Closed-loop polypropylene[1] an opportunity for the automotive sector

by

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FOREWORD

The recycling of PP (polypropylene) plastics relies on the involvement of certain companies and scientific bodies who are working towards developing a French industrial sector for technical products made of recycled plastics taken from end-of-life vehicles. These industrialists ***(MTB Recycling (Trept), Synova SAS (Tilliers sur Avre))*** *have agreed to work together and share their best techniques in order to develop viable and profitable solutions.*

The Renault Group has taken a proactive approach towards incorporating recycled materials in its vehicles since the Megane II, using an average of 30% recycled materials at the end of 2014. It has also set the bar for recycling End-of-Life Vehicles (ELVs) via Indra and the Life+ ***"Icarre 95"*** *project (industrial demonstrator to achieve 95% recycling of ELVs) and also for implementing circular economy schemes (remanufacturing of parts, parts for reuse, material closed loops, etc.).*

Plastic, the second most commonly-used material in vehicles after metal, is making up an increasing percentage of the composition of cars and is able to fulfil new technical functions thanks to high mechanical performance grades. However, recycling plastic is complex and the methods used (shredding, crushing, separation) are insufficiently selective, leading to substantial loss.

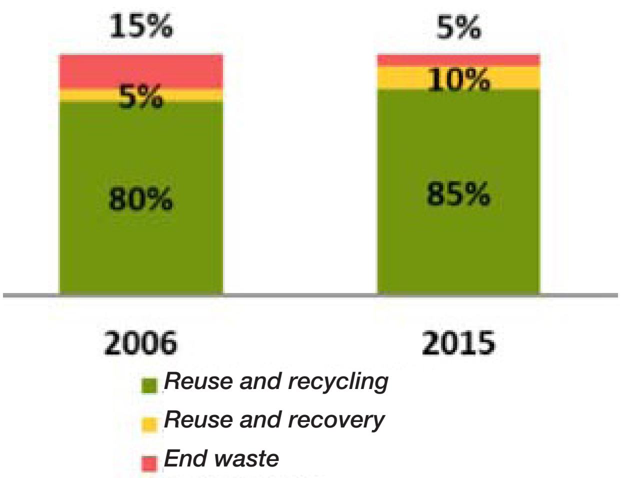
In light of this, the Renault Group has launched a study looking to increase the yield and value of transforming polypropylene (PP) materials, of which the automotive industry is a major consumer – every year, more than one million tons is used by European manufacturers alone.

Resource depletion - a factor we must now all consider

Non-renewable resources such as oil, necessary for manufacturing the majority of virgin plastics, are likely to be in short supply in the future. In order to reduce the pressure on natural resources, an alternative option is to use ***secondary raw materials***, i.e. recycled materials. Regenerating plastic requires half the energy needed for virgin plastic.

Ambitious regulatory targets

Once they reach the end of their service life, ***End-of-Life Vehicles (ELVs)***, deemed hazardous waste in regulatory terms, must be decontaminated and recycled. In order to meet the requirements of ***European Directive 2000/53/EC***, as of 1 January 2015 handlers are obligated to reuse 95% of ELVs overall: 85% recycled and 10% for generating energy.



ELV recovery targets according to the 2000/53/EC directive

In line with the principles of Extender Producer Responsibility (EPR), car manufacturers must design and promote processes for managing the waste created by their products.

Material costs - the key to competitiveness

The cost of raw materials affects the price of recycled materials. As it stands, the recycled plastics market is not yet mature and prices are not entirely correlated with the technical reality - rather than reflecting the transformation costs, they are mostly indexed against the price of virgin resin. Recycled materials are only preferred when they cost equal to or less than the virgin material.

In response to these issues, the Renault Group is actively working to develop and optimise the recycling channels for ELV recovery. Over one million ELVs are processed in France every year, the equivalent of more than one million tons of potentially usable material. There is a dual objective here: increase the recovery of End-of-Life Vehicles and increase the amount of recycled material available for use in new cars.

1 Closed loop: a term used in the Renault Group to indicate that the recycling, collection, logistical, preparation and transformation operations are relatively short (geographical proximity and are reused in the same sector).

The strategy developed by Renault to tackle this forms part of the ***circular economy***[2].

Developing closed loops for polypropylene (PP)

There is a growing demand for recycled plastics in the car industry. However, more than 80% of the available resources are currently derived from manufacturing scraps. Renault's vision is to offer an alternative made using waste from its own industry: End-of-Life Vehicles (ELVs). This is what is referred to as closed loop recycling, as opposed to 'open loop' where the recycled material is used in another industrial sector.

