SUNRISE

MultiSensor sorting tools in a circular economy approach for the efficient recycling of PVB interlayer material in high-quality prodUcts from laminated glass coNstRuction and demolItion waStEs

WHITE PAPER

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958243".

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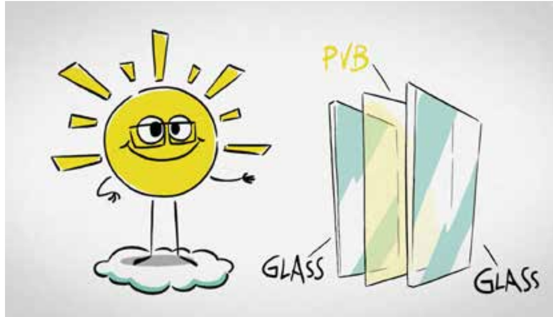
What is LAMINATED GLASS?



Laminated glass is obtained by bonding glass layers using a polymeric interlayer. Polyvinyl Butyral (PVB) is used as interlayer in laminated glass and their use in construction components is growing, therefore the end-of-life should be addressed.

Laminated glass wastes from construction and automotive origin are recycled by glass recyclers around Europe. However, the target is to recover the glass, **PVB is is considered a waste in the glass recycling process**. Up to now, most of the post-consume PVB material in laminated glass is incinerated/landfilled, and only a 9% is recycled in secondary uses.

Up to 1,250,352 tons/year of laminated glass wastes

PVB is used primarily as a raw material for **laminated safety glass sheet** in automotive and architectural applications and the Global consumption of polyvinyl butyral has been growing faster in thiese sectors. In addition to the major use as films and sheets, PVB resins are consumed in coatings, wash rimers, structural adhesives, inks/dry toners and as a binder for ceramics and composite fibers.

More than 125 000 tons of PVB wastes

WHY PVB is not recylced?

PVB is not so used as common plastic like PVC or other but the environmental footprint or recycling this kind of plastic could be bigger than recycle PVC, for example.

So: why PVB is not recycled?

There are different challenges to overcome if we want to recycle PVB from laminated glass:

1. PVB is contaminated with glass and glass content in re-PVB will result in haze and turbidity
2. Aging of laminated glass and PVB (exposure of waste at outdoor conditions) is an extended practice in glass recycling, facilitating the separation of the glass from the PVB.
3. Variability of PVB interlayer compositions, blending PVBs with different compositions can result in haze and turbidity

- Plasticizer types and contents
- Different interlayer functions: acoustic, solar control, uv blocking...
- Different configurations: monolayer, multiple layer

SUNRISE project was funded to overcome these challenges.

