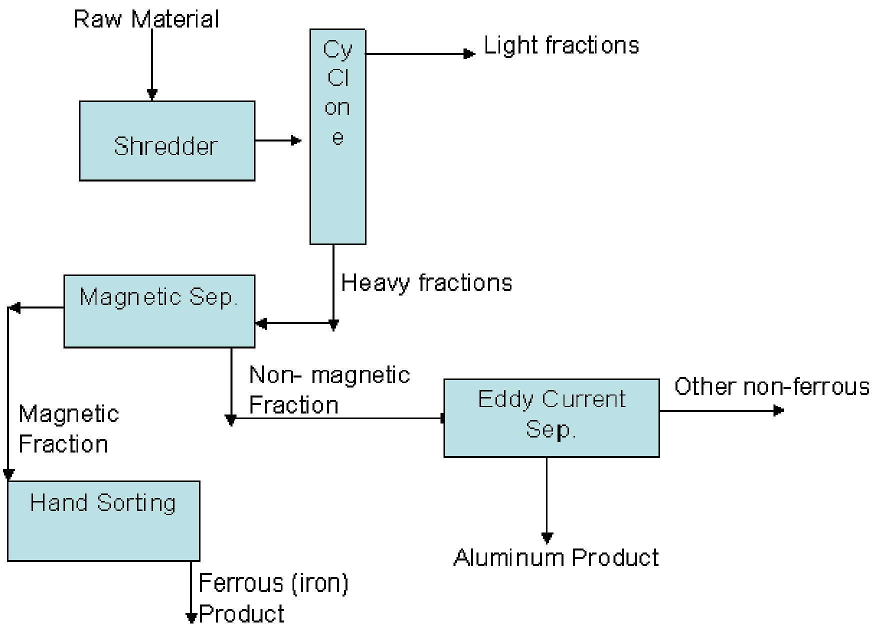

Fig.15- Kuusakoski's main shredding facility

d-2- *Small grinding and separating plant for recovery of the metals from electronic scrap, where ring crusher is used to crush and grind electronic scraps:* Electronic scrap is processed in this section in order to separate ferrous metals and aluminium from the scrap. Therefore, small grinding facility is set up to grind the electronic scrap by using a ring crusher. Then the ground material is passed through magnetic separator where iron and magnetic particles are separated. At the next step an eddy current separator is used for separating of aluminium and its alloys from non-ferrous fraction coming from magnetic separation stage. The remaining part contains mainly of different metals (especially precious metals and their alloys) as well as different kinds of plastics. This part is sent to Boliden for recovering of precious metals.

d-3- *Scrap yard and facilities for cutting big industrial scraps:* There are facilities for cutting and dismantling of industrial wastes that are made of iron and steel. These wastes are too big for shredder. There is no need to do any further process since they just made of iron or steel. Therefore by cutting them to smaller parts they can be sold directly to the costumers (Total production is about 13000-15000 ton/year).

d-4-- *Dismantling facilities:* In some cases cars and appliances are sent to the Kuusakoski's shredding plant without dismantling. Therefore, there is a need for dismantling plant to prepare the raw material for shredding**.**

