The circular economy of cars

Turku University of Applied Sciences

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# Glass dismantling test report

## Glass recovery from end-of-life vehicles

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# 1 Introduction

The purpose of this report is to determine how much tempered glass can be recovered per vehicle, the duration of the work, and the purity level of the collected glass.

The report concerns the recovery of glass from End-of-Life Vehicles (ELV) as part of a car circular economy project. The test was conducted on August 6 and 8, 2025. The collection method focused specifically on breaking and recovering side, door, and rear windows.

The report describes the equipment used, the working methods, and the weighing processes. It also analyses the amount of glass collected, its purity, and the efficiency of the work. The results are compared to the original amount of glass in the vehicles, and the recycling potential is evaluated as part of a broader circular economy project.

# 2 Equipment used

In this section, the equipment and safety gear used during the work are described.

## 2.1 Safety hammer used for breaking glass

A car safety hammer was used to break the glass. It proved to be an efficient and safe tool for the job. The hammer enabled a fast work phase, and the glass was able to be shattered in a controlled manner. It was easy to use and required minimal physical force.

Picture 1. Car safety hammer.

At the beginning of the test, a spring-loaded glass breaker was also tested, but it proved to be impractical. The breaker went through the window along with the user's hand and arm, which posed a safety risk.

## 2.2 Steel pry bar used for removing glass

Glass was removed from the window frames and door seals using a steel pry bar. The tool worked well for removing the remaining glass, and its use required minimal physical force. Since glass almost always remained in the window seals, using this tool was essential.

Picture 2. Steel pry bar.

## 2.3 Glass trolley used for collecting glass

A specially designed glass collection trolley was used to collect glass from the car doors.

### 2.3.1 Structure and function of the glass trolley

The glass trolley is designed for car doors. The trolley is equipped with wheels, which make it easy to move around. The bottom of the trolley serves as a collection surface for the glass shards, and its mobility allows the glass to be tipped from the trolley into a collection bin. The trolley features a fixed safety cover that encloses the sides of the car door, except for the hinge side. The

safety cover protects the user and the environment from glass shards during the breaking process. The purpose of the cover is also to guide the glass shards onto the collection surface.

Picture 3. Glass trolley.

The usage process of the trolley is as follows: The trolley is pushed under the car door, which requires opening the door completely. Once the safety cover encloses both sides of the car door, breaking the glass can begin. The glass is broken through the openings, allowing the largest shards to fall onto the trolley's collection surface. Any glass remaining in the door frames and seals is broken using a pry bar.

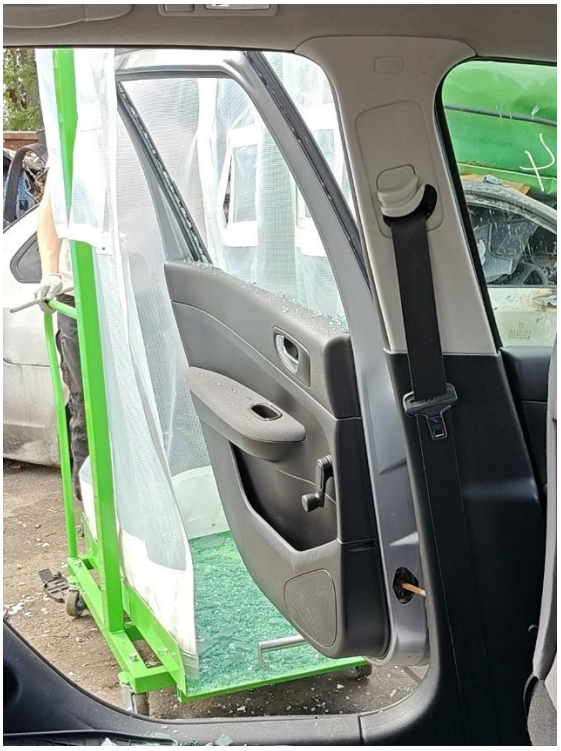
Picture 4. Pouring glass out of the cart.

### 2.3.1 Use of the glass trolley and identified issues

The trolley works as designed, but there were many identified problems with its use. The trolley could not fit under all doors, especially longer ones, causing glass shards to fly into the surroundings. For cars missing their wheels, the trolley could not fit under the doors at all.

