The Eco-Footprint of VinyLoop®

Benchmarking of the environmental impact of PVC compound recycled in the VinyLoop® process with PVC compound produced in conventional route (virgin PVC compound and incineration)

2nd Update, October 2013

Commissioner: VinyLoop Ferrara SpA; Eric Vandevyver, Christian Thamm.
Practitioner: Villers LC Consulting; Joseph Villers.
Critical Review: DEKRA Industrial GmbH; Matthias Schulz

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1 Executive Summary

The recycling of PVC composite waste is challenging due to the complexity of the composite materials. The VinyLoop process, through selective dissolution and filtration, is able to eliminate contaminations and produce recycled PVC (R-PVC) of a quality similar to virgin compound.

After several years of successful operation and optimization, the plant and the production at the VinyLoop Ferrara site are running well. In 2011, a Life Cycle Assessment of the environmental impact of the regenerated product was performed. In order to keep up with the evolution of the process, the shareholders of VinyLoop have now decided to update it with more recent data.

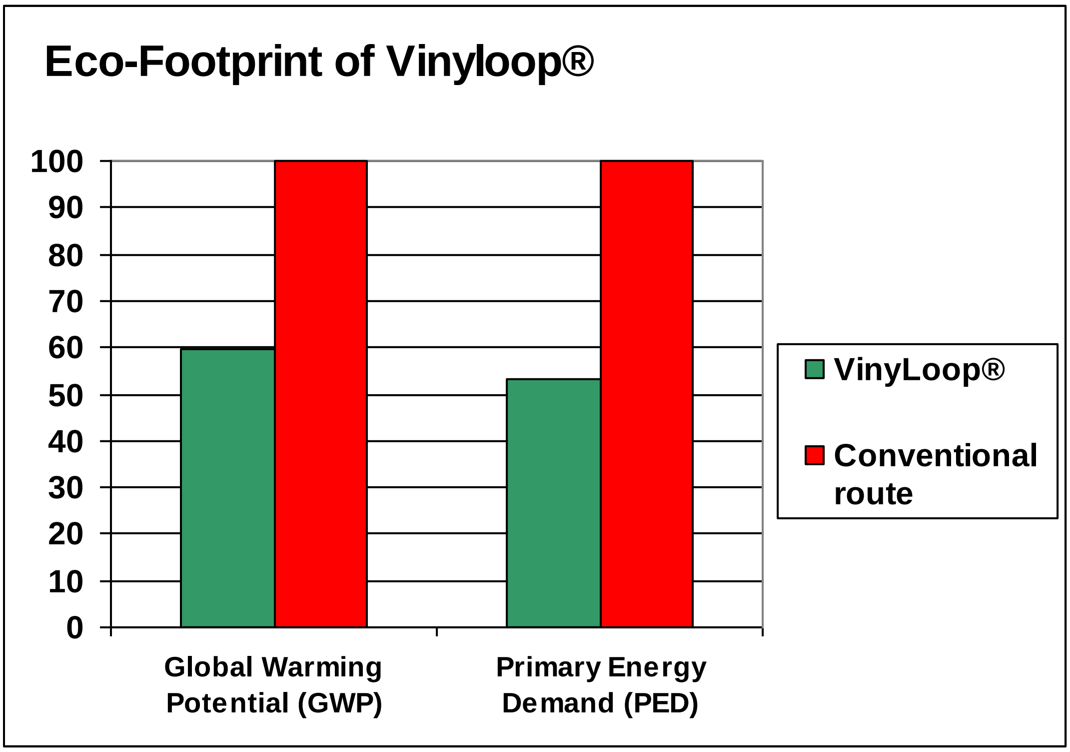
The objective of this study is to assess the environmental impact of producing one kilogram of R-PVC from the VinyLoop process and benchmark it against one kilogram of PVC compound produced by the conventional route. This route consists of incinerating the PVC waste and using virgin PVC compound.

The study is conducted primarily for the commissioners who request sound results in order to use them for their communication activities and their promotion of recycling. The target groups are therefore the general public, customers and policy makers. The aim of the study is further to serve as a general base of methodological function, in order to conduct further product specific studies addressing downstream products containing PVC.

The independent testing organization DEKRA has reviewed and approved the methodologies used in the study and confirmed that it is in compliance with the set of ISO standards 14040-44 for Life Cycle Assessment.

The VinyLoop Recycled PVC from cable waste reduces the environmental footprint. For each kilogram of PVC compound (functional unit) recovered through the VinyLoop process, the production of 1kg of PVC compound and the incineration of the corresponding amount of PVC waste are avoided.
If focused on significant impact categories, such as the Global Warming Potential and the Primary Energy Demand, a significant difference is visible. When benchmarked against PVC Compound in conventional route, R-PVC from VinyLoop has a 40% lower global warming potential (GWP) and a 47% lower primary energy demand (PED).