The Renault Group began using recycled plastic in its vehicles in the 1990s. In 2011, it went one step further and introduced closed loops for reusing parts and materials through its Icarre 95 project, which was co-funded by the European Life+ programme. Channels were developed, from collection to the end product, for three categories of material: plastics, metals and foams & textiles.

The closed loop developed for polypropylene (PP) plastics consists of transforming car bumpers (fenders) and wheel arch liners into directly reusable material that can be injected into new car parts.

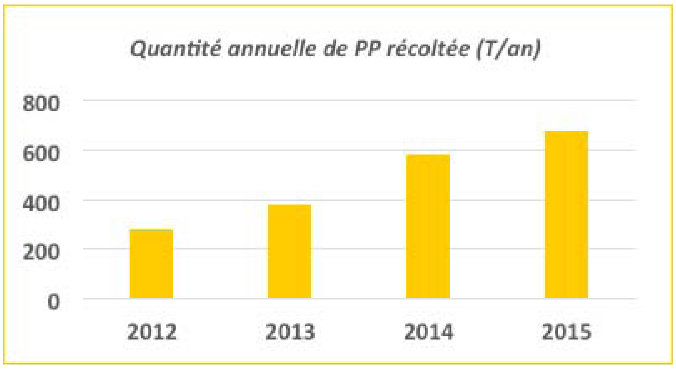
End-of-life parts are compacted into bales to facilitate transport, and are then shredded and placed in a floating tank to separate the different plastic qualities according to their density. The sorted material is then compounded: charges, additives and/or virgin material are added to improve the plastic's technical properties so that it meets client specifications.

Car bumper bales

The PP closed loop is the result of close cooperation between a variety of stakeholders, with each contributing their own specific skillset:

- ***Indra for dismantling materials:*** a joint venture between Renault and SITA/Suez Environnment that specialises in car deconstruction;
- ***Synova for developing and transforming materials:*** a chemical transformer that creates compounds using recycled material from car bumpers;
- ***Workshops in Renault concessions:*** these recover End-of-Life Parts (ELPs) from the vehicles they repair. They supply the recycling loop with its raw material.
- ***Subcontractor to prepare raw material PP to Recycled compounder Synova company.***
- ***Gaia, coordinator and participant in material preparation:*** a subsidiary wholly owned by Renault, Gaia manages the logistics and sales of material produced by the Group's circular economy model. It also ensures that the process meets the requirements of all other contributors in the chain.

The volume of PP collected by Gaia increases every year. The 680 tons of PP recovered in 2015 is the equivalent of almost 42,000 vehicles, from which the front and rear bumpers were taken as well as the wheel arch liners.



Quantity of polypropylene collected (tons / year)

The obstacles to recycling polypropylene

Preparing the material generates significant losses, both when shredding and drying the material, but most of all during the floating stage. The density measurement method is used to separate the different grades of plastic, but it is beset with a host of difficulties. First and foremost, the density ranges for different plastics are concentrated between 0.9 and 1.4. Furthermore, ***the presence of charges*** in the materials, such as mineral charges, natural fibres or glass fibres, increases the density of the material that will flow out during floating. A considerable amount of PP (charged above 15%) will thus flow into the 1.02 density tanks, which is the same density as dirty water and the value normally used in flotation facilities. The flow fraction is deemed waste and is removed from the recycling process.

The processing flow currently used by most recyclers is almost entirely based on density measurements, and the flow-off is hardly recycled, if at all. This means that, on average, one quarter of the material fed into the closed loop is discarded. This is a significant loss that carries a dual cost: firstly for its purchase, transport and processing, and secondly for managing its end of life through storage or energy conversion.

Future research into optimising the processing and separation of vehicular plastics must focus on achieving the highest ***material recovery rates*** possible, while still maintaining ***high end-product quality.*** In order to optimise these areas we need to know the

[2] *Circular economy takes its inspiration from the cyclical nature and processes of natural ecosystems. The purpose of this new model is to move from a linear framework (extract, manufacture, use, discard) to a looped one. In France, the notion of a circular economy was recently included in the environmental code for the first time, through the Energy Transition for Green Growth Act (summer 2015).*

