RecyClass

RECYCLABILITY EVALUATION PROTOCOL

FOR A&EEE RESINS

STANDARD LABORATORY PRACTICE

REP-RESINS-A&EEE-01

VERSION 1.0

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RecyClass

CONTENT

RecyClass

GLOSSARY

A.0	Pellets extruded one time during the pre-treatment phase
A.1	Pellets extruded after the pretreatment phase
ABS	Acrylonitrile butadiene styrene
ASTM	American Society for Testing and Materials
C.0	Specimens to characterize during the pre-treatment phase
C.1	Specimens to characterize after the conversion phase
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicles
EN	European Standard
ISO	International Organization for Standardization
MFI	Melt Flow Index
PC	Polycarbonate
PC-ABS	Polycarbonate - Acrylonitrile butadiene styrene blend
PE	Polyethylene
PP	Polypropylene
PP filled	Polypropylene with filler content and a density lower than 1.09 g/cm^3
PS	Polystyrene
TC	Technical Committee
TGA	Thermogravimetric Analysis
Virgin Material	Resin that will, for the first time, be converted to a plastic product (no thermal pre-treatment)
WEEE	Waste from Electrical and Electronic Equipment
wt%	Weight Percentage

DISCLAIMER

RecyClass is a non-profit, cross-industry initiative advancing recyclability, bringing transparency to the origin of plastic waste and establishing a harmonized approach toward recycled plastic calculation & traceability in Europe. The Recyclability Evaluation Protocols promote recyclability by encouraging the industry to test new plastic technologies, materials or products, providing recommendations on improving their recyclability before market launch.

The Recyclability Evaluation Protocols are freely available to download on the *RecyClass website*. Companies developing new plastic concepts are encouraged to use them to self-assess the impact of their solutions on recyclability and highlight potential issues. **However, compliance with a Recyclability Evaluation Protocol is not a replacement for an official assessment and may not be used as a marketing tool.** The RecyClass Steering Board, following the recommendations of the Technical Committees, will decide on the compatibility of the innovation with recycling according to the evaluation results, granting a Recyclability Approval Letter to the Applicant.

All tests must follow the Evaluation Protocols recommended by the RecyClass Technical Committees and be conducted by an independent laboratory recognised by RecyClass which has no legal affiliation to the applicant.

More information is reported in the RecyClass Internal Procedures, available on the *RecyClass website.*

RecyClass

1. INTRODUCTION AND PURPOSE OF THE PROTOCOL

The "RecyClass[1] Recyclability Evaluation Protocol for Automotive and Electrical and Electronic Equipment (EEE) for resins referred to in this document as "The Protocol" describes the methodology that the applicant must follow at a laboratory scale to determine if a nonstandard resin is processable according to the average recycling condition for the specific polymer. The Protocol targets companies responsible for introducing ABS, PS, PE, PP, PP with mineral fillers, PC and PC-ABS resins into the automotive and EEE markets. Other resin types can be evaluated upon approval by the Technical Committee representatives. The applicant shall proceed with the Protocol as established in the Assessment Process for Applicants of Recyclability Evaluation in the RecyClass Internal Procedures[2] and RecyClass Recyclability Approval Quality Management & Procedures document[3].

The Protocol analyses whether a nonstandard resin will undergo the necessary extrusion and conversion steps described in this methodology at a laboratory scale without negatively impacting the recycling process and the quality of the recycled material. It aims to prove the compatibility with average recycling condition of automotive and EEE nonstandard resins while encouraging innovation in the plastic market. The overall goal is to ensure that the resin is processable and retains its mechanical properties after reprocessing according to average recycling conditions. Resins that successfully pass the tests will be included as control materials in the Annex of the corresponding Recyclability Evaluation Protocol for Automotive and Electrical and Electronic Equipment (EEE), depending on the specific type of resin.

This document provides guidance on the testing methodology that shall be followed, including benchmark recommendations to guide the interpretation of the results.

