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Call Identifier: CIP-EIP-Eco Innovation-2012 PLACARD- Eco/12/332833 Layman's report PLACARD: A project developed by Kommi sas in partnership with University of Salento, Serichim srl, European Plastic Converters (EuPC) and the support of Eco-Innovation Program













## BACKGROUND

Worldwide, about 70% of the soft PVC is produced using phthalate plasticizers. EU banned phthalates for some applications, in which the plasticizer migration can make them harmful to human health. Besides phthalates are synthetic, oil derived products, and therefore have a significant impact on the carbon dioxide balance. Consequently, in recent years, phthalates have been subjected to major revisions, leading to severe restrictions in their use by the EU. On the other hand, most of the alternative plasticizers suffer for an effectiveness lower than that

of phthalate.



EU banned phthalates for several applications

The innovative idea promoted by this project, which applies to products to be used firstly in the civil construction market, **is to substitute phthalates by an eco-friendly, natural plasticizers derived from cardanol**<sup>1</sup>. The result of this idea is the reduction of environmental and toxicological impact of soft PVC, though maintaining mechanical, physical and durability properties comparable to those of conventional, phthalate based, PVC.



#### Anacardium

<sup>&</sup>lt;sup>1</sup> Cardanol is an industrial grade yellow oil obtained by vacuum distillation of "cashew nut shell liquid" (CNSL), contained in the spongy mesocarp of the cashew nut shell from the cashew tree Anacardium occidentale. CNSL is a by product of the most diffused roasted mechanical process of the cashew industry representing nearly 25% of the total nut weight, and its worldwide availability is estimated to be about 300,000 tons per year.





# PROJECT OVERVIEW

# **Objectives**

The PLACARD project proposes the production and application of a **new environmental friendly PLASTICIZER** for SOFT PVC. The product promises improved environmental/economic sustainability and replicability in a joint-venture approach between chemical industries and an European network of plastic converters SMEs. The final products have been developed for building sector. **The final goal** is to provide to the PVC converting sector a more sustainable plasticizer capable to substitute phthalates in some specific application.



Some possible use of soft PVC: cables (sx) and gaskets (dx)

## **Potential Benefits**

The use of the innovative plasticizer in substitution of phthalates is expected to:

- Reduce the amount of lead stabilizers used in soft PVC,
- **Reduce the amount of primary resources** used for the production of the plasticizer, including crude oil and other substances subtracted from the food chain,
- **Reduce climate gas emission** thanks to the improved thermal stability of PLACARD based PVC products and their consequent potential mechanical recycling (instead of incineration).

## Partners involved

<u>Coordinator</u>: KOMMI<sup>\*</sup> sas <u>www.kommi.it</u>; SME, PVC gaskets manufacturers University of Salento <u>https://www.dii.unisalento.it/home\_page</u>; Know-how owner SERICHIM srl <u>www.serichim.it</u>; SME, R&D chemical company European Plastic Converters (EuPC) <u>www.plasticsconverters.eu</u>; EU Association

\* Kommi is supported by the subcontractor CETMA <u>www.cetma.it</u>





# DEVELOPED TECHNOLOGY and RESULTS

## **Production process**

During the project duration a **robust manufacturing process** was developed and scaled-up by the partner Serichim. It was found that it is possible to get PLACARD in three easy steps, safe for human labor and green by the point of view of waste production, energy and raw material consumption of the whole process:

- 1) cardanol acetylation;
- 2) in-situ, continuous production of oxidizing agent;
- 3) cardanol acetate epoxidation.

The technology readiness level is thus estimated to reach a level 7 on the <u>TRL</u> scale.



**Placard plasticizer** 

## **Properties**

The properties of soft PVC obtained with PLACARD plasticizer have been compared with those of soft PVC obtained with commercial plasticizers, both petroleum-based (like DOP, DEHP, DOTP) and natural derived (ESBO; Soft-n-Safe®).

In particular:

- PLACARD is characterized by a higher plasticizing efficiency: lower amount of PLACARD is needed to obtain the same performances with regard to tensile properties, hardness values and thermal conductivity;
- The PLACARD plasticizer has better migration properties;
- The use of PLACARD in the PVC increases its thermal stability and UV stability;
- The use of Placard offers better perspectives for scraps recycling thanks to the increased PVC thermal stability.