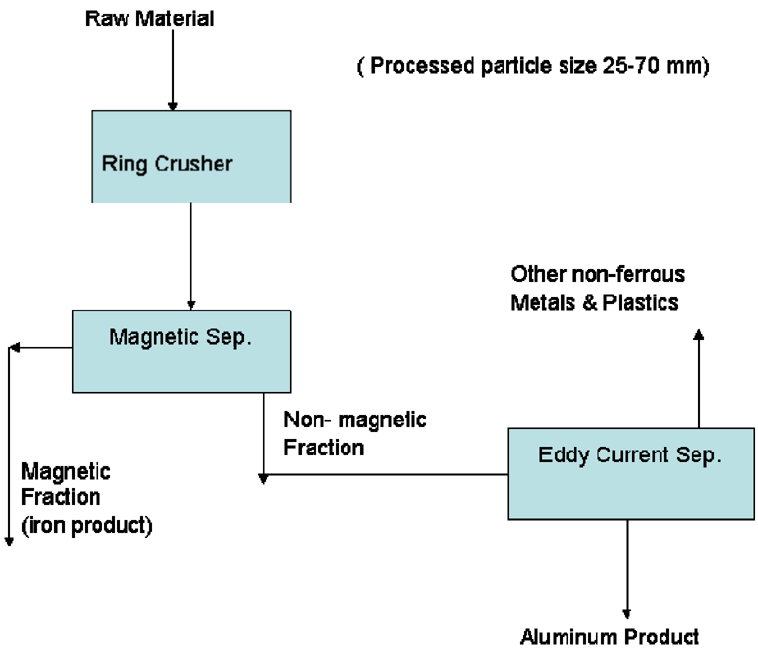

Fig.16- Kuusakoski's facility for processing electronic scrap

Issues With Respect to the Shredding Plants:

Looking at the flow-sheet of the four shredding plants in Sweden indicates that the scrap coming from different resources is first shredded. It is important to look at how effective is the shredder with respect to the energy consumption and also the shreds product. Materials must be shredded enough in order to have maximum liberation of the components being shredded. Better liberation leads for better separation of metals and non-metals in physical separation stages.

In addition, the amount of light material to be vacuumed by the cyclone must be defined. Good shredding leads to have better products (i.e., better liberation for different components) of heavy and light fractions in shredding stage. It is therefore important to have a material balance first through the shredding process.

The second stage is how to screen and classify the light fraction coming out from shredding stage. As it can be seen through flow-sheets there are different rules followed by each shredding facilities. It must be defined what is the logic(s) behind such classifications (screening) and which size fractions are most suitable for following separation stage. Furthermore, the parameters determining the separation efficiency for the subsequent stage must be defined and optimized accordingly.

The under size fraction that goes to the waste, which is generally contains of material with either -8mm or -12mm in size must be analysed in details to see the percentage of ferrous metals, non-ferrous metals, and non-metals for each sub-size fraction.

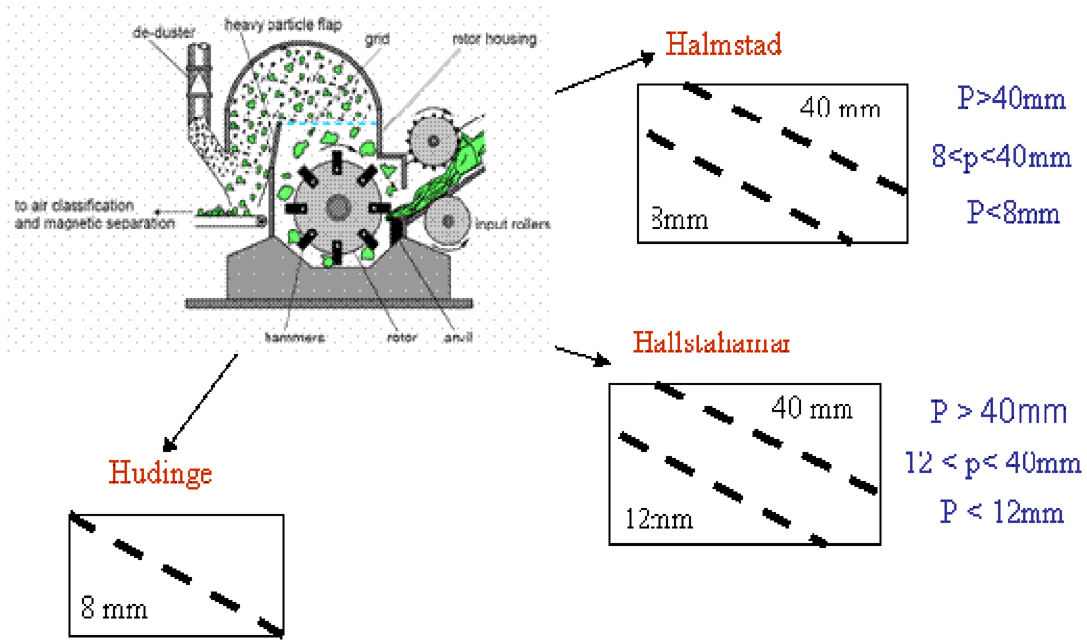

Fig.17- The classification for light fractions after shredding for different Stena's plant, (which classification is the best?)