The biggest problem was the spreading of glass. The safety cover did not fully enclose the door, especially on the hinge side. Glass flew out of the trolley during both the breaking process and while moving the trolley, which negatively affected the collection rate and compromised occupational safety. The trolley was also difficult to move due to glass shards on the ground.

Additionally, the safety cover was not transparent, which made the breaking process and accurately positioning the trolley under the door difficult. It was hard to see the door's position from behind the trolley, reducing work accuracy and ergonomics. Lifting the bottom of the trolley, i.e., the collection surface, from the floor level was physically demanding and ergonomically challenging, especially during repetitive work.



Picture 5. The car door inside the cart.

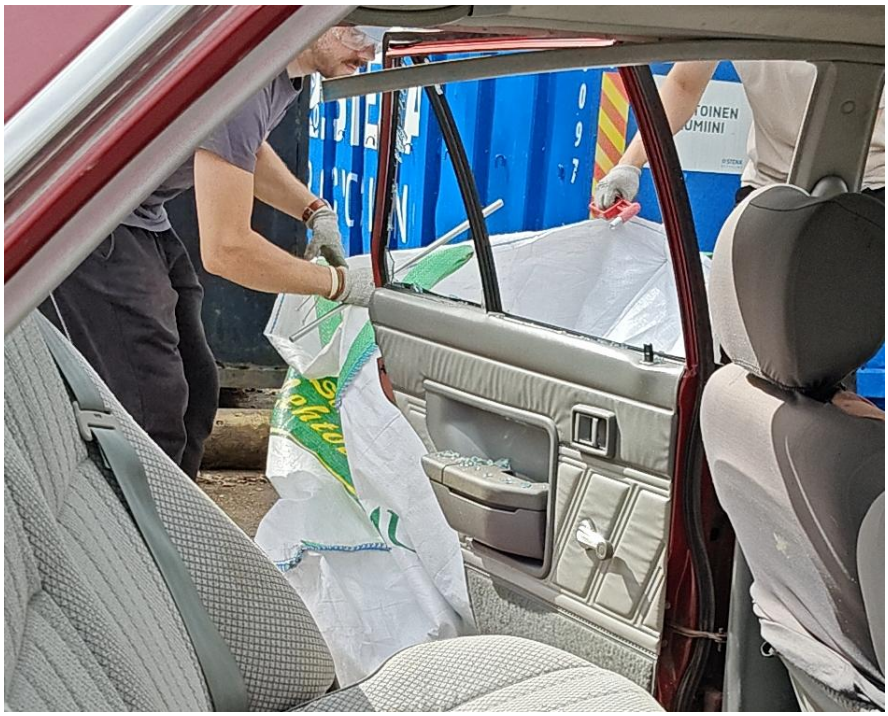
Picture 6. Glass crumb in collection container.

## 2.4 Other equipment used for collection

A plastic mat was used to collect glass attached to the car's body, such as side and rear windows. "Bagging" the car doors was also tested, which involved enclosing the door in a large industrial bag.

### 2.4.1 Industrial bag

A method where the car door or tailgate was enclosed in an industrial bag was tested on a few cars, and this method proved to be surprisingly effective. The industrial bag was easy to place around the door/tailgate with the help of a work partner and stayed firmly in place while breaking the glass. The glass shards remained inside the bag, and no significant amount of glass spread into the surroundings. Using the bag was even faster than using the glass collection trolley.



Picture 7. Removal of industrial bag from the door.

Ergonomically, the industrial bag was more challenging than the collection trolley, as handling, carrying, and emptying the bag required more physical

effort. Although the industrial bag was not ergonomically superior, its functionality and collection rate were better than those of the collection trolley.

### 2.4.2 Plastic mat

In some cases, especially when the glass was attached to the car's body (e.g., side and rear windows), a plastic mat was used to collect the glass. The mat was placed next to the window inside the car so that most of the shards would fall onto it. The mat was easy to move, making it particularly suitable for situations where the rear window is attached to the body. However, the mat did not prevent the glass from spreading into the surroundings; shards fell during both the breaking and collection processes.

Picture 8. Plastic mat and rear glass.

## 2.5 Glass weighing tool: platform scale

A platform scale was used to measure the weight of the collected glass. This allowed the glass to be weighed directly during the collection phase without a separate transfer step. The crushed glass was tipped from the collection trolley into a pre-weighed collection bin placed on the ground.

Picture 9. Collection container and platform scale.