PVC gaskets based on Placard





## EUROPEAN ADDED VALUE

In Europe low molecular weight phthalates are gradually phased out through a combination of increasing legal constraints. In 1999, the EU banned the use of phthalates in some applications where both factors can make the material harmful for the health of children [COMMISSION DECISION of 7 December 1999]. This has represented the starting point for the industrial research on low toxicity, low migration plasticizers. Though being specifically directed towards the toys articles, it is likely that the road map for soft PVC will be directed to the progressive replacement of phthalate plasticizers with other types of plasticizer, characterized by lower toxicity and lower migration. The PLACARD based PVC can respond to these requirements, by using a bio-based raw material, characterized by an excellent miscibility with PVC, and therefore by a very low migration. In this view, different markets, such as those of biomedical products, toys and packaging, are under severe criticism. Though accepting the use of phthalates, it is evident that these markets are under constant monitoring, and therefore the substitution of phthalates with natural plasticizer represents the main issue for the next years. In Europe, legislations are pushing towards the replacement of phthalates, whose perception from governments is very negative. PVC and phthalates are under pressure, replacements are being pursued actively, and a gradual shift in medical applications from DEHP to alternatives is expected. As a consequence, politics and legislation on PVC and phthalates will continue to find increased limitations.

In the construction field the use of the PLACARD product will lead to the development of low environmental impact products. It should be noted that from July 2013 the Construction Products Directive CPD 89/106 will be replaced with the new regulation CPR 305. The CPR Regulation 305/2011, published in April 2011, makes compulsory some important new issues in line with the sustainability objectives of the PLACARD project thus strengthening its innovative aspect. In fact, CPR 305 introduces the seventh requirement "Sustainable use of natural resources" which encourages the use of recycled and **bio-based materials**.



Demand for non-phthalate plasticizers will increase around the globe

Source: SRI, CMAI, BASF estimates

#### Growth in plasticizer demand around GDP.





# POTENTIAL MARKET

# **Overview**

DEHP is the most commonly used phthalate worldwide (50% of a world consumption of about 7 million tons of plasticizers per year). It is followed by DINP and DIDP (high molecular weight phthalate family), which are general purpose plasticizers as well.

World consumption of other plasticizers (terephthalates, aliphatics, trimellitates, epoxy, polymerics, benzoates and phosphates) is forecast to grow at an average annual rate of 5.7% till 2018.

Europe differentiates from the rest of the world in having almost completely substituted low molecular weight phthalates by other plasticizers through market and regulatory pressure.



Plasticizers consumption in Europe. Source: The European Council for Plasticisers and Intermediates (ECPI 2014).

Starting from the above reported figures it is clear that the use of innovative (non-phthalate based) plasticizers like **PLACARD could have a significant impact in the future European soft PVC conversion industry**.

## PLACARD selling points

- Phthalate and lead free
- Biobased and Non-food based
- Reduction of greenhouse gases
- Replacement of petroleum based plasticizer
- Enhanced recyclability
- Excellent UV light stability
- Positive public image compared to traditional plasticisers such as phthalates
- Similar properties to DEHP but less volatile and less migration





# ECOLOGICAL FOOTPRINT

The environmental impact linked to PLACARD production was calculated. As shown in the following figure, the most relevant influence for all the impact assessed (human health, ecosystem quality and resources), is related to the epoxidation stage due to the use of a specific reagent whereas the transport of cardanol from non EU countries (India and Brazil firstly), as well as the treatment of the raw CNSL have a very low influence.



Graphic damage assessment impact for PLACARD production process on the categories Human health, Ecosystem Quality, Resources

## Comparison with commercial plasticizers

Because PLACARD is not yet an industrial product, a comprehensive comparison in terms of environmental impact PLACARD vs phthalates was not feasible. Notwithstanding an evaluation of the recycling potential of soft PVC containing the two plasticizers can be used as a valid meter to compare the end of life scenarios that clearly has a large influence on the eco-sustainability of the products.

To this aim granulated soft PVC containing PLACARD or DOTP were re-extruded three times to simulate a recycling process. After these extrusion steps the properties of the PVC was measured in terms of color and mechanical properties. The main color change due to repeated extrusions was the yellowing of sample of soft PVC with DOTP, due to the increasing concentrations of polyene sequences with number of extrusion. On the contrary, for soft PVC with Placard, color coordinates were almost unchanged during repeated extrusions. Tensile properties did not undergone significant changes; this indicates that, until three extrusions, the degradation mechanisms after dehydrochlorination have not yet occurred and the materials have not lost their mechanical properties.

Placard is confirmed better than the DOTP in terms of recycling of processing waste.





# TOXICOLOGICAL AND ECO-TOX DATA

As phthalates plasticizers are subjected to severe restrictions by EU due to concerns about the potential impact on human health, a complete tox and eco-tox characterization of PLACARD was carried out. The results are reported in the tables below.