For ferrous fraction, or generally heavy fraction, comes out from the shredding plant there is no classification. This may lead to contamination of un-wanted elements, such as copper or tin, to the ferrous fraction that is processed for iron and steel companies. Classification of heavy fraction coming from shredders and study on each size fraction in details help us to define the degree of liberation for different components and may lead to a possibility to select and sort out one size fraction with out sending that fraction(s) for physical separation process.
In addition, in steel production from recycled scrap the density of the scrap to be used is paramount important. Low dense scrap is not required by steel companies. Density improvement for the recycled ferrous scrap can be achieved by different ways, one is sizing the scrap. This means the requirements for iron and steel industry can be provided by further classification and mixing of different size fractions of recycled ferrous metals in a proper manner. However, ferrous fraction can be ground further in order to achieve an optimum density that is required by iron and steel manufacturers.
Look at the heavy media plant is the next challenge for recycling of non-ferrous metals. The heavy fraction coming from shredding stream contains of iron, steel, and other ferrous metals as well as heavy non-ferrous metals and their alloys. This heavy fraction is passed through magnetic separation and then forwarded to a screening stage where the material is first classified by to remove fines, i.e., $p<10$mm, and in some cases very coarse, i.e., $p > 80$mm or $p >100$mm, in size. Undersize and oversize materials as well as materials in between must be characterized in order to define the optimum size fraction to be sent for heavy media separation. Here, again, the liberation plays a vital role in heavy media separation efficiency. The material constitute for each size fraction must be warily characterized in order to define the optimum specific gravity for the media used in separation stage.
Characterization of each product obtained from heavy media separation defines the possibilities for further purification of that product by utilizing other physical separation technique(s).
Although the main aim of Mistra project is to improve the quality of ferrous scrap for metallurgical applications and also reduce the environmental impacts with respect to

recycling, but these aims cannot be achieved without considering better recycling of other metals, plastics, and composites that are used in manufacturing goods.
As an example, ELVs are addressed as a waste-management problem in near future in Europe. Therefore, EU directive specifies the minimum reuse and recovery rate for ELVs. Certainly, in near future, similar regulations will come out for other sources of scrap like obsolete appliances and other industrial wastes. The targets for ELVs recycling established by EU directive are:

- until 01/01/2006:
  - reuse and recovery of 85% on the mass basis (reuse and recycling 80%) for vehicles
- until 01/01/2015:
  - reuse and recovery of 95% on the mass basis (reuse and recycling 85%) for vehicles

This directive has encouraged car manufacturers to promote the avoidance of wastes by reducing the use of hazardous substances in new cars, improving the ease of dismantling in order to increase the rate of reuse, recycling and recovery, and integrating an increasing quality of recycled material in vehicles in order to develop the market for recycled material(s).
Although several studies on recycling ELVs have indicated these targets are too ambitious to be achieved, or at least the target for 2015 cannot be achieved according to the current composition of manufactured cars and the technologies available for recycling, the only way to achieve these targets is to consider the main actors in the vehicle life cycle that consist of components suppliers, original equipment manufacturers, car owners, repair shops, dismantlers, material recyclers, and shredders.
In future, the same perspective can be expected for the other manufactured good that are potentially recyclable.
To attain a high recycling rate and the targets established by authorities, one can think about two main strategic schemes. These strategic planes can not only be used for recycling of ELVs but for recycling other end of used manufactured products. These strategic schemes are shown and described in Fig.18.
According to Fig.18, recycling can be improved through either of each strategic scheme or, in a best case, by combination of these two strategic schemes.
For the first plan, Scheme 1, higher recycling rate and reduction the amount of produced ASR are sought by more intensive dismantling of ELV or other obsolete appliances. This can be carried out under financial encouragement for pre-established parts or materials used for manufacturing. For recycling of ELVs in European Union this has been considered as the main policy.
For the second strategic scheme, the higher efficiency and better recycling of different streams are looked for by upgrading processing available for the light and heavy fractions of the shredding streams as well as auto shredder residues (ASRs). Developing of separation technologies and finding recycling possibilities for products gained from separation stages are key factors with this respect.
Of course, the optimum way would be the combination of both strategies. This must be sought through complete identifying and understanding of key parameters determining technical, economical and environmental feasibility for the two strategic plans.