Impact Category	Unit	VinyLoop®	PVC conventional route	Delta
Global Warming (GWP 100a – IPCC 2007)	kg CO2-Eq	**60%**	**100%**	**-40%**
Primary Energy Demand	MJ	**53%**	**100%**	**-47%**



2 Introduction and Background

Solvay has developed the VinyLoop process as waste treatment option for difficult and post-consumer PVC waste in alignment with PVC industry's voluntary commitment Vinyl 2010 and its successor VinyPlus. In order to prove its own claim to do sustainable business with its activities, VinyLoop has commissioned the realization of an LCA study.

3 Description of the VinyLoop process

The VinyLoop plant of Ferrara is capable at present to treat 2 types of waste:

- Electrical cable waste, from which most of copper content has already been extracted by professional collectors. The waste is a mixture of variable grain size containing mainly PVC compound (old cable sheath) as well as other plastic resins and some residual particles of copper.
- Tarpaulin waste, a composite PET textile (woven fibers) coated with PVC compound.

In 2012, the plant produced 0.965 kg of PVC Compound and 0.035 kg of raw fibers from the treatment of 1.286 kg of cable waste and of 0.106 kg of tarpaulin waste.

3.1. Cable waste treatment (VinyLoop)

Cable waste lots containing more than 1% copper are pre-treated to remove excess copper. This pretreatment consists of a passage of the waste on a vibrating table with a flow of water to separate the residual copper, particles of polyethylene and other materials constituting the PVC cable jacket. The copper reclaimed in this pretreatment is recycled. Lots containing less than 1% copper are sent directly to the dissolution stage.

Dissolution
The waste is sent in a reactor with a solvent mixture (methyl ethyl ketone based) to complete the dissolution operation. This is a selective dissolution as the non PVC compound impurities remain insoluble.

Primary Filtration / Decantation
The primary filtration is used to separate the insolubles from the PVC solution. A further decantation eliminates the insoluble not separated during the primary filtration. The insoluble materials with the exception of copper are considered as waste and sent to incineration. The copper is recycled.

Precipitation
The precipitation stage is where, with the help of steam injection, the PVC compound is precipitated as granules and separated from the solvent. The solvent is recovered and reused.

Drying
The compound PVC is then dried in a fluidized bed dryer and packaged to be sent to the customers.
VinyLoop provides a ready made PVC compound that in most cases does not require further compounding.

3.2. Tarpaulin waste treatment (TexyLoop)

The raw material used by this process consists of tarpaulins made of polyester fibers coated with PVC compound. The tarpaulins are collected in various European countries and sent to MTB Trept (France) where they are shredded down to approximately pieces of 100 cm² and then sent to the Ferrara plant.

The tarpaulins are introduced with a solvent in a dissolving vessel where the PVC compound is dissolved and the polyester fibers are separated by filtration. The mixture of PVC-solvent is sent to the inlet of the VinyLoop decanter.

3.3. Carded PET fibers

The wet PET fibers are sent to la Tour de Pin for an additional drying, a visual inspection and a final carding operation.

4 Definition of Goal and Scope

4.1. Structure and organization of the study

Commissioner of the Study is VinyLoop Ferrara Spa. Responsible Eric Vandevyver, Christian Thamm.
Practitioner is Villers LC Consulting; Joseph Villers.
Stakeholders: VinyLoop customers (in particular corporate customers, waste management firms); public authorities (in particular municipalities and waste management authorities).

This Life Cycle Assessment (LCA) study was conducted in agreement with the international standards ISO 14040/14044.

The study has been critically review by DEKRA Industrial GmbH, Matthias Schulz.

4.2. Objective of study

The objective of the study is to update the precedent study which benchmarks the environmental impact of the recovered PVC compound (R-PVC) produced at the VinyLoop Ferrara plant in Italy against the PVC compound made by the conventional route (incineration of the waste and use of virgin PVC compound).

4.3. Target group and intended use of the study

The study is aimed primarily at commissioners who request sound results in order to use them for their communication activities and their promotion of recycling, in the framework of its sustainable development initiatives. The targets groups are therefore the general public, customers and policy makers.
Further, the aimed of the study is to serve as a general report for a methodological foundation to conduct further product specific studies addressing downstream products containing PVC based.

- The functional unit is: 1 kg of ready to use compound PVC (or 1 kg of wet PET fibers).
- The reference year is 2012.
- The software used is Umberto (version 5.6).

For the operations not related to the Ferrara and la Tour du Pin plants, Ecoinvent data (version 2.2) have been used with the exceptions of the phthalates esters for which the PricewaterhouseCoopers study of January 2001 has been used (see reference 2).

The Ecoinvent data set for S-PVC are based on the PlasticsEurope average European data set[1].