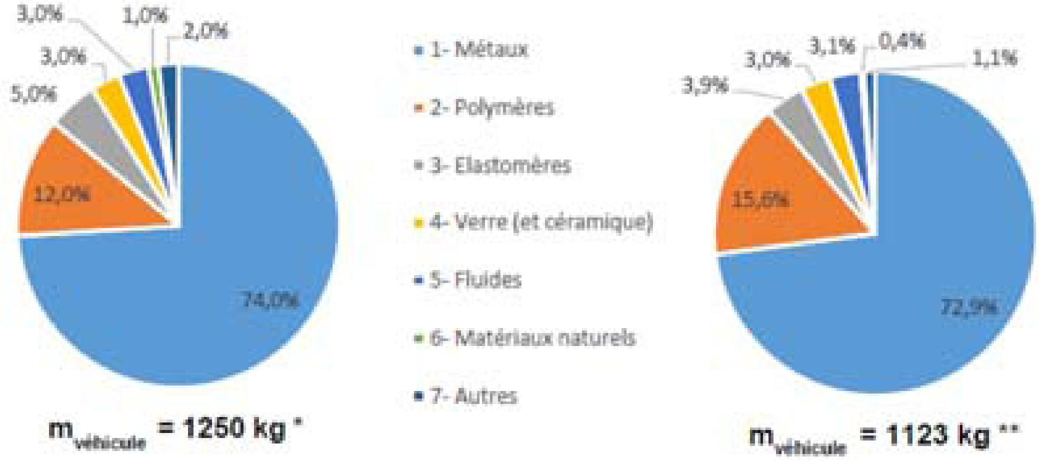
characteristics of the inflow, so that the separation process can be adapted to recover all of the desired materials and remove any others.

What will our ELVs look like in 2030?

The average age of the vehicles delivered to ELV centres is gradually increasing; in 2014 it was 17.5 years. This means that vehicles currently on the market will reach the end of their service lives sometime around 2030.

A compositional analysis of recent vehicles has shown how the composition of future ELVs is likely to change compared to now - they will contain an average of 25 kg more plastic. These estimates take into account the growing use of plastics in the automotive industry, often as a substitute for parts that were previously made from metal but also as decorative and/or useful parts in the car interior.

However, it must be possible to clearly distinguish between the easily removable portion composed of homogeneous plastics, and the more diverse portion comprising multi-material plastics, metallic inserts, elastomers, etc.



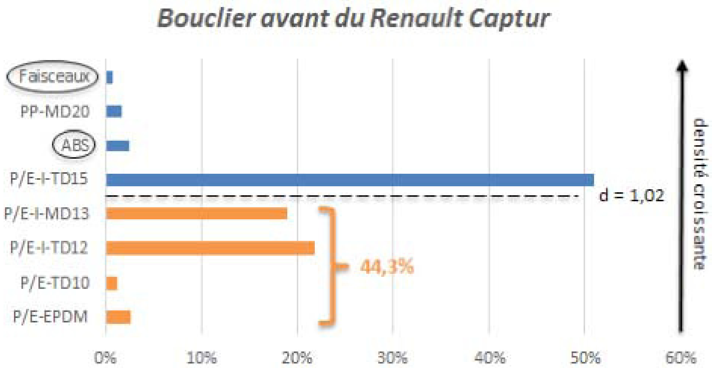
Evaluation of the composition of the ELV in 2015 (to the left) and in 2030 (to the right)

Focus on the car bumper

The car bumper is a compulsory safety feature on all vehicles. Located at the bottom of the bodywork on the front and rear, it is made from deformable material in order to cushion against impact. In general it is made from plastic, but its composition and appearance varies - it may be painted the same colour as the bodywork, there may be chrome or aluminium inserts, or it may be adorned with decorative parts.

Renault Captur front bumper (2013)

A study into the composition of car bumpers in different makes and models has shown that they are almost exclusively made from polyolefins3 (over 91%), and this is true for both front and rear bumpers. This high concentration is a crucial fact when it comes to recycling the materials in these parts, especially since the same is true for several vehicles from different manufacturers.
For example, only 44.3% of the material in the front bumper of the Renault Captur has a density of less than 1.02, which means that 4.7 kg of material will flow out into the tank and thus be wasted.