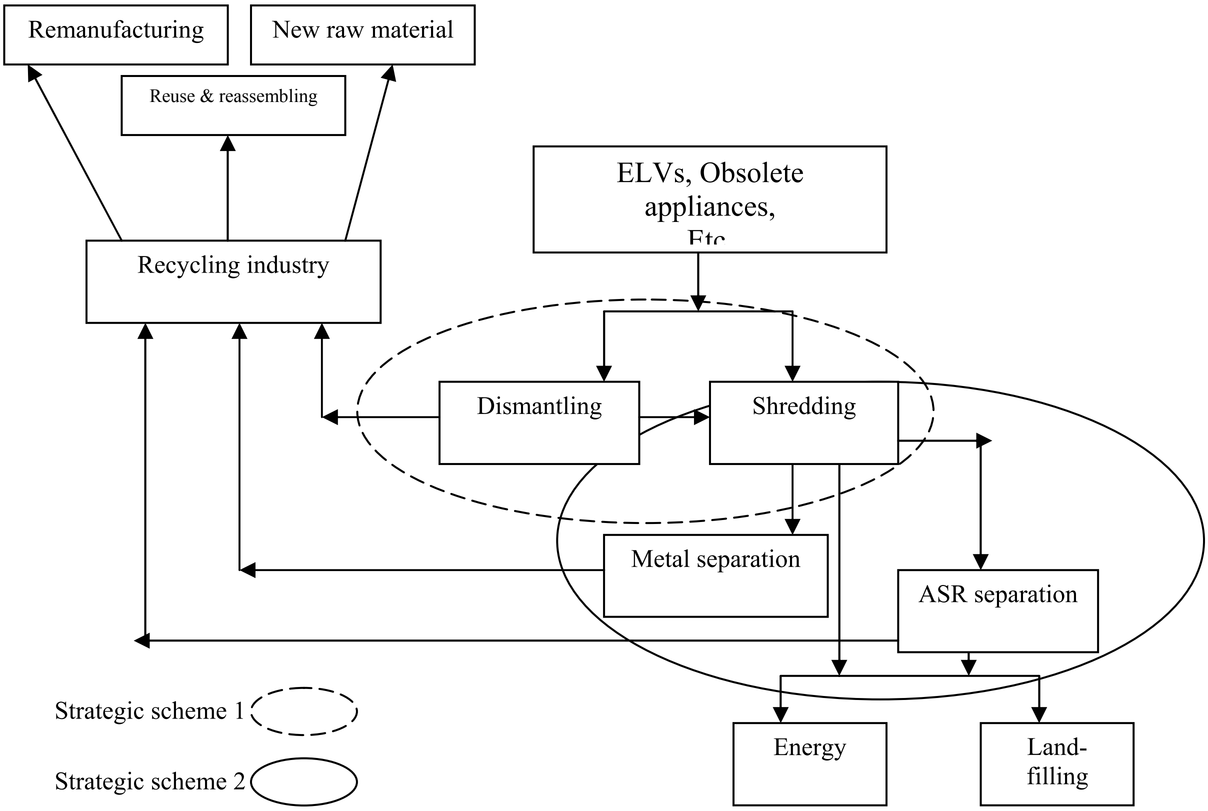

Fig.18- Strategic schemes for optimum recycling

Recycling of obsoletes consists of a combination of processes raging from de-pollution, dismantling, shredding, and physical separation to metallurgy and ended with the processing and combustion of inorganic/organic components for energy recovery. Even incineration and land-filling can be considered as part of recycling scenario, although due to legislation, these two actions are not considered as a recycling if there is no recovering of energy. Land-filling and incineration are included in the recycling flow-sheet in order to determine and control the system efficiency and losses. These are most determinant factor to point out poor design choices for separation.