## 2.6 Safety equipment

The safety equipment used for breaking the glass included safety goggles and cut-resistant gloves, which were worn throughout the entire test. Additional safety gear included safety shoes and, when necessary, work overalls to protect against glass shards.

# 3 Methods

This section describes step-by-step how the vehicle glass was broken, collected and weighed. The study material consisted of 25 vehicles.

## 3.1 Material

The test was conducted on a total of 25 End-of-Life Vehicles (ELVs). The vehicles were depolluted and positioned in a queue using a forklift and the details of each vehicle were recorded prior to the commencement of the work. The study sample consisted exclusively of four-door passenger vehicles. All vehicles had intact side windows and rear windows. The test was performed by a two-person team.

Picture 10. Cars in queue.

## 3.2 Collection process

The glass collection process proceeded as follows. The collection time was recorded separately for each vehicle and commenced when both workers were positioned at the designated starting point. The workers then proceeded to the vehicle with the necessary equipment to collect the glass. After all glass, excluding the windshield, had been removed and collected, the workers returned to the starting point. The collected glass was transferred to a weighing container and the timing was stopped. The glass was subsequently weighed and then transferred to a collection container.

Picture 11. Collecting process in progress.

### 3.2.1 Handling of side windows

The window was broken with a safety hammer, and the glass shards fell into the trolley or onto the plastic mat. The glass remaining in the frames was removed with a pry bar. If the side windows were attached to the car's body, a plastic mat was used.

### 3.2.2 Handling of rear windows

When the rear window was installed in the tailgate and the tailgate could be opened, the tailgate was enclosed in an industrial bag, and the glass was shattered using a safety hammer. If the tailgate could not be opened or if the rear window was attached directly in the vehicle body structure, a plastic mat was used to contain the glass fragments during breakage and collection.

## 3.3 Weighing process

The collected glass was weighed using a platform scale, which enabled accurate and efficient weighing after the collection phase. The weighing process proceeded as follows. Before the actual weighing, all used measuring bins were weighed, and their weights were recorded. This allowed the calculation of the net weight of the collected glass material.

Once the glass was in the measuring container, the container was placed on the platform scale. The scale displayed the total weight, from which the tare weight of the container was subtracted to obtain the exact weight of the glass.

The measurement results were rounded to the nearest gram to ensure the data was consistent and easily comparable.

After weighing, the glass was poured into a larger collection container, which in this case was a battery recycling box. This allowed for convenient storage for further processing of the glass.

## 3.4 Dismantling the door structure

In addition, a detailed assessment was conducted on two vehicles to determine the amount of glass remaining within the door structure after glass removal. For this purpose, the side doors were dismantled, and the interior door trim panels

and window seals were removed. Residual glass fragments were collected from the door cavities and window frames using an industrial vacuum cleaner and subsequently weighed.

Picture 12. Doors ready to be taken apart.

# 4 Results

This section examines the results of the collection test. The section includes the averages of collected glass, an assessment of the purity level, and observations from the data.

## 4.1 Amount of tempered glass per vehicle

During the collection test, an average of 12.4 kg of tempered glass was recovered per vehicle. This amount does not include the windshield but consists of the side and rear windows. The amount of glass varied depending on the vehicle type and the structural location of the windows. The amount of glass vacuumed from the door structures averaged approximately 1 kg per vehicle.

## 4.2 Working time

The working time was measured per vehicle; the average working time was 5 minutes and 9 seconds per car. The working time was affected by factors such as the location of the windows, the collection method used (trolley, plastic mat, industrial bag), and the different workers.

## 4.3 Purity level of the glass

The collected glass exhibited a generally high level of purity. Nevertheless, impurities were identified within the material that adversely affected its acceptance classification. Fragments of rubber window seals constituted the most significant contaminant and were the primary factor lowering the quality grade of the recovered glass. Had these impurities been absent, the material would have qualified for the highest purity classification. Organic contaminants, such as pine needles and leaves had a negligible impact on the overall purity of the collected glass.

Picture 13. The purity of the glass, rubber seals (2pcs) at the bottom of the image.

Based on the quality assessment, the recovered glass was classified as acceptance category 2 (chargeable material), primarily due to contamination by fragments of rubber seals. Materials in this category typically include clean windshield glass. In the absence of these contaminants, the purity of the recovered glass would have satisfied the criteria for acceptance category 1 (creditable material).

