Fig 3.1: Deserted oil pump (Linda L

03 beyond fossil fuels

3.1 Introduction

This chapter studies the unsustainable condition of the present automotive industry, the future thereof and the resources it depends on.

In order to design spaces for automobiles to be transported, disassembled, stored and displayed in different categories of components, the technical issues regarding automotive recycling and waste management must first be understood. The current life cycle of automobiles will be studied and critiqued in order to form a new strategy of sustainable development, correctly positioning the proposed project within this cycle.

The process of automotive disassembly forms the basis of the strategy as well as the programme of the proposed building through the adaptive re-use of materials and parts.

Finally, the relevance of the proposed project and the contribution it can make to the surrounding community, as well as to the greater City of Tshwane, will form the conclusion.
The following aspects of the automotive industry will be analysed:
- Environmental impacts
- Embodied energy
- Life cycle of automobiles
- Disassembly process

Fig 3.2: "Fill it up!" (Foshie 2001)

3.2 Environmental Factors

Today's society assumes that an abundance of oil will be available for future generations and transport systems. The basic infrastructure of communities depends on the reliable supply of affordable oil. However, the growing demand for oil indicates that the days of affordable, ample oil will come to an end (Electrification Coalition 2010).

There are two underlying challenges regarding the state of fossil fuels: the extraction and consumption of oil.

More than 80 million barrels (13.25 billion litres) of oil are consumed around the world per day, with 44.2% used by automobiles in the form of petroleum (U.S. Energy Information Administration, Petroleum Statistics 2010).

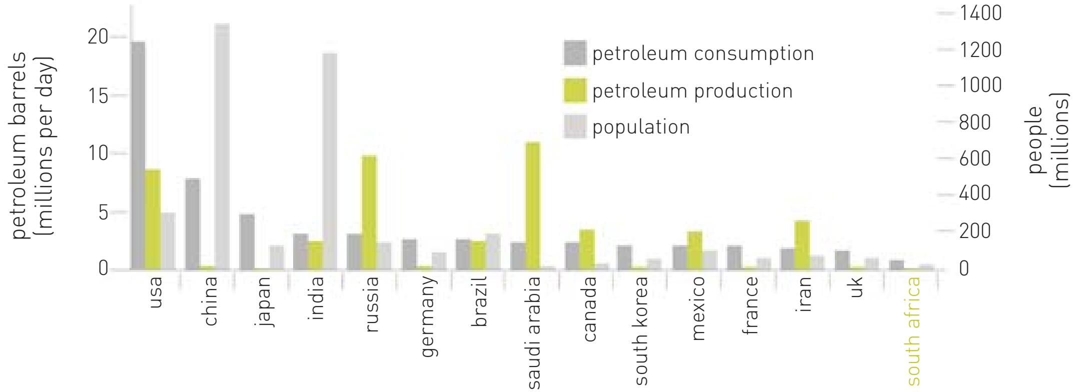

Fig 3.3: (Top) World Map of annual oil consumption per capita (Electrification Coalition 2010)

Fig 3.4: (Bottom) International petroleum consumption, production, and population (Electrification Coalition 2010)

Fig 3.5: Oil rig pump in operation (FAQS 2005)

The widespread use of automobiles has resulted in dangerous environmental impacts. Various toxic emissions (Carbon Dioxide (CO_2), Carbon Monoxide (CO), Nitrous Oxide (NO_x), Volatile Organic Compounds (VOC) and Sulphur Dioxide (SO_2) are released into the air when burning large quantities of oil in the form of petroleum (Institute for Energy Research (IER) 2010).

According to the United States Information Administration (2010), the emission of Carbon Dioxide (CO_2), which is the most influential Greenhouse Gas contributing to global warming, will double by the year 2035. On average an automobile releases approximately 9 tons of CO_2 every year, which adds up to 10% (1.5 billion tons) of total CO_2 emissions annually (National Resources Defence Council 2010).