Except incineration and land-filling, each of the processes involved in recycling scenario contributes to recycling, recovery/losses either by producing a product stream or an intermediate recycling stream that can be fed to a subsequent separation or recovery stage(s). This means that within the recycling schema there are very close relationships among different processes and material flows. This close relationship and the interrelations among different stages for recycling can be confirmed by Fig.19.

Efficiencies for each unit involved in recycling schema and the related process itself are factors strongly affecting the recovery of material.

There is a closing loop for material cycle, starting from raw material and product(s) manufacturing, ending with recycling and disposal. To close this loop, it is required to have a resource cycle approach transpiring all sequences, including shredding, mechanical separation, and metallurgical operations, and their mutual interrelations.

Quality of the materials achieved in each stage, e.g., material's quality and liberation, type of materials, their size fraction(s) and shape(s) at different stages of recycling, etc., are paramount important when the material cycle flow is ended.

In fact the quality of materials obtained from recycling chain, their liberation degree, as well as their type, shape and size are strongly determined by product design, shredding facilities and separation technology. This means in optimizing of resource cycle and recycling it is crucial to account and consider the incorporating among design, liberation, the quality of recycling intermediate product(s) from physical separation stages, and the metallurgical recovery. Of course, the final solution cannot meet success until we overcome the economy and environmental impacts.

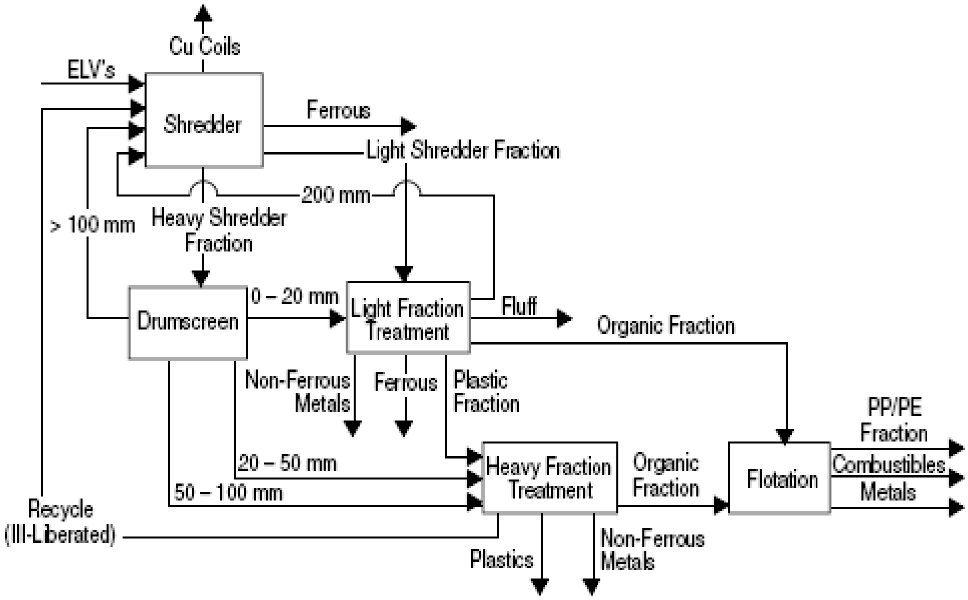

Fig.19- Simplified industrial recycling plant for ELVs due to current technology

Author believes that recycling would be improved and optimized by through understanding of all technical, economical, and environmental factors affecting the recycling processes. Identifying the materials composing the scrap and doing mass balancing for each material composing scrap bring a great benefit in constructing the optimum plant flow-sheet. Calculating the separation efficiency of the processes and the quality of the recycling streams as a function of particle size distribution, degree of liberation, and suitability for the potential user(s) are vital in leading us to a sustainable recycling.