Project OVERVIEW

42 months
Duration

2021
Starting year

20
Partners

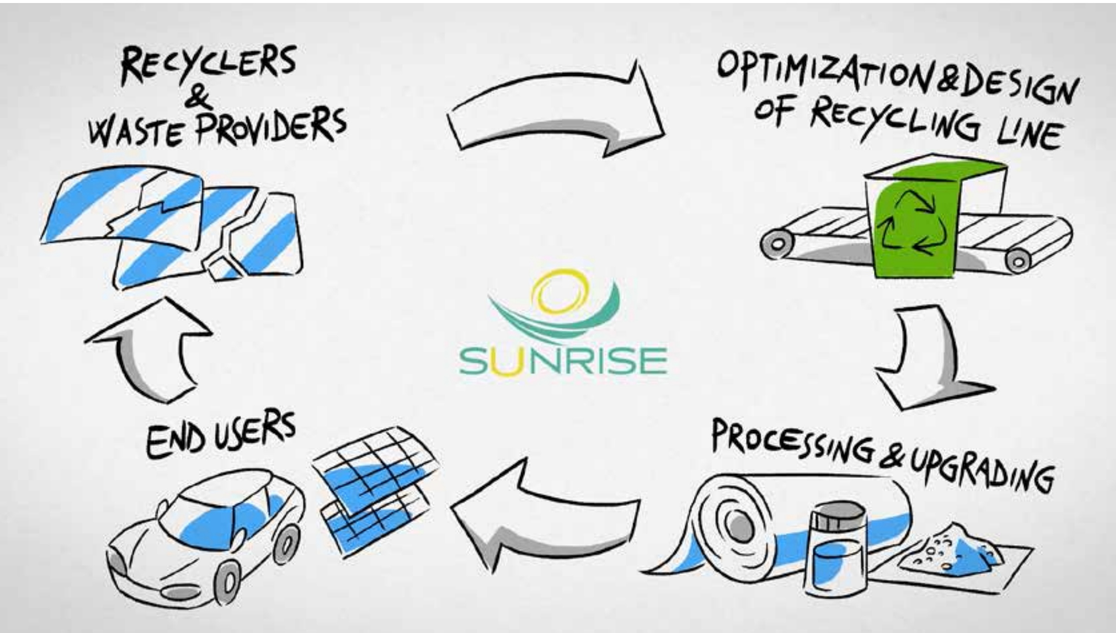
8,040,302.51 Euro
EU Contribution

SUNRISE PROJECT:
main objectives

SUNRISE is an Horizon 2020 funded project which aims to increase the collection and treatment of laminated glass, improving the separation of glass from PVB and therefore increasing the fraction of glass and quality from laminated glass for reuse.

SUNRISE aims to create a new circular economy for the PVB in glass sent for recycling.

In order to ensure the success, the project counts on glass recycling associations and companies and main actors in mechano-chemical treatment of PVB and optical in-line systems.



The project SUNRISE presents a solution for the post-consume PVB recycling consisting in the integration of a **multi-sensor system** based on non destructive and real-time data processing methodologies of spectral data, followed by the mechanochemical recycling process achieving a sorted PVB according to optical quality and composition, thus obtaining different batches which will allow a **functional recycling** and **higher quality** of the final polymer.

At the beginning of the project, the following objectives were set up:

1. To develop a multisensor tool
2. To develop and evaluate artificial intelligence (AI) algorithms
3. To construct an advanced sorting system
4. To integrate previous sorting module to a mechano-chemical pilot line

DEVELOPMENT OF A multisensor sorting tool

The tool allows to sort PVB within a full laminated glass according to different caractheristics of composition and degradation.

- Multisensor sorting system based on advanced characterization spectroscopic techniques (Raman, NIR and transmittance).
- The prototype tool developed in the project allows fast inspection (33 seconds for whole area inspection), allowing a sorting capacity higher than 100 laminated glass/hour.
- Haze measurement method allow to detect the haze value with accuracy ±1 % points