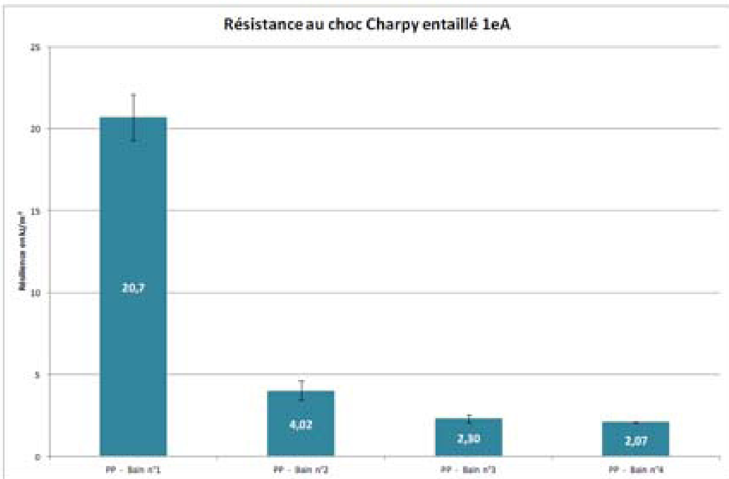
Composition front bumper of the Renault Captur car

A necessary change in processing methods

The study estimates that, if a batch of bumpers from multiple manufacturers of future ELVs were processed in 2030 in the same way as they are today, there would be an additional average loss of 9.5% of material. Therefore, if no changes are made, ***material recovery yields will inevitably decrease in the future***.

This situation will worsen over time, so we need to start thinking now about how to change the shredding/washing/floating process in order to reduce wastage and improve recycling of PP from ELVs.

The study proposal focuses on eliminating impurities: styrenic polymers4, foams and films. Styrenics have a damaging effect if they are left in the final PP compound, dramatically reducing shock resistance for example.
To remove these unwanted substances, it may be worthwhile investigating the use of airflow technology such as the zigzag or densimetric tables. Another suggestion is the use of ***electrostatic separation*** to over-separate the flow products. This technique can sort particles according to the charge they acquire, instead of density as is usually the case.



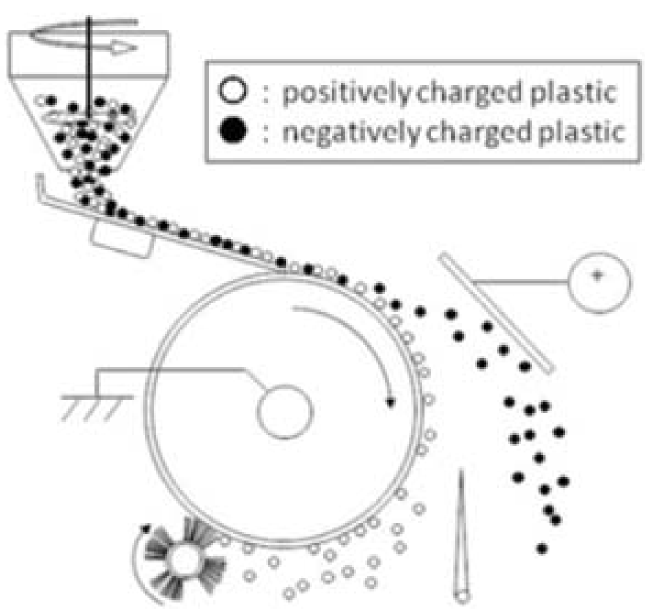
Result of Charpy test sample reactions to impact, taken from four batches

The mean density of samples increases (1.008/1.046/ 1.052 /1.056) with the density of the separation tanks. Impact resistance is more than quartered between tank 1 and the others, which is due to a higher tank density in tanks 2, 3 and 4 causing styrenic materials to float.

However, the biggest problem would then be the overlap between polymer density ranges (and other elements that need to be removed, such as elastomers or wood).