1 For more information please see http://www.plasticseurope.org/plasticssustainability/life-cycle-thinking-1746/frequently-asked-questions.aspx

4.4. Completeness, Level of Precision and Uncertainties

Operation	Inclusion	Justification
Solvent condensation flue gases and nitrogen incineration (Flare)	Partially included	Lack of available data related to the quantity of nitrogen sent to the flare
Waste water treatment	Partially included	Lack of plant specific data for the waste water treatment because waste water is handled by external service company.
Impact of tarpaulins collection upstream of the collecting points	Not included	No data available
Dispersing agent used in the precipitation process (PVAL type)	Partially included	Lack of data to allow specific impact modelisation. Vinyl acetate data were used as an approximation
Tarpaulins Shredding	Assessed at shredding plant	Data generated by a single measurement on site. No written report available
Solvent losses	Impact overestimation	Lack of data for solvent losses in the VinyLoop plant. Data used corresponds to the volumes purchased in 2012
Used cables shredding operations to obtain the cable waste raw material	Not included	Used cables shredding is made exclusively to extract copper. The VinyLoop plant uses the waste generated by this first separation.
Fiber losses during carding operation	Neglected	This impact was neglected because the quantity is very limited and that no specific treatment of this waste is necessary
Infrastructure	Not included	Infrastructure specific impact was not taken into account (high productivity industrial system)

5 Life Cycle Inventory (LCI) Analysis.

5.1. Flow Diagrams

Annexes 1 and 2 show schematically the system boundaries of both studied systems: the VinyLoop gate to gate operation and the conventional route.

5.2. VinyLoop process: data collection and assumptions

All internal data are from the year 2012.

Partitioning between both outputs (PVC Compound and wet PET fiber) has been made by mass. This is acceptable since the selling prices of both products are very similar. Other partitioning methods would be too complex and probably not realistic. In accordance with Plastics Europe recommendations,

recycled cables and tarpaulins waste are considered to enter the system without any burden.
The recovered copper is credited to the compound PVC using the module "copper at regional storage- (RER)", but after halving its impact. This is coherent, since this copper is resold at about half the price of primary copper.
In accordance with EU legislations, it has been considered that all other secondary waste produced during the treatment are incinerated. Specific Ecoinvent data have been used for each type of incinerated waste: PE, rubber, PVC. Due to the lack of such data for calcium carbonate waste, they have been assimilated to glass waste.
For the electricity supply, Italian data have been used. For the steam, the module "heat, natural gas, at industrial furnace, > 100 kW (RER) "has been used.

The Ecoinvent data don't take into account the impact of steam (1.58 MJ/kg) and electricity (0.2185 kWh/kg) produced during the incineration. So, a specific module has been created to calculate these impacts which are then subtracted from the main module. Electricity production data in Germany has been used since the waste is treated in this country.

5.3. Conventional route: data collection and assumptions

It is assumed that the mix R-PVC / wet PET produced at Ferrara replaces the equivalent amount of virgin PET / PVC compound. Furthermore, the mechanical properties of both recovered materials are comparable to those of the corresponding virgin materials. As a consequence, the manufacture of the desired articles requires the same weight quantities of material in both cases (recycled or virgin).

The composition of the PVC compound has been assumed as:

- PVC: 46.9 %
- Limestone: 18.8 %
- Phthalate esters: 32.8 %
- Zinc and Calcium stearates : 1.5%
-

If the waste would not have been recovered in the Ferrara unit, it would have been incinerated. The treatment of tarpaulins and cables waste has been calculated accordingly. Due to the lack of specific data, the incineration of phthalate esters has been assimilated to the incineration of PET (polyethylene terephthalate).

Since Ecoinvent data for incineration don't take into account the impact of steam (5.53 MJ/kg) and electricity (0.755 kWh/kg) produced, here again a specific module has been created to calculate these impacts. Electricity production in Germany has been used since this country is the biggest market for PVC and there are no average European electricity data in Ecoinvent.

5.4. Transports

All transports are by truck. Unless otherwise specified, trucks are not returning empty and are fully loaded (24t). The following distances have been used:

- Tarpaulin waste: 681+656 = 1337 km
- Cable waste: 110 km
- Waste to incineration: 650 km
- PVC to compounding: 500 km (return empty)
- Wet PET fibers to la Tour du Pin: 625 km. (Load of 8.6 t)

6 Life Cycle Impact Assessment (LCIA).

The following impact categories have been selected for the Life Cycle Impact Assessment (LCIA):

Impact	Methodology		Unit
Global warming	IPCC 2007	100a	kg CO2-Eq
Water		Total of river, ground, lake and unspecified water intake	m3
Resources	CML 2001	Depletion of abiotic resources	kg Sb
Acidification potential	CML 2001	average European	kg SO2-Eq
Eutrophication potential	CML 2001	generic	kg PO4-Eq
Stratospheric ozone depletion	CML 2001	ODP steady state	kg CFC-11-Eq
Photochemical oxidation	CML 2001	high NOx POCP	kg ethylen