Fig 3.6: (Top) Total oil produced in South Africa (Statistics South Africa 2010)

Fig 3.7: (Bottom) Total oil consumption in South Africa (Statistics South Africa 2010)

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Fig 3.8: Toxic exhaust fumes (Carsala 2009)

Pollution, by means of burnt fossil fuels, is most intensive in large metropolitan areas where high densities of automobile activity take place. The prevailing use of internal combustion engines is one of the sources of major environmental issues we face today.

However, recent studies suggest that the production of oil has reached its peak, making the future of obtaining oil and the reliance on imports more difficult, pushing prices of oil past the point which make personal mobility feasible (Index Universe 2010).

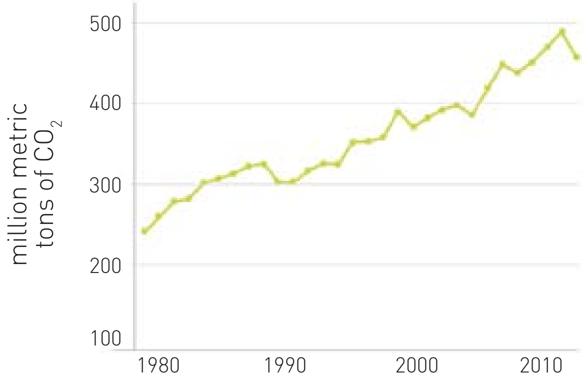


Fig 3.9: Average CO_2 emissions by cars in South Africa (Statistics South Africa 2010)