Please note that all units in this protocol are expressed following The International System of Units[4], from the Bureau International des Poids et Mesures.

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1 RecyClass assesses the recyclability of a plastic product. and provides specific indications and recommendations on how to improve the design of a plastic product to fit current recycling technologies. More information at https://recyclass.eu/

[2] *RecyClass Internal Procedures*

[3] *RecyClass Recyclability Approval Quality Management & Procedures*

[4] SI Brochure - BIPM

2. SCOPE OF THE PROTOCOL

The scope of the Protocol covers any nonstandard resin used to produce automotive or EEE components.

The following non-exhaustive list of resin solutions is covered by the Protocol:

1. Heat stabilized resins
2. Impact modified resin
3. Mineral filled resin
4. Polymer blends
5. Other resins

This protocol applies to the following resin typologies: PP, Mineral-filled PP, PE, ABS, PS, PC and PC-ABS.

In addition, other materials commonly recovered in recycling streams, such as Styrene Acrylonitrile (SAN), Acrylonitrile Styrene Acrylate (ASA), and Acrylonitrile Butadiene Styrene–Acrylonitrile Styrene Acrylate blend (ABS-ASA), can also be assessed under this protocol. These materials should be evaluated according to the processing conditions of the primary polymer stream in which they are ultimately recovered. For example, SAN, ASA, and ABS-ASA found within ABS recycling streams shall be tested under the ABS processing conditions defined in this protocol.

Resins containing degradable plastics, restricted hazardous substances, substances of very high concern (SVHCs), REACH above the threshold limits allowed by the legislation should not be covered by this Protocol. Consequently, resin components containing any of these features do not fall under the scope of this Protocol.

3. DISCLAIMER

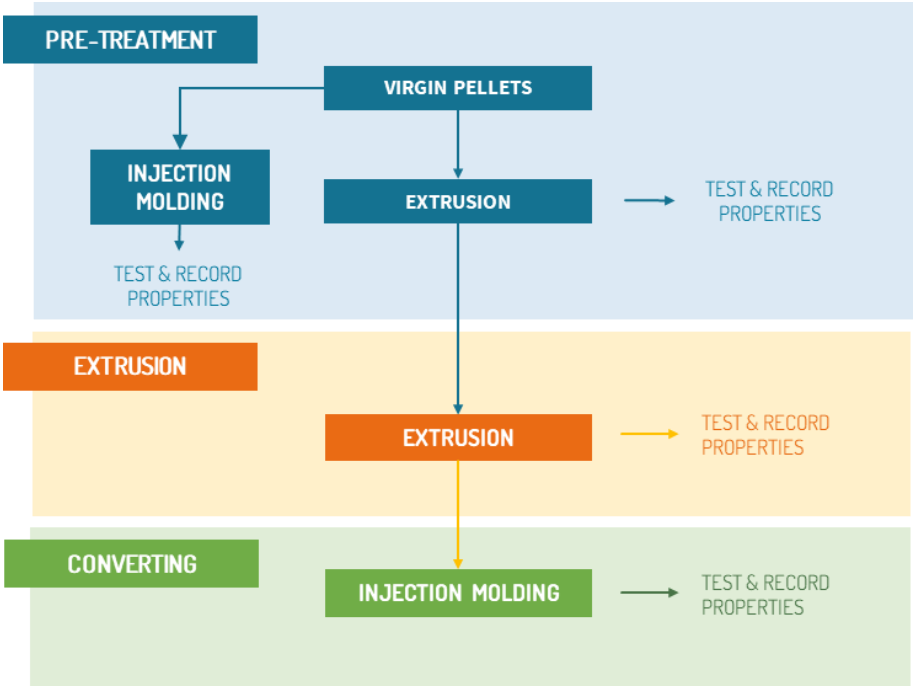
The Protocol is created to validate the processability of nonstandard resins under the average European recycling condition in the automotive and EEE sectors. The RecyClass Automotive & EEE Technical Committee (TC) reserves the right to request further testing, if necessary, to issue a final decision on the recyclability of the tested plastic.