Table 1. Measurement results and car data.

| | Manufacturer | Model | VIN | Duration | Car weight | HC | Glass purity | Remarks | Weight of glass |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Ford | Mondeo 2.5 | WF05XXGBB52T67303 | 5 min 40 s | 1507 kg | 2 | Excellent | Red hammer was be | 12.40 kg |
| 2 | Opel | Meriva A 1.6 | W0L0XCE7564222940 | 4 min 51 s | 1375 kg | 2 | Excellent | Rear door did not op | 10.30 kg |
| 3 | Opel | Astra F Sedan | W0L000057R5028052 | 4 min 45 s | 1030 kg | 2 | Excellent | Black hammer used | 11.46 kg |
| 4 | Ford | Mondeo 2.5 | WF0FXXGBBFRA77884 | 5 min 04 s | 1390 kg | 2 | Excellent | Could not collect all | 10.86 kg |
| 5 | Saab | 9-3 2.0 | YS3FF45SX41014748 | 4 min 18 s | 1530 kg | 2 | Excellent | Less glass recovered | 12.96 kg |
| 6 | Nissan | Primera 2.0 | SJNFCAB12Q0122392 | 5 min 41 s | 1414 kg | 2 | Excellent | Passenger door lock | 13.06 kg |
| 7 | Renault | Clio 1.4 | VF1BB0C0F18706074 | 5 min 02 s | 1035 kg | 3 | Excellent | Rear door did not op | 9.80 kg |
| 8 | Nissan | Almera 1.8 | SJNBBAN16U0351674 | 3 min 16 s | 1261 kg | 2 | Excellent | | 12.90 kg |
| 9 | Peugeot | 307 1.6 | VF33E9HXC84831857 | 5 min 25 s | 1359 kg | | Moderate | Doors removed befo | 9.90 kg |
| 10 | Opel | Astra 1.8 | W0L0AHL3552150536 | 6 min 40 s | 1325 kg | 2 | Excellent | Trunk did not open | 11.82 kg |
| 11 | Nissan | Almera 1.8 | VSKTBAV10U0092466 | 6 min 00 s | 1445 kg | 2 | Excellent | Small windows of tr | 13.18 kg |
| 12 | Volvo | 850 | YV1LW7202T2255232 | 6 min 30 s | 1580 kg | 2 | Excellent | | 16.42 kg |
| 13 | VW | Golf 2.0 | WVWZZZ1KZ8M359643 | 11 min 13 s | 1489 kg | 2 | Poor | Glass has film. Tires | 14.70 kg |
| 14 | Peugeot | 307 | VF33ENFUB83351931 | 4 min 29 s | 1344 kg | 2 | Excellent | Rear window missin | 8.30 kg |
| 15 | Datsun Nissan | Sunny | JN100HB11U0535303 | 3 min 48 s | 850 kg | 2 | Excellent | Method: industrial b | 12.74 kg |
| 16 | Nissan | Almera | SJNBAAN16U0301054 | 3 min 28 s | 1254 kg | 2 | Excellent | | 13.10 kg |
| 17 | BMW | 316i | WBAER11090KC15798 | 3 min 26 s | 1385 kg | 2 | Excellent | | 13.16 kg |
| 18 | Citroen | Xsara Picasso | VF7CHNFVB39096052 | 14 min 25 s | 1315 kg | 2 | Moderate | Nine windows. | 16.44 kg |
| 19 | Renault | Megane Scenic | VF1JA0B0227473981 | 10 min 05 s | 1355 kg | 2 | Moderate | | 13.36 kg |
| 20 | Opel | Vectra | W0L0ZCF6951102274 | 4 min 25 s | 1375 kg | 2 | Excellent | | 13.28 kg |
| 21 | Mazda | | JMZGY193671450232 | 6 min 40 s | | 2 | Poor | | 12.92 kg |
| 22 | Ford | Mondeo | WF0FXXGBBFTY70774 | 3 min 48 s | 1350 kg | 2 | Excellent | | 12.00 kg |
| 23 | Citroen | Saxo | VF7S1HDZF56383844 | 3 min 30 s | 900 kg | 2 | Poor | | 10.90 kg |
| 24 | Fiat | Punto | ZFA18800000950750 | 4 min 01 s | 950 kg | 2 | Excellent | Method: industrial b | 11.62 kg |
| 25 | Renault | Megane Scenic | VF1JM0U0A32543368 | 11 min 27 s | 1485 kg | 2 | Good | | 12.70 kg |

## 4.4 Dispersion and sample size

The sample consisted of 25 vehicles, which is a limited sample size, but enough to indicate the effectiveness of the method. The dispersion was small, and most of the vehicles produced results close to the average in terms of both the amount of recovered glass and the working time.