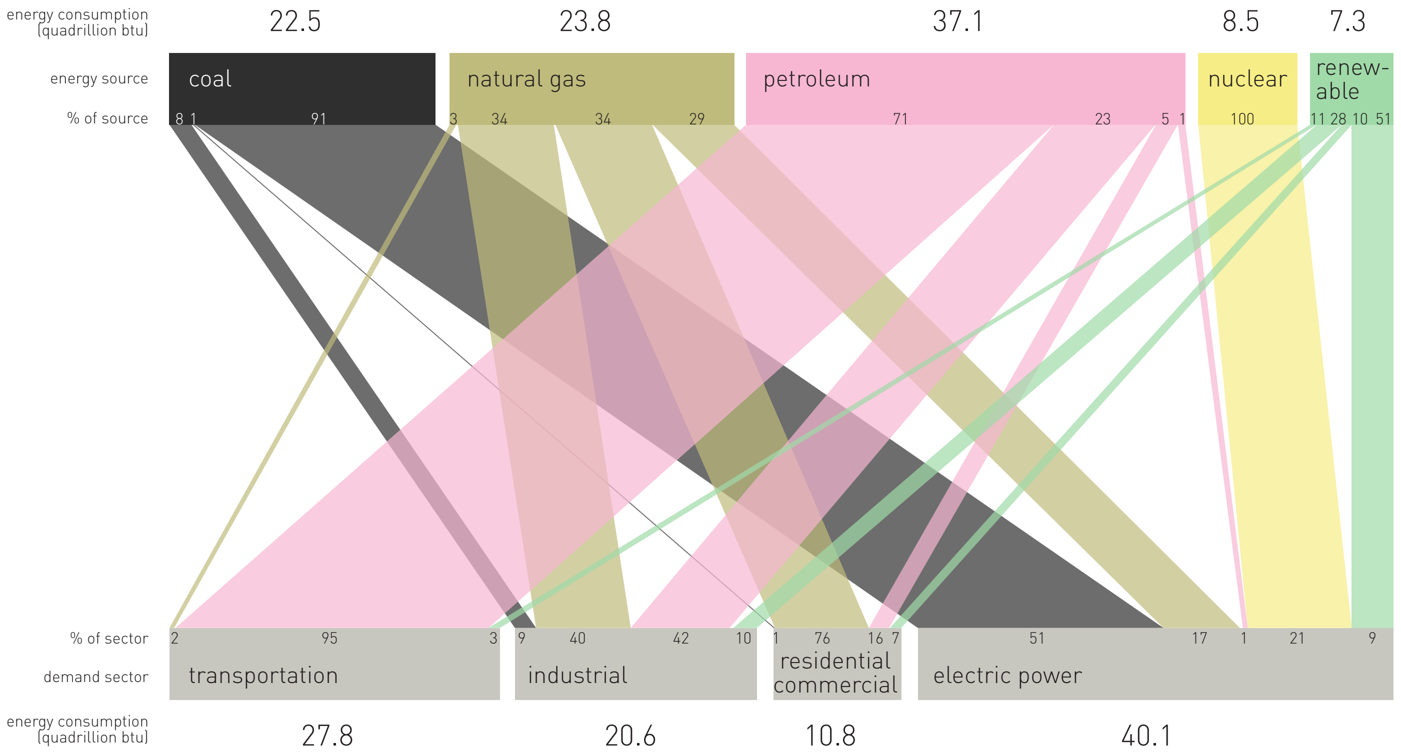


Fig 3.10: Worldwide energy consumption by source and end-use sector (Electrification Coalition 2010)

3.3 Embodied Energy

The term 'embodied energy' refers to the amount of energy (expressed in Joules) used in the entire life cycle of a product. The life cycle consists of raw material extraction, transport, manufacture, assembly, installation, disassembly, decomposition and recycling (Grant and Pearce, 2007: 435).

Therefore, a relationship forms between the embodied energy and the type/number of processing steps. For example, if a material's production consists of fewer and simpler processing steps, the embodied energy will be less - a material's embodied energy is often reflected in its price (Sustainable Design & Technology 2004).

Embodied energy units are generally measured in MJ/Kg, which is the number of megajoules of energy needed to produce a kilogram of product, providing a good indication of the sum total of the necessary energy for an entire product life cycle (WattzOn 2009).

There are a number of underlying problems regarding automobile manufacture. Besides the fact that automobiles are constructed using a wide spectrum of materials with high embodied energies, the production of materials occurs at various plants around the world. In the end of an automobile's production process, all the different components must converge at a single geographical location for assembly.

Recent studies show that the Toyota Prius, the world's most popular environmentally friendly passenger car, is not as sustainable as Toyota claims it is (WattzOn 2009).

Nickel, for example, has a high embodied energy (164 MJ/Kg) and is used in the batteries of a Prius to power its electric (hybrid) motors. The nickel in this case suffers a higher embodied energy due to transportation between three continents to reach the assembly format (Hammond and Jones, 2008: 12).

Fig 3.11: Toyota Prius (Motor Trend 2009)

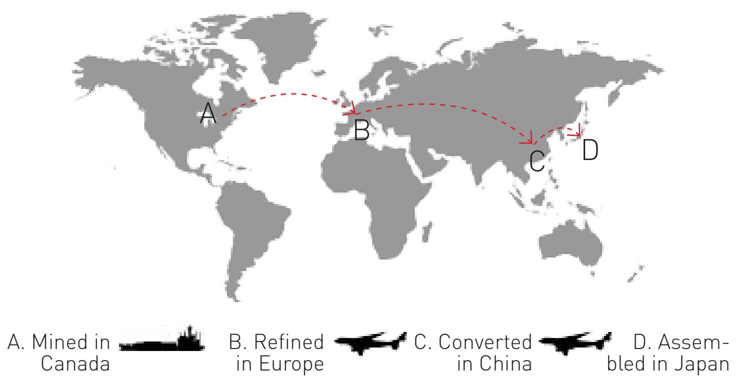
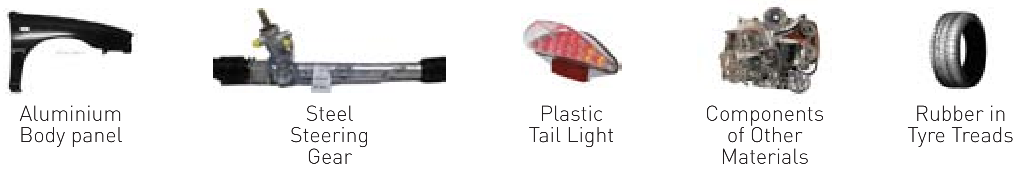