AI ALGORITHM TO DEFINE sorting categories

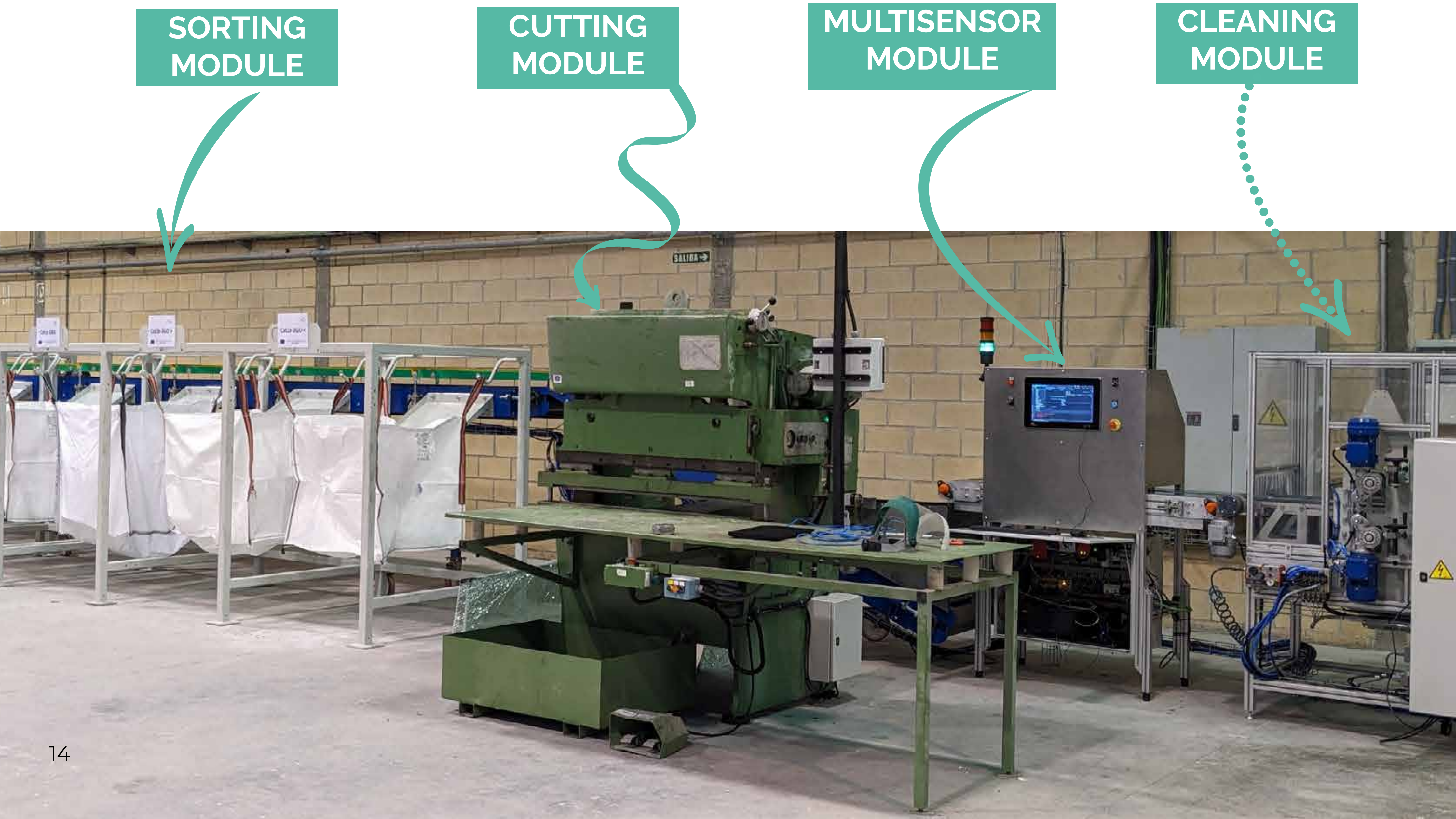
AI algorithms has been used for real time assessment of the laminated glass wastes by correlating the spectral data with the target properties and for sorting the laminated glass wastes in qualities and pre-defined compositions for recycling.

- NIR and Raman are equally sensible to identify PVB from non PVB and also in identifying the presence of 3GO as plasticizer
- Discrimination between DBS and DHA plasticizers is better with Raman data
- Prediction of quantification of plasticizer content is more complex (more data are needed)

Category	Subcategory	Description	Critical parameter to evaluate
Cat1	High quality interlayer laminated glass waste-only PVB		Low degradation level according to haze and yellowness
	Cat1a	Plasticizers of ethylene glycol oligo-esters chemical class (plasticizer content <32%)	Additional identification of plasticizer type
	Cat1b	Plasticizers of ethylene glycol oligo-esters chemical class (plasticizer content >32%)	
	Cat1c	Plasticizers of dibutyl sebacates chemical class	
	Cat1d	Plasticizers of dihexyl adipate chemical class	
Cat2	N/A	Low quality interlayer laminated glass waste-only PVB	Higher degradation level according to haze and yellowness
Cat3	N/A	Rejection. Non-classified and non-PVB	