As an example, a study carried out by Matsuto et al., (2004) on recycling systems available for home appliances in Japan is referred herein to show how detail study on recycling flow-sheet and material balancing for different compositions give a clear perspective for material recycling and waste generation through different recycling patterns.

According to the Matsuto et al., the comparison for material balances for 4 different scenarios of home electrical appliance recycling indicated that careful dismantling followed by shredding and separation results in higher recovery of metals and non-metal components and also less emission to the environment. The flow diagrams for these 4 different scenarios are depicted in Fig.20; however, the material balance for this study is given before in Fig.3-6.

As it can be seen from the Fig.20 in the case of conventional (C) scenario the primary objective is volume reduction and all products are indiscriminately shredded in one shredder without the recovery of any components, except for refrigerant CFCs in refrigerators and air conditioners. The ferrous and non-ferrous metals are then recovered by magnetic and eddy current separator.

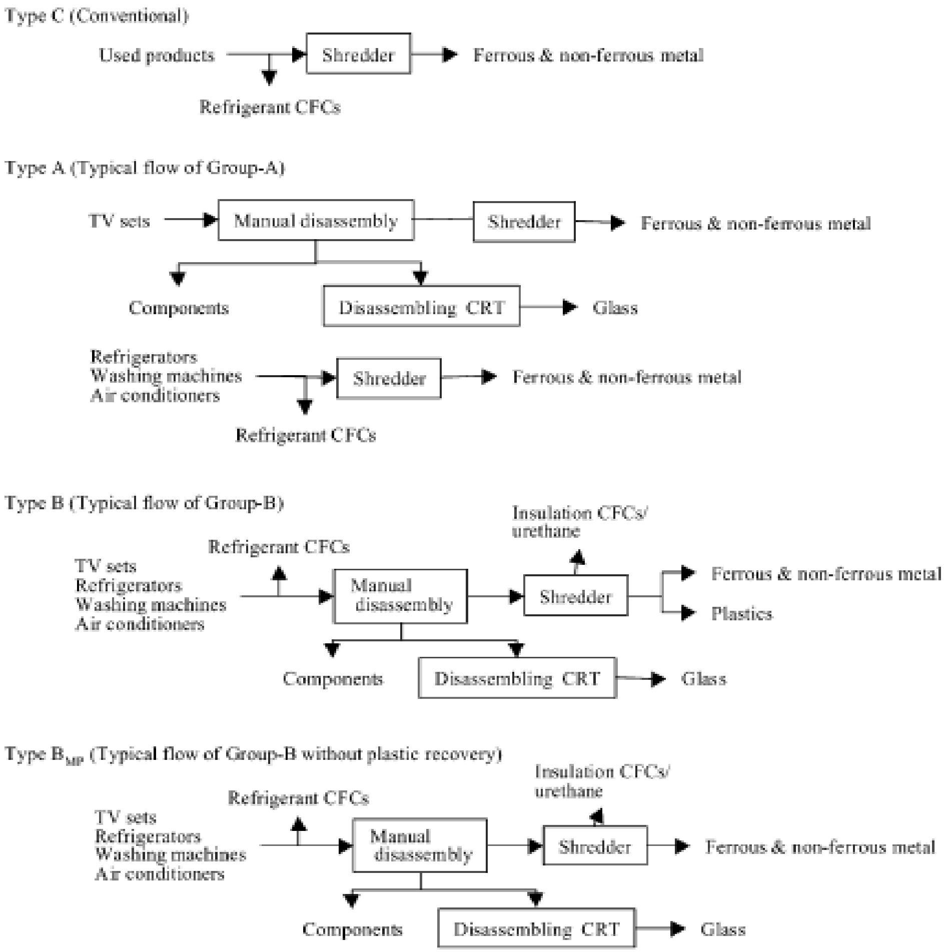

Fig.20 – Scenarios for home appliance recycling

For the scenario type A, however, the refrigerators, washing machines and air conditioners are treated like conventional scenario but TVs are processed in a separate line because of cathode ray tubes (CRTs). These tubes are recovered before sending the remaining of TV sets to the shredder. Then ferrous and non-ferrous metals are recovered by magnetic and eddy current separation.