Fig 3.12: Toyota Prius Nickel production (Motor Trend 2009)

Material	Joule	Weight	Embodied Energy
Aluminium	49 897.812 MJ	269.82 Kg	184.9 MJ/Kg
Steel	32 089.087 MJ	734.51 Kg	43.6 MJ/Kg
Plastic	25 483.000 MJ	251.83 Kg	101.1 MJ/Kg
Other	11 992.000 MJ	122.92 Kg	97.5 MJ/Kg
Rubber	10 249.562 MJ	115.56 Kg	88.6 MJ/Kg
Manufacturing	35 500.000 MJ	-	-
Transportation	4 511.240 MJ	(12 038 Km)	-
Total	169 772.701 MJ	1494.64 Kg	515.7 MJ/Kg

Fig 3.13: Embodied energy of a automobile's main materials (Motor Trend 2009)

Fig 3.14: Automobile components made from different materials, Image Collage by Author 2011



Advances in technology, performance, safety and style have resulted in the use of materials with a higher embodied energy. It is estimated that the energy needed to manufacture an automobile is equivalent to 15% of the total fuel used during a 20 year life cycle (Green Choices 2010).

The purpose of automotive recycling through disassembly can lead to an automotive industry which use the minimum required spectrum of materials, materials with low embodied energy and automobiles that are designed specifically for this end result.

Fig 3.15: Components of a Toyota Prius (Motor Trend 2009)

3.4 Life Cycle of Automobiles

Similar to any other product that is used and/or consumed on a daily basis, automobiles can be seen as products with an expiry date. Whether the expiry is reached through mechanical failure or an accident, automobiles have a limited life span (average of 9 years in the Gauteng Province) (Statistics South Africa 2010).

All stages of a product's life cycle require evaluation in order to determine the environmental attributes of the product. The product's production, use and disposal must be taken into account.

Currently, the automotive industry is geared to produce automobiles on a monumental scale, concentrating on making the final product available to the user – an "Open Life Cycle".

A new strategy of a "Closed Life Cycle" will be formed to substantiate the proposed building programme and to address the sustainability of automobiles.

Fig 3.16: Daily consumption of milk (Drink Milk Campaign 2002)

Fig 3.17: Best before date of a vehicle (Junkmail 2010) Edited by Author 2011

3.4.1 Open Life Cycle:

Characterised by the disposal of products (automobiles) after use, this cycle is generally adopted by the automotive industry. The focus here is to produce a product; preservation of resources by saving energy and materials are not a priority. The outcome is poor waste management of end-of-life automobiles (ELV's).

Fig 3.18: Open life Cycle of automobiles (Joachim Schmidt 2011), Illustrated by Author 2011

3.4.2 Closed Life Cycle:

Instead of focusing on the product, this cycle concentrates on how automobiles can be recovered after their service life – creating a system where waste equals food for future use. Materials can be recycled and reintroduced in the production of new parts. Operational parts obtained from recovered automobiles can be re-used as spare parts (without reworking/repair of the parts) or as exchange parts (reworked and repaired parts/components by different industrial methods for re-application).