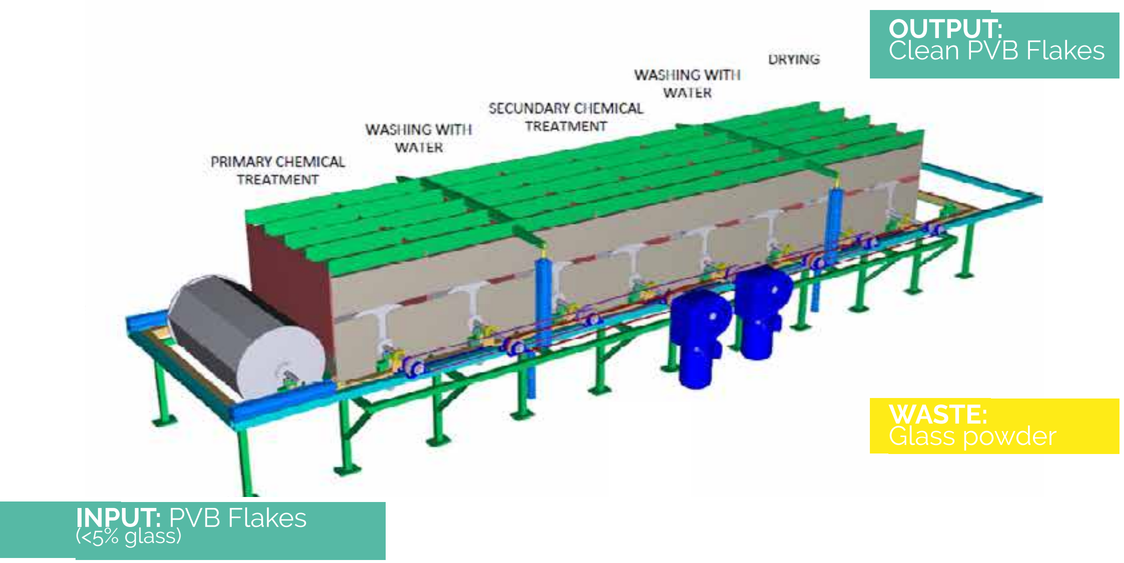
We have defined two categories, one with high quality and one with lower quality taking into account the level of degradation and yellowness.

IMPLEMENTATION OF THE full sorting system



MECHANO-CHEMICAL pilot line

The sorting module has been integrated with a mechano-chemical pilot line with a capacity to produce **360 Kg/h (544 tons/year) of recycled PVB** capable to **remove the 98% of glass** and obtain a PVB with a moisture < 2%. The aim of this processes was to increase the purity and remove the glass.



PVB Flakes before chemical treatment

PVB Flakes after chemical treatment

PROCESSING OF RE-PVB thermal re-stabilization

In function of the use of recycled PVB in applications, the material is expected under different physical properties: flakes, pellets or solutions/dispersions.

Each potential user of recycled PVB was asked to provide the minimum specifications required to introduce such recycling material in a production process:

1. Avoidance of exposure to moisture and UV through the entire collection, storage and treatment of laminated glass / PVB-waste
2. Traceability of the origin of the material, if possible, between construction and automotive and between acoustic and non-acoustic laminated glass/ PVB
3. Avoidance of chemical treatment / additions, modifying the chemical structure / optical and physical properties of the recycled PVB
4. Quality criteria, certainly the optical ones, must be measured on laminated form and not on PVB flake or film. This requires the preliminary production of laminated samples, with knowledge of the properties of the glass used for lamination.
5. High light transmittance, low ash and moisture content.

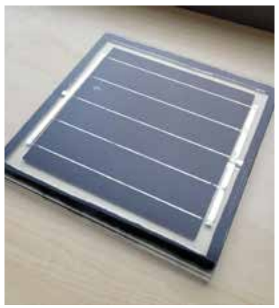
Project RESULTS

FILM PRODUCTION and lamination

The project has ensured the circular economy concept by demonstrating the production of recycled PVB film for laminated glass applications with high optical and mechanical properties.