The VinyLoop process recovers copper as a by-product. For this recovered copper, a credit is awarded to the main product R-PVC compound. The credit is based upon a generic dataset of primary copper production (European average). As a consequence, environmental impacts for the production of primary copper are subject to the impact assessment step of this study. For energy and greenhouse gases, such impacts and the associated credits are quantified. A qualitative impact assessment identifies copper production as a potential source of human and eco-toxicity impacts. Avoiding such impacts is pointed out qualitatively as a significant additional benefit, but is not quantified in this study.
The reasons for not conducting a quantitative toxicity impact assessment are twofold:

(a) The underlying LCI data is a third-party generic dataset -- assessing whether its data quality was sufficient for the purposes of toxicity impacts was outside the goal and scope of this study;
(b) The impact assessment models used to quantify toxicity impacts are subject to on-going debates in the scientific community and are hence considered insufficiently reliable to base business decisions on them.

The results for both systems studied are given in annexes 3 and 4.
Note that some figures are negative due to the fact that the credited impacts (copper and energy recovered) are sometimes bigger than the main impact.

In the VinyLoop gate to gate system, the contributions of the key operations to the GWP are broken down as shown in the table below:

Origin of GWP emissions	in %
Nitrogen production	1,4
Water consumption	0,3
Solvent production	2.4
Steam production	48.9
Electricity production	31.8
Natural gas	0,7
Transport	1,2
Incineration	14.3
Recovered copper	-1,1

Steam and electricity use are clearly the key factors impacting the GWP.

The impact of the carded PET fibers is outside the system boundary. Nevertheless, the impact of these carded fibers can be calculated by adding the impact of the carding to the impact of the wet fibers. See annex 5.

7 Life Cycle Interpretation

7.1. Discussion of results

The study shows that when the PVC produced at Ferrara using the VinyLoop process is benchmarked against the PVC produced by the conventional route, all selected environmental impacts, with the exception of the Ozone Depletion, are significantly reduced.
The primary energy demand (PED) of the VinyLoop process is 47 % lower that the one of the conventional one. This is clearly due to the recovery of the energy content of the PVC and of the phthalates.

The GWP 100a is 40 % lower than the one of the conventional process. This is less than for the PED and is mainly due to the high steam consumption of the process. The installation of a cogeneration plant in Ferrara would improve this situation.

The water consumption is reduced by 24 %.

7.2. Analysis and evaluation of results

The impacts of the recovered copper are given in annex 6. For the major impacts (PED, GWP), the effect is small.

Annex 7 shows the results of the study in the hypothesis of an incineration with no energy recovery. In this case, all impacts are higher (by about 20 to 30%) in both systems. This could be expected since the positive impact of the recovered energy is missing.
More interesting, is the fact that the absolute gains offered by the VinyLoop process are substantially increased:

PED: the reduction obtained by the VinyLoop process represents 33.64 MJ/Kg when no energy is recovered, where as it is 22.50 MJ/kg when energy is recovered.
GWP: the reduction is 1.94 kg CO2-eq versus 1.31.