4. LABORATORY TESTING METHODOLOGY

This methodology aims to reproduce the average recycling processing condition at a laboratory scale to determine the compatibility of an automotive or EEE resin with recycling conditions. The methodology described below shall be followed precisely and any modifications or problems during the testing phase must be noted. A Laboratory Evaluation Report compiling objectively all the results obtained shall be prepared to report to the Automotive & EEE TC which will interpret the results. Any remarks during the laboratory tests described in the Protocol shall also be noted down.

See below in Figure 1 a diagram describing the methodology.

Figure 1: Methodology Diagram



4.1 SAMPLE SELECTION

To execute the protocol, the Applicant need to provide 25 kg of virgin pellets.

More material could be requested if optional tests are required by the RecyClass Automotive & EEE TC.

5. LABORATORY TEST PROCEDURES

5.1 PRE-TREATMENT STEPS

5.1.1 EXTRUSION

5 to 10 kg of virgin pellets need to be extruded as defined in the procedure below. This step is necessary for the simulation of the production process of the plastic used in the automotive or EEE sectors. The scope is not to consider aging history, but to determine whether a material can serve as a control resin during the protocol and can be reprocessable under standard recycling conditions.

The extruder has to be cleaned before starting the extrusion process. This involves pulling the screws out of the barrel and then mechanically cleaning them with brass brushes until they reach a glossy finish. The barrel also has to be mechanically cleaned with round brass brushes from the mandrel to the run-out zone.

Procedure:

- Dry pellets or flakes at the condition reported in Table 1. Any agglomeration of flakes must be reported.
- Extrude the pellets with the corresponding melt temperature conditions reported in Table 1, without using filter. The obtained pellets will be designated as A.0.
- Recommended throughput is between 5 and 10 kg/h and rotation speed between 100 and 200 rpm.
- Monitor the extrusion process for heat stability.
- Rapidly cool the extrudate in a water bath and fed into a pelletizer.
- The pelletizer speed has to be controlled to get a final pellet with a diameter of 3 mm.
- Monitor pressure build-up during pelletizing and report significant differences.
- Randomly select the pellets to perform all the characterizations reported in Table 2.

Record the resulting properties in Table 2. A small amount of each sample (50 g) will be retained for the RecyClass TC and the Applicant. The extruded pellets will be tested for pellet properties characterisation (Table 2). Pellets should meet the requirements reported in Table 2.

5.1.2 INJECTION MOULDING

An amount between 2 and 4 kg of virgin pellets need to be injection moulded into specimens to evaluate tensile and thermal properties.

Procedure:

- Dry the samples according to the condition reported in Table 1.
- Mould sample A.0 to multipurpose specimens' type 1A according to EN ISO 527-2 and to plaques with measures of about 60 x 60 x 2 mm^3. Sample C.0 will be obtained.
- The specimens should be completely filled without any shrinkage, overspray, or inclusions.
- Variations in operating conditions could be acceptable but must be documented in the report.
- Monitor the injection pressure, the heating zone temperature, mould temperature, closing force, injection time and maximum holding pressure (time)

Record the resulting properties in Table 3. Mechanical data must be analysed on the 1A or 1B specimen, possible inclusions and surface appearance of the specimens should be reported.

5.2 EXTRUSION

5.2.1 PELLET PRODUCTION

The pellets must be dried with a desiccant bed drying unit or with hot air as reported in Table 1 and then extruded using co-rotative twin-screw extruders with melt temperature and melt filters according to the condition reported in Table 1.

The extruder has to be cleaned before starting the extrusion process. This involves pulling the screws out of the barrel and then mechanically cleaning them with brass brushes until they reach a glossy finish. The barrel also has to be mechanically cleaned with round brass brushes from the mandrel to the run-out zone.