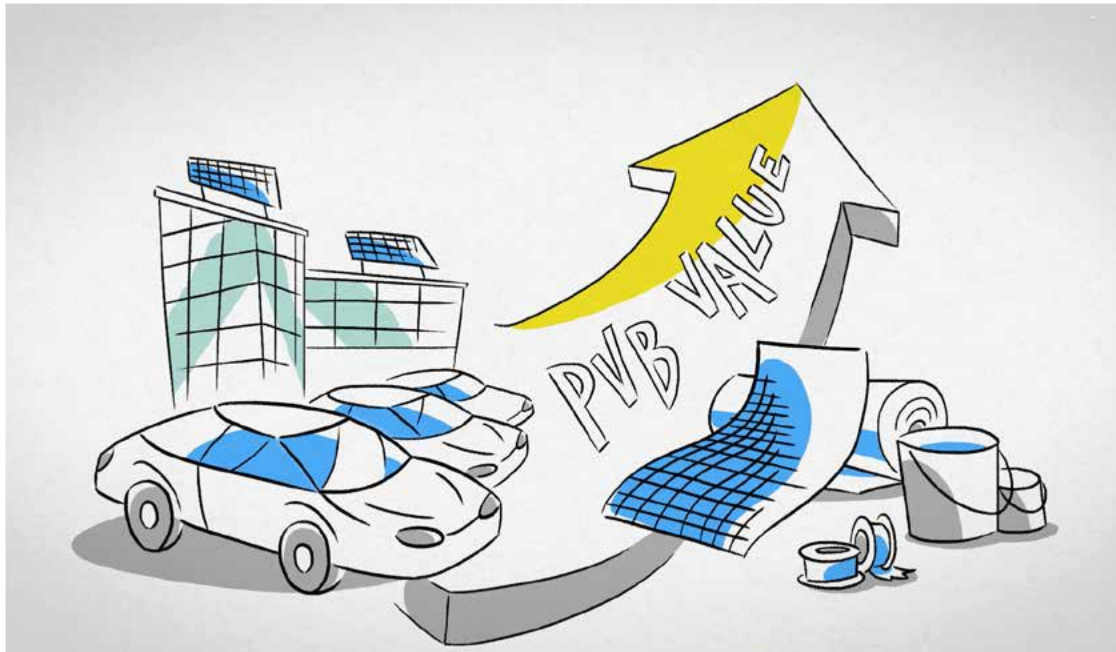
- Lurederra re-PVB materials results in much clearer film than currently benchmarked one.
- Mixtures of virgin/re-PVB are being processed to fulfill requirements.
- Films are being tested in laminated glass for construction sector and for solar applications.

End-user companies, partner of SUNRISE project, validated the achieved results including the production of prototypes of laminated glass for construction sector and solar panels.



OTHER APPLICATIONS: coatings, carpets, batteries

Re-PVB has been tested in other application to revalorise other PVB fractions by the production of dispersions and solutions for coatings, carpets and high-value products in energy storage sector such as binder for electrodes processing for batteries.



Environmental OUTCOMES

In general, incorporating the reprocessing operations to the recycling process of PVB for the intended applications added a significant source of environmental impacts when compared to the production of primary virgin PVB, especially for those impact categories more related to electricity consumption. This is a usual LCA result obtained when pilot-scale processes are compared to more mature industrial-scale manufacturing processes. Nevertheless, the recycling of PVB and reprocessing into the desired formats is still worthy, as it prevents the consumption of materials derived from fossil resources, as shown by the beneficial outcomes mostly obtained in impact categories such as carbon footprint and those related to depletion of resources. This is expectable when assessing a recycling process based on valorising a wate material when compared to obtaining this or equivalent materials form non-renewable sources.

Hence, this may be taken as a promising result for the SUNRISE project proposal, provided that the electricity consumption of the involved operations would be optimised in further upscaling developments until being comparable to the market equivalent alternatives. Besides the main application of rPVB for laminated glass, these results were particularly encouraging for the replacement of other primary polymers like EVA in PV panels or PVDF in batteries.

BEST PRACTICE

of the (final) destination of the R-PVB

The storage of laminated glass waste must be kept as far as possible under **dry and clean conditions**, to avoid external contaminations and degradation by moisture and UV-light.

When flakes are used to produce pellets, the applied treatment, including i.e. heating steps, use of (mineral) additives, etc. makes that the optical and chemical properties of the recycled PVB render its use only possible in specific applications with global lower quality level than in the production of laminated glass. Heating and addition of additives will affect the specific properties of PVB, especially its gluing and transparent (colourless) properties. The **absence of residual glass is also mandatory**, otherwise extrusion tools will be damaged.

When flakes are used in the production of solutions/dispersions, the residual glass content is not critical, but is anyway a limiting factor in the setting of the economic value of such secondary raw material. The dissolution of PVB makes indeed possible to 'clean' the PVB from glass thanks to sedimentation by gravity in the solution.

When flakes are used **in the production of film**, for lamination of other uses (i.e. batteries, solar panels, etc.) **the residual glass content is critical**.

To use recycled PVB-flakes in the production of laminated glass, a set of **additional requirements** is mandatory:

- automotive) type (acoustic, non-acoustic), year of production, etc.
- Light transmittance
- Moisture content
- Ash content, expressed as such, completed by specific concentrations of ions as i.e, iron, calcium, silicium, etc..
- Colour (yellowness index)

The CONSORTIUM

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SUNRISE

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