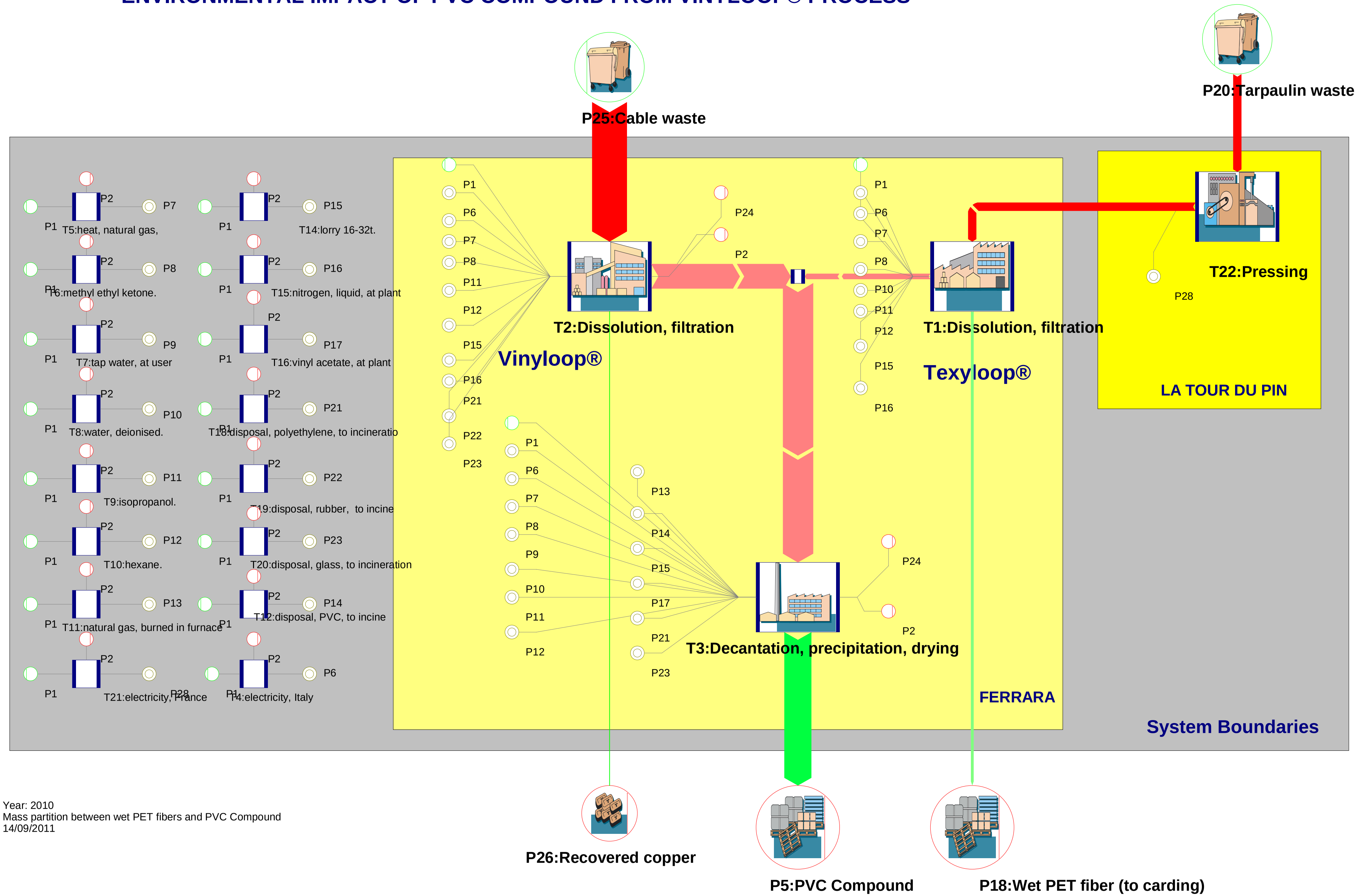
This shows that the conclusions of the study are conservative. Adoption of incineration models with less efficient yields would have given more favorable results for the R-PVC.

References:

1. The Eco-Footprint of VinyLoop®
Benchmarking of the environmental impact of PVC compound recycled in the VinyLoop® process with PVC compound produced in conventional route (virgin PVC compound and incineration)
August 2012

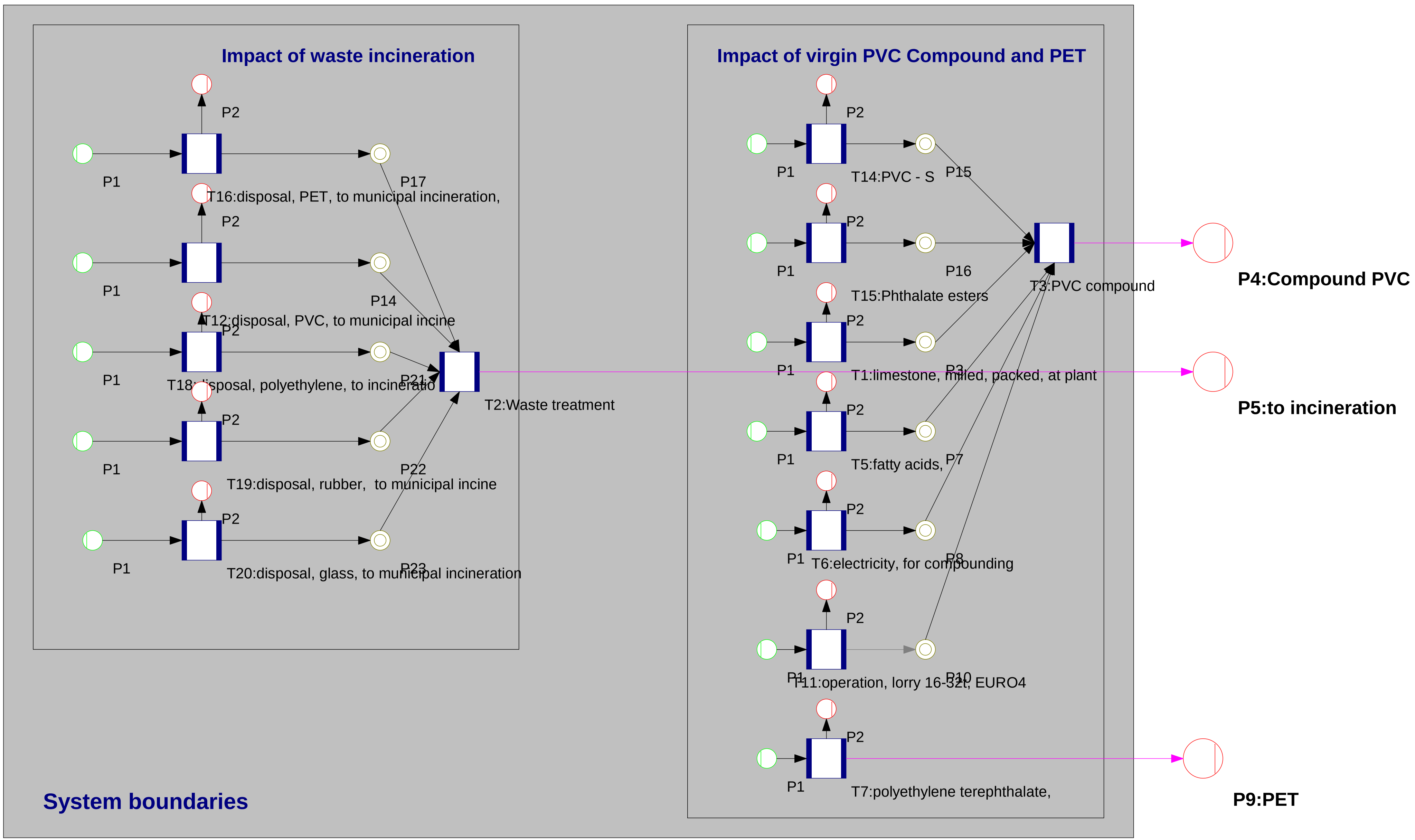
2. Price Waterhouse Coopers
Eco-profile of high volume commodity phthalate esters (DEHP/DINP/DIDP)
January 2001
Prepared for ECPI