Table 1. Drying and extrusion conditions for the different resins

	DRYING CONDITION		EXTRUSION CONDITION	
Resin	***Temperature (°C)***	***Time (hour)***	***Temperature (°C)***	***Mesh Size (µm)***
ABS	80 °C	4 h	230 ± 10 °C	150
PE	60 °C	2 h	220 ± 10 °C	250
PP	60 °C	2 h	220 ± 10 °C	250
PP with Mineral Fillers	60 °C	2 h	230 ± 10 °C	400
PS	80 °C	3 h	220 ± 10 °C	150
PC-ABS	90 °C	4 h	260 ± 10 °C	150

Procedure:

- Dry pellets or flakes at the condition reported in Table 1. Any agglomeration of flakes must be reported.
- Extrude the pellets with the corresponding melt temperature and melt filter conditions reported in Table 1, for no less than 30 minutes. Melt residence time should be less than 6 minutes. The new pellets will be designated as A.1.
- Recommended throughput is between 5 and 10 kg/h and rotation speed between 100 and 200 rpm.
- Monitor the extrusion process for heat stability.
- If the process doesn't reach steady state conditions (i.e. pressure and/or temperature increase), extrude for no less than 1 hour.
- Rapidly cool the extrudate in a water bath and fed into a pelletizer.
- The pelletizer speed has to be controlled to get a final pellet with a diameter of 3 mm.
- Monitor pressure build-up during pelletizing and report significant differences.
- Randomly select the pellets to perform all the characterizations reported in Table 2.
- Change the melt filter pack between samples for visual examination.
- Be sure to produce enough pellets for all the tests, including the conversion tests.

Record the resulting properties in Table 2. A small amount of each sample (50 g) will be retained for the RecyClass TC and the Applicant. The extruded pellets will be tested for pellet properties characterisation (Table 2). Pellets should meet the requirements reported in Table 2.

5.2.1.1 PELLET PROPERTIES CHARACTERISATION

Samples preparation and testing conditions for the following characterisations must be done according to:

For ABS pellets for the following characterisations must be done according to ISO 19062-2:2019 (Acrylonitrile-butadiene-styrene (ABS) moulding and extrusion materials —Part 2: Preparation of test specimens and determination of properties).

For PE pellets for the following characterisations must be done according to ISO 17855-2:2016 (Polyethylene (PE) moulding and extrusion materials — Part 2: Preparation of test specimens and determination of properties).

For PP pellets for the following characterisations must be done according to ISO 19069-2:2016 (Polypropylene (PP) moulding and extrusion materials —Part 2: Preparation of test specimens and determination of properties).

For PS pellets for the following characterisations must be done according to ISO 19063-1:2016 Plastics - Impact-resistant polystyrene (PS-I) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties).

For PC-ABS pellets for the following characterisations must be done according to ISO 21305-2:2019 (Polycarbonate moulding and extrusion materials —Part 2: Preparation of test specimens and determination of properties).

Table 2. Pellet properties characterisation

ASSESSMENT	STANDARD	BENCHMARK RECOMMENDATION
Density (kg/m^3)	ISO 1183-1	ABS, PS, PP with filler lower than 1.09 g/cm^3 PP and PE lower than 1 g/cm^3
Volatiles (wt%)	Heat 10 g blends (before extrusion) and pellets (after extrusion) exposed to 220 °C for 10 minutes	No increase higher than then 0.5 wt% respect A.0
Melt Index (g/10 min)	ISO 1133 - PE: 190 °C/2.16kg - PP: 230 °C/ 2.16 kg - PS: 200 °C/5 kg - ABS: 220 °C/ 10 kg - PC/ABS: 260 °C/ 5 kg - PC: 300 °C/ 1.2 kg	No more than the following deviations respect to A0 - MFI up to 2 → ± 75 % - MFI 2 to 5 → ± 50 % - MFI 5 to 15 → ± 30 % - MFI 15 to 40 → ± 15 % - MFI > 40 → ± 10 %
Ash content (%)	ISO 3451-1 (muffle) up to 750 °C	No more than a 15 % delta to A.0
Surface appearance	Visual inspection	Record
Filtration (µm)	Visual inspection. In case of the presence of build-ups, an FTIR analysis is recommended to identify the origin of the deposit.	No build-up on the screen
Pressure Variation (MPa)	($P_{25\text{-}30minutes}$ - $P_{5\ first\ minutes}$)	No increase higher than 25 % compared to start in 30 minutes
Extrusion process	Unusual sticking, fumes, odour, and any build-up	Record