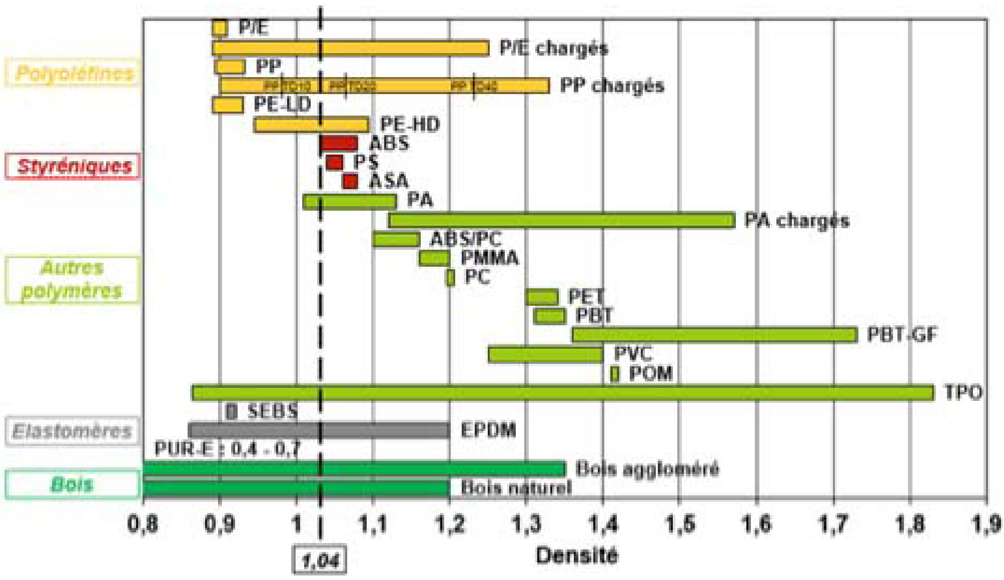
Electrostatic separation relies on the ability of particles to become positively or negatively charged. There are two ways to do this: subject them to an electrical field (corona charge) or stimulate intense friction between them (electrostatic charge). The former is suitable for separating conductors from non-conductors, whereas the latter works better when separating plastics. In either case, it is imperative the materials being processed are clean and dry (moisture less than 0.1%). The size of the fragments varies between 1 mm and 1 cm.

The use of this technique would result in a number of flows that need to be recycled separately. This could prove useful in reducing the amount of waste generated and may pave the way to a new opportunity - creating a market for regenerated charged PP. In addition to this, ABS that is also contained in the floating flow-off could be recovered in the same way, and could benefit from similar technical advances as those for PP.



Principle of electrostatic separation[5]

The plastic particles are friction-charged inside a rotating drum. They exchange their electrons with each other, with one material becoming positively charged and the other becoming negatively charged. The - charged particles are attracted to the + charged electrode.



Covering of slot of density

[3] *Polyolefins are a category of polymers that include polypropylene (PP) and polyethylene (PE). They have the special ability of being able to float on clean water (density less than 1).*

[4] *The category of styrenic polymers includes all polymers derived from styrene monomer, such as polystyrene (PS), acrylonitrile butadiene styrene (ABS) and acrylonitrile styrene acrylate (ASA).*

Processing multi-source flows

Plastic obtained from parts of dismantled ELVs must be processed in addition to other sources so as to increase the flows as much as possible, make use of the line's maximum processing capacity, and improve the benefits of optimising the separation line. This must be accompanied by higher customer demand for recycled materials.

The increase in "inbound" volumes could come from Waste Electrical and Electronic Equipment (WEEE) or from waste packaging, such as those from expanded household waste sorting guidelines (plastic containers, plastic film, yoghurt pots, etc.). Such waste could be processed on the line in different campaigns. These sectors are also facing the same issues - a range of materials within the same product and separating mixed materials at end of life - even if the polymer resins used are vastly different from those used in the automotive sector.

Recycled resins for more technical uses

For the moment, recycled plastics are mostly used for parts that are not overly technical or visible. When the flows of materials for transformation or transportation have relatively little value, it is harder to be competitive (due to fixed transport costs). It may therefore be worthwhile concentrating on higher added value applications, such as parts visible inside the vehicle.