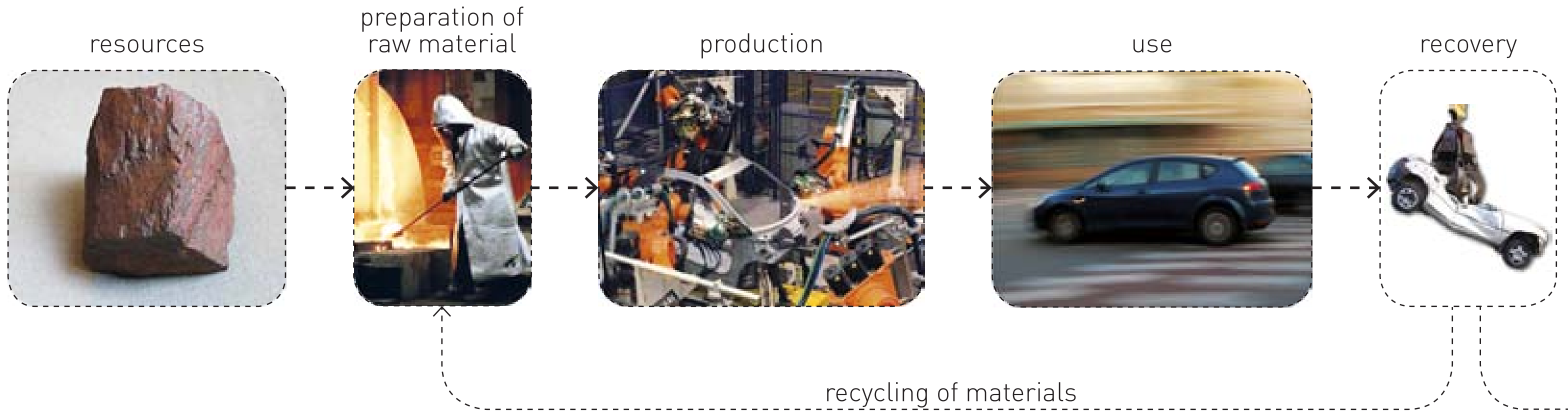


Fig 3.19: Closed life Cycle of automobiles (Joachim Schmidt 2011), Illustrated by Author 2011

The proposed building programme is specifically positioned in the life cycle and use of cars to ensure reuse and recycling of materials and parts.

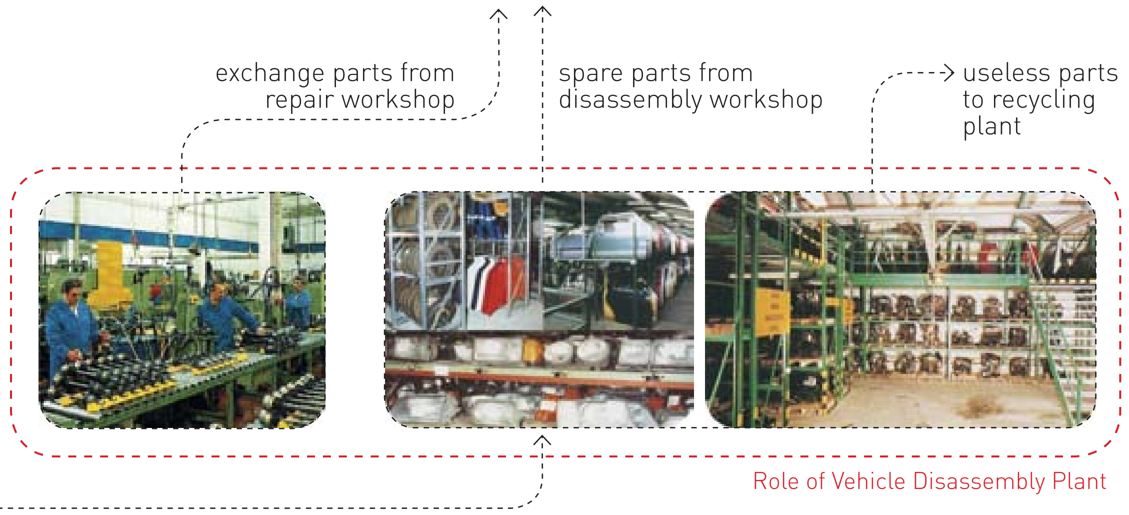


Fig 3.20: Positioning the proposed project, Illustrated by Author 2011

3.5 Disassembly Process

The term 'disassembly' can be described as the process of systematic removal of desirable individual parts and components from an assembly, while ensuring that there is no impairment of the parts due to the process (Brennan, Gupta & Taleb: 2003: 59).