5.2.2 ADDITIONAL PROPERTIES EVALUATION

Note that the RecyClass Technical Committee can decide to add other treatments and/or characterisations to the recyclability evaluation to focus on specific properties. In this case, additional treatments and/or characterization steps will be required. They will be performed according to the procedure described in the Recyclability Testing Protocol for the specific plastic stream (PE, PP, PS, ABS, PP filled, PC, PC-ABS).

5.3 CONVERTING

The pellets must be tested for injection moulding to evaluate tensile properties, as well as defects. The Protocol aims to assess the highest value recyclate application.

5.3.1 INJECTION MOULDING

Pellets A.1 must be tested for injection moulding to evaluate tensile properties, colours, as well as defects.

Procedure:

- Dry the samples according to the condition reported in Table 1.
- Mould sample A.1 to multipurpose specimens' type 1A according to EN ISO 527-2 and to plaques with measures of about 60 x 60 x 2 mm^3. Sample C.1 will be obtained.
- The specimens should be completely filled without any shrinkage, overspray, or inclusions.
- Variations in operating conditions could be acceptable but must be documented in the report.
- Monitor the injection pressure, the heating zone temperature, mould temperature, closing force, injection time and maximum holding pressure (time)

Record the resulting properties in Table 3. Mechanical data must be analysed on the 1A or 1B specimen, possible inclusions and surface appearance of the specimens should be reported.

5.3.1.1 INJECTION MOULDED PARTS PROPERTIES CHARACTERISATION

Samples preparation and testing conditions of samples for the following characterisations must be done according to:

- For PP samples, ISO 19069-2:2016 (Polyethylene (PP) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties).
- For HDPE samples, ISO 17855-2:2016 (Polyethylene (PE) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties).
- For PS samples, ISO 24022-2:2020 (Polystyrene (PS) moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties).
- For ABS samples, ISO 19062-2:2019 (Acrylonitrile-butadiene-styrene (ABS) moulding and extrusion materials- Part 2: Preparation of test specimens and determination of properties).
- For PC-ABS samples, ISO 21305-2:2019 (Polycarbonate moulding and extrusion materials - Part 2: Preparation of test specimens and determination of properties).

Table 3. Injection moulded parts properties characterisation

ASSESSMENT	STANDARD	BENCHMARK RECOMMENDATION
Heat Deflection Temperature (°C at 1.8 MPa) or Vicat (°C) only applicable for automotive assessment	ISO 75 or ISO 306 VST B50	No more than a 15 % delta decrease compared to C.0
Flexural Modulus (MPa)	ISO 178	No more than a 20 % delta decrease compared to C.0
Tensile Modulus (MPa)	ISO 527	
Tensile Stress at Yield (MPa)	ISO 527	
Elongation at Yield (%)	ISO 527-2	
Charpy Impact Strength – Notched (kJ/m^2)	ISO 179-1 ISO 179-2 (optional)	

Surface appearance/ Inclusion of materials	Visual inspection	Record

* ABS and PC-ABS samples for HDT or Vicat need to be annealed according to the following conditions: 90 °C for 60 min.

RecyClass

DOCUMENT VERSION HISTORY

VERSION	PUBLICATION DATE	REVISION NOTES
1.0	July 2025	Recyclability Evaluation Protocol for Resins Release

RecyClass

RecyClass
Avenue de Broqueville 12
1150 Brussels – Belgium

Phone : +32 2 786 39 08
info@recyclass.eu

www.recyclass.eu