ENVIRONMENTAL IMPACT OF PVC COMPOUND FROM VINYLOOP® PROCESS



Year: 2010
Mass partition between wet PET fibers and PVC Compound
14/09/2011

ENVIRONMENTAL IMPACT OF THE ALTERNATIVE SYSTEM



ANNEX 3

VinyLoop Eco-Footprint
gate to gate data

Impact Category	Unit	VinyLoop
Biogenic CO2 Emissions	kg CO2-Eq	**1,55E-03**
Global Warming (GWP 100a)	kg CO2-Eq	**1,94E+00**
Renewable Energy Resources	MJ	**7,86E-01**
Coal-Hard Energy	MJ	**8,48E-01**
Natural Gas Energy	MJ	**2,00E+01**
Crude Oil Energy	MJ	**3,21E+00**
Nuclear Energy	MJ	**7,82E-01**
Primary Forest Energy	MJ	**1,82E-05**
All Energy Ressources	MJ	**2,57E+01**
Water	m3	**6,26E-02**
Depletion of abiotic resources	kg Sb	**1,18E-02**
Acidification	kg SO2-Eq	**2,40E-03**
Eutrophication	kg PO4-Eq	**-1,46E-03**
Ozone Depletion	kg CFC-11-Eq	**1,61E-07**
Photochemical Oxidation	kg ethylen	**1,55E-04**

data per FU (kg of material)

ANNEX 4

VinyLoop - Benchmarking of the environmental impact of the VinyLoop against PVC compound using the conventional route

Impact Category	Unit	PVC conventional route	VinyLoop	difference
Biogenic CO2 Emissions	kg CO2-Eq	-1,94E-02	1,55E-03	n/a
Global Warming (GWP 100a)	kg CO2-Eq	3,25E+00	1,94E+00	-40%
Renewable Energy Resources	MJ	1,56E+00	7,86E-01	-49%
Coal Energy	MJ	1,69E+00	8,48E-01	-50%
Natural Gas Energy	MJ	1,58E+01	2,00E+01	27%
Crude Oil Energy	MJ	2,24E+01	3,21E+00	-86%
Nuclear Energy	MJ	6,62E+00	7,82E-01	-88%
Primary Forest Energy	MJ	6,85E-02	1,82E-05	-100%
All Energy Resources	MJ	4,82E+01	2,57E+01	-47%
Water	m3	2,63E-01	6,26E-02	-76%
Depletion of abiotic resources	kg Sb	1,88E-02	1,18E-02	-37%
Acidification	kg SO2-Eq	6,71E-03	2,40E-03	-64%
Eutrophication	kg PO4-Eq	6,83E-04	-1,46E-03	n/a
Ozone Depletion	kg CFC-11-Eq	-2,87E-08	1,61E-07	n/a
Photochemical Oxidation	kg ethylen	4,52E-04	1,55E-04	-66%

data per FU (kg of material)