In type B scenario, the components of obsolete appliances are recovered to the greatest degree possible. Motors and compressors are excluded prior to the shredding. In addition not only refrigerant CFCs, but also insulating chlorofluorocarbons are recovered.

For scenario type B_{MP}, plastics and urethane insulation are used as fuel and they are not recovered as the separate product(s).

A complete mass balancing has been carried out for all aforementioned scenarios that indicated the material recovery rate for TV is considerably enhanced through CRT recovery. In general, better recovery can be achieved by scenarios type B, i.e., type B and type B_{MP}, However, minor increase in recovery rate is achieved for obsolete refrigerators, washing machines, and air conditioners. As it can be conceived from the Fig.21 the highest material recovery and lowest waste generation are achieved due to scenario type B. In this case, the rate of recycling reaches the 80% in which recycling of ferrous metal exceeds 40%.

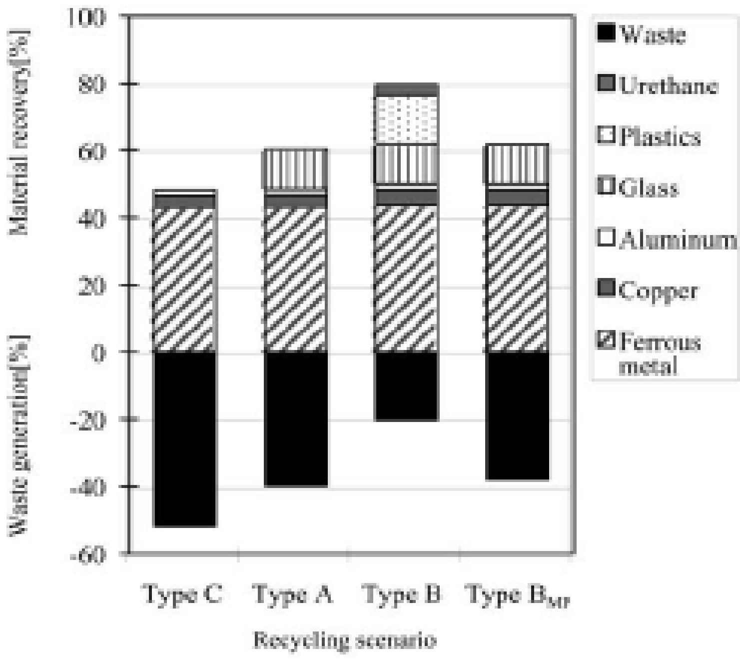

Fig.21 – Material recovery and waste generation rates for 4 types of recycling scenario

Mistra project with respect to iron and steel recycling would be a successful one if all possible and available classification and separation processes are tested with respect to industry needs for recycled materials that are obtained from shredding streams. Detail mass and recovery balancing with respect to the quality of the processed materials (liberation degree) and their particle size and shape must be done for the existing plants. At the same time flexibility of plants to accept different feeds and also the possibilities for minor or major changes in plant layout must be tested in laboratory and pilot scale. Meanwhile, emergence of new technologies, like sorting techniques, and their potential for improving the quality and quantity of the recycled streams must be considered and examined.

It is also noteworthy to mention that since ELVs, obsolete, derelict appliances, and other industrial wastes constitute of not only iron, steel and other ferrous materials, but aluminium and other nonferrous metals and their alloys, as well as plastics and rubber. This means that our society is characterized by production and use of complex multi-component products that are manufactured by using of wide range of different raw materials. Although the main objective within the Jernkontoret Stålkretsloppet program is to have optimum recycling for ferrous material with respect to the needs for iron and steel industries, the needs for other nonferrous and non-metal industries must not be kept beyond. Therefore, in order to have a comprehensive "roadmap" for recycling in Sweden a close collaboration among iron and steel industries and other industries, such as aluminium, copper, etc., is paramount important and strongly suggested. This is the way that shall be paved for sustainable development.

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