### ECA<sup>2</sup> health hazards and comparisons

Test type	DOP	ESBO	ECA
Acute oraltoxicityrat	LD50: 3000 mg/kg	LD50: >5.000 mg/kg	>2000mg/kg Unclassified (OECD 423)
Bacteria reverse mutation (Ames test)	n.d.	Negative	Negative (OECD 471)
Skin corrosion/irritation	Mild skin irritation	Mild skin irritation	Negative (OECD 439)
Eye irritation	Mild eye irritation (rabbit)	Mild eye irritation (rabbit; OECD 405)	Negative (in vitro; OECD 492)
Eye corrosion			Negative (BCOP test; OECD 437)
Skin sensitization	Does not cause skin sensitization (OECD 406)	Does not cause skin sensitization (OECD 406)	MODERATE skin sensitizer (OECD 429)

#### ECA environmental hazards and comparisons

Test type	DOP	ESBO	ECA
Acute toxicity to fish	LC50: 0.32 mg/l	LC50: 900 mg/l	LC50: 1.77 mg/l
Long-term toxicity to fish	NOEC: >0.3 mg/l	n.d.	NOEC: 1.25 mg/l
Acute Daphniatoxicity	EC50: >0.16 mg/l	EC50: >100 mg/l	EC50: 1.62 mg/l
Long-term Daphnia toxicity	n.d.	n.d.	NOEC: 0.47 mg/l
Algal growth inibition	n.d.	EC50: 8 mg/l	EC50: 0.69 mg/l
Long-term Algal growth inibition	n.d.	n.d.	NOEC: 0.05 mg/l

ECA presents better properties with respect to DOP (2-Ethylhexyl Phthalate), while ESBO<sup>3</sup> looks more eco-friendly: however, the right comparison is with DOP, which plays the same role of primary plasticizer as ECA. The main issue seems to be skin sensitization that may depend on traces of by-products present in the samples. This characteristic may be improved adopting more stringent specifications on the acetylation degree and on residual acidity.

<sup>&</sup>lt;sup>2</sup> ECA (epoxidated cardanol acetate) = PLACARD;

<sup>&</sup>lt;sup>3</sup> Epoxidated soybean oil (usually commercialised as secondary plasticizer)





## ECONOMIC SUSTAINABILITY

According to the estimates **the sum of the variable and fixed costs related to PLACARD is 1.82€/kg**. Three different economic scenarios were investigated starting from the costs linked to PLACARD production with different contribution margin (see next figure).

## Scenario 1

## WACC 8,62% Investment = 5.000.000

	The NPV is negative IRR < WACC: It is positive but less than the average weighted cost of capital ROI is low-mid respect the average ROI chemical manufacturing EBITDA (as a % of revenue/yr) is 4%, lower than the market average	Contribution margin 5,00% IRR 3,8%	Added value 16% IRR < WACC Negative	NPV - 2.093.368,63 ROI (average/yr.) 5,8%
	Scenario 2			
:	The NPV is positive IRR > WACC: It is positive and higher than the cost related to investment capital	Contribution margin 8,00%	Added value	NPV 35.821,84
	ROI is mid-high respect the average ROI chemical manufacturing EBITDA (as a % of revenue/yr) is 6/7%,	IRR 8,7%	IRR > WACC Positive	ROI (average/yr.) 10,1%
	Scenario 3			
:	The NPV is very positive	Contribution	Added value	NPV
-	higher than the cost related to investment capital	15,00%	26%	1.023.956,78
•	ROI is mid-high, and growing faster	IRR	IRR > WACC	ROI
	respect the other scenario EBITDA (as a % of revenue/yr) is 7/8%,	10,9%	Positive	(average/yr.) 12.0%

#### Economic scenarios for PLACARD production<sup>4</sup>

that is the average EBITDA of chemical

manufacturing market.

From the above reported figures, derive that a contribution margin of 15% is enough to reach an IRR and a ROI that could justify the investment made. The corresponding selling price of PLACARD is 2€ per kg, higher than phthalates based plasticizer but in line with other natural derived ones existing on the market.

<sup>&</sup>lt;sup>4</sup> NPV: Net Present Value; WACC: Weighted Average Cost Of Capital; IRR: Internal Rate of Return; ROI: Return on investment; EBIDTA: Earnings Before Interest, Taxes, Depreciation and Amortization.





# PLACARD AT A GLANCE

Project Acronym	PLACARD
Project Full Title	Cardanol based PVC plasticizer
Agreement Number	ECO/12/332833/SI665957
Starting date	1 <sup>st</sup> of January 2014
End date	31 <sup>th</sup> of December 2016
Total cost of the project	987,402€ (50% funded by the European Agency for Small and Medium Enterprises –EASME)

The PLACARD project partners are available to:

- **Provide samples** of the innovative plasticizer.
- **Provide technical and financial information** to those companies interested in investing in the industrial production of the innovative plasticizer.

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