ANNEX 5

TexyLoop - Carded PET fibers
gate to gate data

Impact Category	Unit	Carding operation	Carded PET fibers
Biogenic CO2 Emissions	kg CO2-Eq	-1,02E-05	1,53E-03
Global Warming (GWP 100a)	kg CO2-Eq	6,27E-02	2,01E+00
Renewable Energy Resources	MJ	3,15E-02	8,18E-01
Coal Energy	MJ	4,22E-02	8,90E-01
Natural Gas Energy	MJ	6,55E-02	2,01E+01
Crude Oil Energy	MJ	7,66E-01	3,98E+00
Nuclear Energy	MJ	6,33E-01	1,41E+00
Primary Forest Energy	MJ	9,32E-07	1,91E-05
All Energy Ressources	MJ	1,54E+00	2,72E+01
Water	m3	6,64E-04	6,33E-02
Depletion of abiotic resources	kg Sb	3,98E-04	1,22E-02
Acidification	kg SO2-Eq	2,42E-04	2,64E-03
Eutrophication	kg PO4-Eq	5,80E-05	-1,40E-03
Ozone Depletion	kg CFC-11-Eq	8,79E-09	1,69E-07
Photochemical Oxidation	kg ethylen	5,86E-06	1,61E-04

data per FU (kg of material)

ANNEX 6

VinyLoop - Impact of the recovered copper on the R-PVC

Impact Category	Unit	VinyLoop	recovered Copper	Ratio Copper /VinyLoop
Biogenic CO2 Emissions	kg CO2-Eq	1,55E-03	-7,35E-05	n/a
Global Warming (GWP 100a)	kg CO2-Eq	1,94E+00	2,16E-02	1,11%
Renewable Energy Resources	MJ	7,86E-01	5,86E-02	7,45%
Coal Energy	MJ	8,48E-01	8,52E-02	10,05%
Natural Gas Energy	MJ	2,00E+01	7,57E-02	0,38%
Crude Oil Energy	MJ	3,21E+00	1,07E-01	3,34%
Nuclear Energy	MJ	7,82E-01	6,26E-02	8,00%
Primary Forest Energy	MJ	1,82E-05	1,29E-06	0,00%
All Energy Ressources	MJ	2,57E+01	3,89E-01	1,52%
Water	m3	6,26E-02	8,93E-04	1,43%
Depletion of abiotic resources	kg Sb	1,18E-02	1,63E-04	1,38%
Acidification	kg SO2-Eq	2,40E-03	1,60E-03	66,67%
Eutrophication	kg PO4-Eq	-1,46E-03	1,89E-03	n/a
Ozone Depletion	kg CFC-11-Eq	1,61E-07	1,60E-09	1%
Photochemical Oxidation	kg ethylen	1,55E-04	5,97E-05	38,57%

data per FU (kg of material)

ANNEX 7

VinyLoop - Benchmarking of the impact of the R-PVC with the PVC compound using the conventional route (sensibility analysis: incineration without energy recovery)

Impact Category	Unit	PVC conventional route	VinyLoop	difference
Biogenic CO2 Emissions	kg CO2-Eq	-1,847E-02	1,230E-03	n/a
Global Warming (GWP 100a)	kg CO2-Eq	4,141E+00	2,199E+00	-47%
Renewable Energy Resources	MJ	1,912E+00	9,083E-01	-52%
Coal Energy	MJ	6,173E+00	2,146E+00	-65%
Natural Gas Energy	MJ	2,352E+01	2,224E+01	-5%
Crude Oil Energy	MJ	2,274E+01	3,299E+00	-85%
Nuclear Energy	MJ	9,317E+00	1,561E+00	-83%
Primary Forest Energy	MJ	6,849E-02	2,020E-05	-100%
All Energy Ressources	MJ	6,380E+01	3,016E+01	-53%
Water	m3	2,818E-01	6,812E-02	-76%
Depletion of abiotic resources	kg Sb	2,574E-02	1,379E-02	-46%
Acidification	kg SO2-Eq	7,691E-03	2,681E-03	-65%
Eutrophication	kg PO4-Eq	2,696E-03	-8,802E-04	n/a
Ozone Depletion	kg CFC-11-Eq	3,824E-08	1,799E-07	370%
Photochemical Oxidation	kg ethylen	5,107E-04	1,719E-04	-66%

data per FU (kg of material)

ANNEXE 8

Comparison of the results with those of the original study

1 Introduction

The actual study is an update of the original one (see reference 1) which was made on the basis of 2010 data.
It is interesting to evaluate the evolution of the results.

2 Evolution of the VinyLoop process between 2010 and 2012

No major changes were made to the process between 2010 and 2012.

The steam consumption decreased from 16.7 MW/kg to 13.4 MW/kg or -20 %, whereas the electricity consumption increased from 0.82 to 1.06 kWh/kg or +29%.
The increase in electricity consumption is linked to the facts that a lower amount of tarpaulins was treated and that the data are more accurate. In 2010, some data were extrapolated.
The decrease in steam consumption is due to:

- an optimization of the precipitation stage,
- the replacement of the steam ejectors by a nitrogen sweep for inertization processes,
- a generally more stable consumption.

A significant reduction in the raw water consumption of the site during the stage cable dissolution / filtration (-35%) resulting from steam consumption reduction as well as recycling of cooling water. A small increase in the solvent consumption should also be noted.