## 4.5 Windshield collection comparison

The windshield was not weighed in this test, but as a comparison, a previous test conducted at the Turku Vocational Institute can be used, where the windshield was removed using a reciprocating saw, achieving a collection rate of almost 100%. This method for windshield removal takes approximately 2 minutes. The average weight of a windshield per vehicle was approximately 10.44 kg.

## 4.6 Total amount and proportion of side windows

According to the test conducted at the Turku Vocational Institute, where the collection rate for side windows was almost 100%, a total of 16.55 kg of tempered glass was recovered. When comparing this to the 12.4 kg result achieved with our glass-breaking method, the collection rate for this method is 74.92%.

Calculation formula:

(12.4 kg / 16.55 kg) × 100 % = 74.92 %

## 4.7 Total amount and proportion of windshield and side windows

When the average weight of the windshield (10.44 kg) is added to the test results, the total amount of glass recovered per vehicle is 22.84 kg.

Calculation formula:

10.44 kg (windshield) + 12.4 kg (side windows) = 22.84 kg

When comparing the total glass amount from our test (22.84 kg) to the total glass amount obtained at the Turku Vocational Institute (26.99 kg), the collection rate for the method is 84.62%.

Calculation formula:

(22.84 kg / 26.99 kg) × 100 % = 84.62 %

# 5 Areas for improvements

The test demonstrated that the methods used were largely effective, although several opportunities for improvements were identified. The most significant areas for further development included the containment of glass fragments during breakage and collection, the design and functionality of the collection cart, and the overall ergonomics of the work process.

## 5.1 Use of the industrial bag for bagging doors

One of the methods evaluated during the testing process was the enclosure of vehicle doors using an industrial bag commonly employed in industrial operations. The bag played a significant role in the test due to its effectiveness in containing glass fragments. Majority of the shattered glass remained within the bag, resulting in substantially less dispersion of glass into the surrounding environment compared with the collection cart method. Although the ergonomic characteristics of the method were not ideal, the use of industrial bags appears to be a promising avenue for further development and optimization in future studies.

## 5.2 Development suggestions for the collection trolley

The collection cart design could be further improved by adding a closed or partially enclosed section on the hinge side to reduce the escape of glass fragments during the breakage process. Furthermore, the collection surface could be equipped with a fixed or mechanically assisted lifting mechanism to minimize physical workload and improve operator ergonomics. The incorporation of a transparent protective cover would enhance visibility and thereby facilitate accurate cart positioning and improving the efficiency of the glass fragmentation and collection process.

## 5.3 Purity of the glass

The reception class of the glass was assessed as Class 2 (chargeable material) due to the rubber seals. The seals could have been easily removed during a visual inspection, either directly from the trolley or while tipping the glass out. To maintain the purity level, sieving or a similar method could also be applied, as the shattered glass itself is small compared to the impurities.

# Conclusions

The main objective of the report was to determine what percentage of tempered glass from End-of-Life Vehicles (ELVs) can be recovered using the applied method. The test demonstrated that a significant amount of tempered glass can be recovered using the breaking method.

The working method was fast, and the glass collection succeeded relatively efficiently. Although the collection rate did not reach the best possible level, the test demonstrated it to be a potential method for collecting car glass.

The method's biggest limitation related to the spreading of glass shards, as the glass spreading into the surroundings during the breaking phase and transport reduced the total amount of glass recovered, and made moving the trolley more difficult. Additionally, there were challenges with the glass purity level, as small pieces of rubber seals got mixed in with the glass. This may require additional processing before recycling or using other collection methods to maintain the purity level. The reliability of the results may also be limited by the small sample size, as the test was conducted on only 25 vehicles.

The test results can be used as a basis for developing even more efficient car glass collection processes. The method can be improved so that the collection rate increases, and the number of impurities decreases. In further development, the potential use of the industrial bag or improvements to the glass collection trolley should be investigated. Additionally, it would be beneficial to conduct a broader test with a larger number of vehicles to gain a more comprehensive understanding of the method's efficiency. In a broader test, improved collection methods should be used to maximize the amount of glass recovered. The goal of further development is to recover as much of the car's side windows as possible.