A substantial percentage of total manufacturing activity worldwide consists of discrete parts manufacturing. As the term suggests, discrete parts manufacturing includes the production of distinct end products such as automobiles, computer systems, weapons systems and consumer appliances.

The initial manufacturing systems, which dealt with assemblies, consisted of one way flows and were driven by material requirements (as discussed in 'The Life cycle of Automobiles' p. 50). New forces, such as increased awareness of the condition of the environment, have led to new challenges, such as the reappraisal of the traditional manufacturing paradigm.

According to Brennan et al (2003) forward-thinking companies are anticipating opportunities arising from this environmental change. Therefore, item segregation (the separation of a part or group of parts from an assembled component by adopting a reverse assembly process) is currently being facilitated in the form of disassembly plants and the introduction of designs which specifically regard disassembly processes. Once disassembled, components can be reused, recycled or stored for future use.

Leaders amongst car manufacturers regarding disassembly research and design are BMW, Volkswagen and Audi. BMW has invested in a disassembly plant where five automobiles are dismantled every day. Problems arising from disassembly are then studied to improve the design automobiles (Nussbaum and Templeman, 2007: 3).

Fig 3.21: Crushed Cars (Lee Jordan 2007)

Automotive manufacturers are confronted with two main sets of issues when addressing the disassembly of a car, namely technical and operational issues (Brennan, Gupta & Taleb: 2003: 59-62).

3.5.1 Technical:

The most significant technical challenge is to design a product with 'easy' assembly properties as well as 'easy' disassembly properties. Traditionally, machines were designed only with the assembly in mind, but designers should start thinking about disassembly and recycling of parts. Certain design criteria have been identified regarding the technical aspects of disassembly:

- Ease of separation: Design for easy separation, handling and cleaning

- Reduced energy use: The design must aim to reduce the embodied energy

- Intelligent fasteners: Existing screws, glues and welds should be replaced by new two-way snap-fit fasteners

- Reduced number of material types: The spectrum of different materials must be minimised and changed to accommodate recycling processes

- Component/Part consolidation: Reduced total number of operational components through consolidation allows for easier sorting

Fig 3.22: Completely disassembled automobile (Team BHP 2003)

3.5.2 Operational:

In order for a disassembly process to work, the following major operational guidelines must be investigated:

- Accumulation: The treatment of materials and components after disassembly

- Location: The transportation cost of materials to different facilities (recycling, storage and market/retail area) is the main issue regarding location

- Resource availability: A constant supply of resources for the plant to operate

- Networking systems: Operations must be planned from a larger perspective to accommodate different role-players, for example manufacturing plants, resource sites, scrap yards and recycling facilities.

The disassembly scenario has the following economic and environmental advantages (Brooke: 2000: 71):

3.5.3 Reduction in lead time:

Products might have to be disassembled in order to recover some of their subassemblies or component parts which are scarce or in urgent demand by other products and customers. In such an event, substantial lead time (time interval between the initiation and the completion of a production process) reduction can be achieved with the procurement of disassembled components.

3.5.4 Forced disassembly:

As in the case of automotive disassembly, plants are forced by recycling regulations to disassemble automobiles before discarding the materials and components, even if the parts are rendered useless.

3.5.5 Discontinued products:

In some instances, for example a suddenly discontinued product line, this can lead to excess inventory of undesirable assemblies. Disassembly scheduling can be harnessed to retrieve valuable components used in other products which are still being produced. The remainder of the components and materials can be recycled, sold or stored for future use.