The input of tarpaulin waste decreased from 20 to 7.6 %. Since tarpaulin is the source of PET, this resulted in a much lower amount of recovered PET.

3 Life Cycle Inventory (LCI) Analysis.

All partitioning rules and assumptions adopted in the 2010 study have been kept.
The Ecoinvent modules have been kept with the exception of CaZn stabilizer whose data have been updated by reconstitution on the basis of literature data, but this is not significant since it relates to a small consumption (<2%).

The composition of the PVC compound is unchanged:
- S-PVC: 46.9 %
- Limestone: 18.8 %
- Phthalates esters: 32.8 %
- CaZn 1.5 %

4 Life Cycle Impact Assessment (LCIA).

The results of the gate to gate operations for both studies are given in the table below (per kg of R-PVC):

Impact category	Unit	2010	2012	Diff. (%)
Biogenic CO2 Emissions	kg CO2-Eq	1,71E-03	1,55E-03	-9
GWP 100a	kg CO2-Eq	2,06E+00	1,94E+00	-6
Renewable Energy Resources	MJ	5,60E-01	7,86E-01	40
Coal Energy	MJ	1,80E-01	8,48E-01	371
Natural Gas Energy	MJ	2,24E+01	2,00E+01	-10
Crude Oil Energy	MJ	2,51E+00	3,21E+00	28
Nuclear Energy	MJ	3,37E-01	7,82E-01	132
Primary Forest Energy	MJ	1,96E-05	1,82E-05	-7

All Energy Resources	MJ	2,60E+01	2,57E+01	-1
Water	m3	6,92E-02	6,26E-02	-10
Depletion of abiotic resources	kg Sb	1,21E-02	1,18E-02	-3
Acidification	kg SO2-Eq	1,67E-03	2,40E-03	44
Eutrophication	kg PO4-Eq	-1,84E-03	-1,46E-03	20
Ozone Depletion	kg CFC-11-Eq	1,74E-07	1,61E-07	-8
Photochemical Oxidation	kg ethylen	1,27E-04	1,55E-04	22

The contributions of the key operations to the GWP are broken down as shown in the table below:

Origin of GWP emissions (in %)	2010	2012
Nitrogen production	1,0	1,4
Water consumption	0,3	0,3
Solvent production	1,5	2,4
Steam production	57,8	48,9
Electricity production	23,1	31,8
Natural gas	0,6	0,7
Transport	1,2	1,2
Incineration	15,7	14,3
Recovered copper	-1,1	-1,1

5 Life Cycle Interpretation

If we examine the major impacts, such as the Global Warming Potential and the Cumulative Energy Demand, the differences are no really significant.

Compared to 2010, the Global Warming Potential (GWP) in 2012 is 6 % lower. The Cumulative Energy Demand is 1% lower, but with some disparities between its components: the reduction in the natural gas consumption is due to the lower steam consumption. The increase in coal and nuclear energy consumptions (respectively 371 and 132 %) are due to the higher electricity consumption.
The increase in Acidification Potential (44%) is also linked to the higher electricity consumption.

The total water consumption is down by 10%.

VinyLoop: Eco-Footprint

Critical Review of Life Cycle Assessment
Offer No: 2330270518

SOLVIN S/A,
VinyLoop Ferrara SpA,
Christian Thamm

DEKRA Consulting GmbH
Sustainability & Process
Excellence
25.10.2013

CRITICAL REVIEW SUMMARY

This updated Life Cycle Assessment (LCA) of the **VinyLoop** process operated at Ferrara, Italy, was conducted in a gate-to-gate approach based on site data for the year 2012. The goal of the study was to assess the potential environmental impacts per kg of R-PVC (functional unit) against the benchmark of the European production average of a conventional plasticised PVC compound (cradle-to-gate).

While the LCA study can be disclosed to interested parties when positioning VinyLoop as a recycling process, it is not expected to affect the interests of competitors (virgin PVC producers). Key results are:

- The VinyLoop process produces a high-quality secondary PVC compound (R-PVC) which can replace virgin PVC compound produced with conventional technologies for use in relevant downstream applications.
- The Primary Energy Demand of VinyLoop R-PVC is 47% lower than the benchmark;
- The Global Warming Potential of VinyLoop R-PVC 40% lower than the benchmark;
- In addition to preserving raw material resources, the VinyLoop process avoids incineration of post-consumer PVC waste;
- Aside from plastics recovery, the recovery of other valuable materials, such as copper from cables, can further improve the advantageous performance of the VinyLoop process.

Further, this critical review[2] confirms that –

- The LCA was conducted in accordance with the applicable international standards on LCA, ISO 14040–44.
- The data are appropriate with respect to the stated goal and scope.
- The conclusions are supported by the data and calculations.

More detailed comments regarding particular issues and further explanations can be found in the main part of this review report.

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[2] As per ISO 14040–44, this critical review does not imply an endorsement of the LCA method, nor of any comparative assertion based on this LCA.