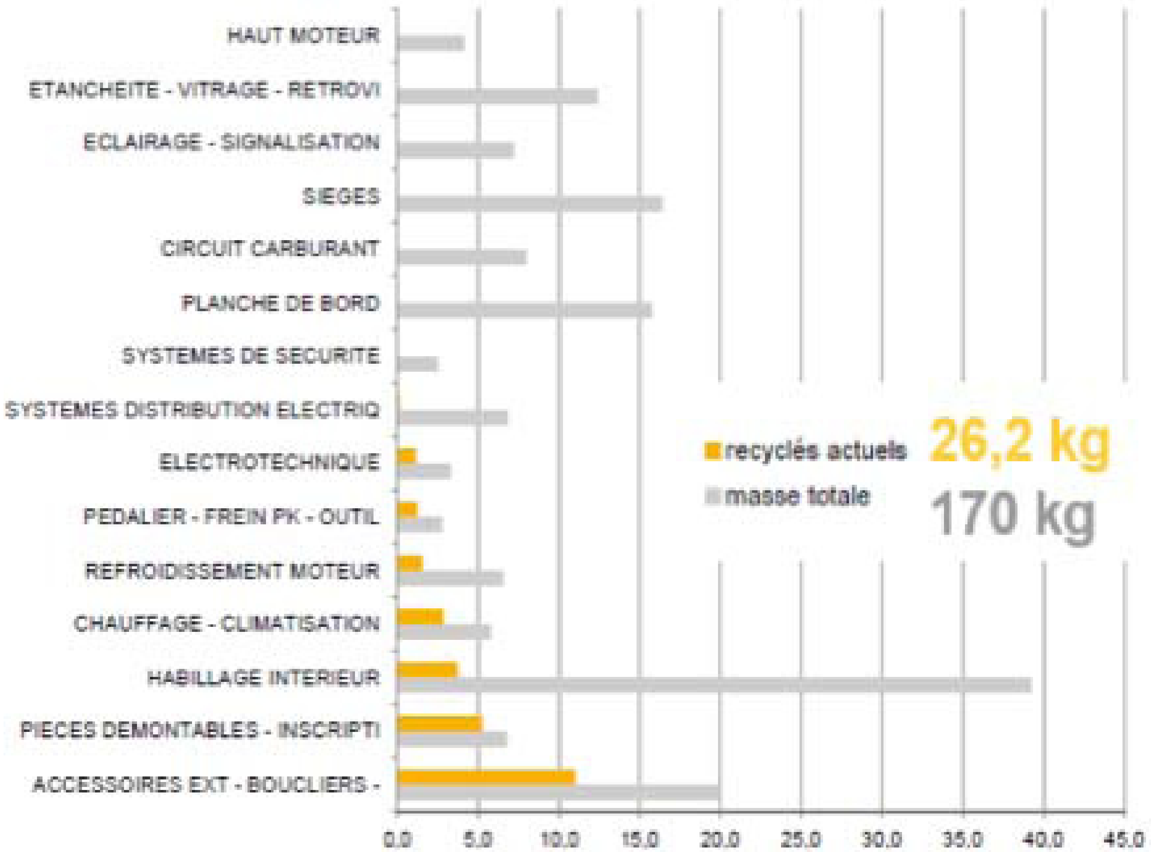
For example, in the restyled Clio IV (2016), recycled plastic is the main material used in bumpers and wheel arch liners. Conversely, the interior trim of the Clio, which is the obvious application with almost 40 kg of plastic, contains very little recycled material. There is therefore much room for improvement, and in particular a significant opportunity for developing technical polymers from recycled materials. This change will only be possible if certain processing rules are adhered to, namely the exclusion of soiled PP materials (batteries, fuel tanks, automotive shredder residue) and unwanted plastics (PUR, POM, PMMA, styrenics).

Permissible output quality becomes essential for technical grades, and the problems encountered differ depending on whether the part is designed for the interior or exterior of the vehicle:

- for validation of visible materials inside the car, the ***appearance (colour and texture), odour, and VOC emission*** characteristics must be controlled;
- for exterior accessories, the hurdles are more linked to ***paintwork*** and ***durability (aging, sun exposure, paint adhesion)***

In both cases, the fluidity of the material must be checked to make sure parts are usable if made from these recycled materials.

Automotive plastics have a wide range of applications, all with have varying levels of technical requirements. It would be worth developing different material qualities in order to minimise losses during separation, and offer applications for a diverse range of uses. However, automotive specifications remain extremely stringent, and numerous criteria must be met before recycled plastic materials can be used in this sector.



Weight distribution of virgin and recycled plastics in the restyled Renault Clio IV (2016), Gérard Liraut

[5] *Source: http://www.hitachizosen.co.jp/english/technology/hitz-tech/material.html*

Lessons learned from the study

The study has highlighted several crucial points for introducing an optimised processing and separation line for recovering plastics:

- the necessity for a large volume of plastic to process;
- multiple sources: ELVs, WEEE, household waste, etc.;
- in-house expertise in the use of equipment such as floating, densimetric tables, and electrostatic separators;
- obtain flows of varying qualities to minimise losses;
- find applications for these flows: shredded/floated PP as well as ABS and charged PP flows;
- connection to a compounder capable of transforming the obtained flows for specific client requirements.

CONCLUSION

The regeneration of automotive plastics, and polypropylene in particular, has enormous potential as a new supply source for the car industry that also ensures the regulatory requirements for ELV recovery are met.

Optimising the processing and separation framework helps boost the ***competitiveness of these recycled materials***. Increased PP recovery yields thus lead to ***higher profitability, a stronger recycling value chain*** and a doorway to the ***development of new technical grades***. As a consequence, recyclers see their revenues increase, Renault loses less material, and the developed grades can be applied to the 52,000 tons of recycled plastic used by the group every year. The ultimate goal is to sustainably increase tonnage.