The proposed vehicle disassembly plant focuses on the recovery of subassemblies and components of ELV's found in Pretoria West. Thus, the building programme will adapt the reduction in lead time strategy by making components available that are scarce or in urgent demand.

Due to the fact that recycling and safety regulations must be adhered to, the forced disassembly strategy forms part of the project when dealing with ELV's which are recycled.

Fig 3.23: Car Recycling Systems, Holland (Joachim Schmidt 2011)

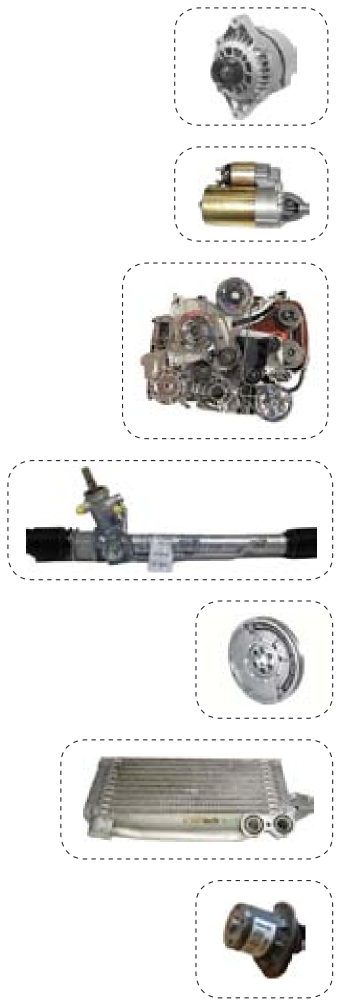


Fig 3.24: Car parts on demand due to accidents and failures (Joachim Schmidt 2011)

Fig 3.25: Prescribed disassembly process, Joachim Schmidt 2011, Illustrated by Author 2011

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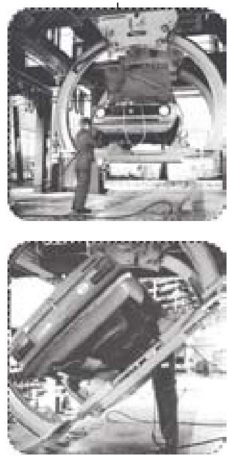
prescribed steps of the disassembly process

storage of end-of-life vehicles (ELV's)

Vehicles mounted on 'C-Arm', enabling workers to manipulate vehicles in any position for better ergonomics.



1

air bags
seat belt
tensioners

Neutralization of explosive components: Air bags and seat belt tensioners are disassembled in an explosion control chamber by specially trained staff in order to adhere to safety regulations.

2

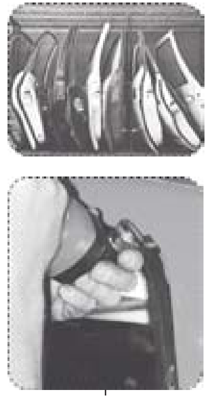
batteries
tyres

Standard specification for tyre and battery removal is recommended.

3

oil
petrol/diesel
brake fluid
anti-freeze

Removal of 20-30 litres of liquids:
Fuel: Tank is bored into with a drill containing a hole in the centre where the fuel is pumped through. Oil: Drained through provided plugs by free fall.



4

glass
bumpers
doors
suspension

Bumpers, doors and suspension are generally dismantled by standard tools found in automotive workshops.
Glass: The adhesive bond must be dissolved by induced heating or cut by a hydraulic/electric knife in order to remove the glass panel.

5

seats
upholstery
plastics

The interior components are disassembled with standard tools found in automotive workshops.

6

engine
catalytic-converter
transmission

Engines and transmission systems are generally dismantled by standard tools found in automotive workshops, additional systems to lift and move heavy components are essential.

7

compression of body

After the disassembly process the empty shell of the car is compressed by a hydraulic compressor, improving the ease of transport to the shredder plant.