EVERYTHING ABOUT PVC

FROM MANUFACTURING TO RECYCLING

Everything about PVC

PVC FROM A TO Z

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AGPU e.V.
Am Hofgarten 1-2
D-53113 Bonn, Germany
Tel. +49 228 91783-0
Fax +49 228 5389594
agpu@agpu.com
www.agpu.com

PVCH – Arbeitsgemeinschaft der Schweizerischen PVC-Industrie
c/o Swiss Plastics – Schachenallee 29c
CH-5000 Aarau, Switzerland
Tel. +41 62 832 7060
Fax +41 62 834 0061
info@pvch.ch
www.pvch.ch

API PVC- und Umweltberatung GmbH
Paniglgasse 24/19a
A – 1040 Vienna, Austria
Tel. +43 1 712 72 77
Fax +43 1 712 72 77-88
office.at@plasticseurope.org
www.pvc.at

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PVC – WHAT YOU SHOULD KNOW

For more than 50 years, PVC has been very successful throughout the world. Today, this versatile material is one of the most important plastic materials recognised internationally and proven on the market.

PVC has distinguished itself especially with its wide range of applications. PVC products are often cost-effective in terms of purchasing and maintenance. At the same time, they contribute more and more to sustainable development throughout their entire life cycle: this occurs by means of state-of-the-art manufacturing and production methods, the responsible use of energy and resources, cost-effective manufacturing and processing, as well as established recovery possibilities. This progress has led to a continuous increase in the demand for this plastic material. Moreover, through cost-effective PVC products, society saves money which can be spent on further sound ecological and social investments.

ECONOMIC IMPORTANCE

In 2014, the European plastics industry had a turnover of 350 billion euros. Over 1.45 million employees in the plastics industry work in approximately 62,000 different companies, most of them being SMEs.[1] PVC is one of the most important plastic materials in Europe and is in a class of its own worldwide. The PVC industry has achieved enormous economic importance through its extremely wide range of high-quality products. The prognosis shows continued growth.

Processing in Europe

In 2014, PVC processing in Europe was at 4.9 million tonnes.[2] PVC is one of the most important plastic materials after the polyolefins polyethylene and polypropylene, which have a 48% market share. The outstanding importance of PVC is documented in the chart below.

International Growth

Worldwide, PVC is in a class of its own. Vinyl is in third place among distributed plastic materials. All predictions point towards the continued growth of plastic materials[3] as well as of PVC.

Large Manufacturers supply the Market

The concentration of suppliers varies according to continent. In China, a large number of small suppliers dominate. In North America, on the other hand, five major manufacturers control 88% of the market. In Europe, the five largest producers supply 71% of PVC. Taking into consideration the forecasted capacities of the largest manufacturers worldwide in 2016, Shin-Etsu is at the top, followed by Inovyn (the joint venture between Solvay and INEOS), Formosa Plastics and Oxychem. In terms of PVC specialities for paste processing, the main European producers are Vinnolit (acquired in 2014 by Westlake), Vestolit (acquired in 2014 by Mexichem) and Inovyn.

Processing shaped by Medium-Sized Companies

The PVC-processing industry in Germany, Austria, and Switzerland is extremely efficient and predominantly characterised by medium-sized businesses. It is very export oriented – just like the plastics manufacturing industry. Several of these PVC converters lead the worldwide market with their products. In particular, these products consist of window profiles and rigid

European plastics demand* by polymer type 2014

* EU28+NO/CH
Source: PlasticsEurope (PEMRG) / Consultic / myCeppi

[1] PlasticsEurope: Plastics – The Facts 2015
[2] PlasticsEurope Market Research Group, 2014
[3] PlasticsEurope Market Research Group / Consultic Marketing & Industrieberatung GmbH, 2014

films, as well as medical applications, roofing und sealing membranes, and flexible films. Approximately 1.52 million tonnes of PVC was processed in Germany in 2014.

Important Economic Factor

In 2014, the German plastics industry earned 92 billion euros. The 370,000 employees in the plastics industry work in approximately 3,300 different companies.[4] The Swiss PVC industry contributes considerably to the success of the entire plastics industry. It achieves an annual revenue of approximately 15.1 billion Swiss francs with its 34,000 employees, i.e., more than 16 billion euros in some 850 companies. The Austrian plastics industry employs more than 29,000 employees in approximately 560 companies and generates an annual turnover of 13 billion euros. PVC plays a decisive role in this economically important sector.

Photo: Südsalz GmbH

Salt crystals are of essential importance in PVC production. It is made of 57 percent salt, which is available on the planet in virtually unlimited amounts, and 43 percent crude oil.

PLASTIC MATERIALS: PREVIOUS AND EXPECTED DEMAND 1990 - 2019

Demand in million tonnes 1990 – 2019	1990 in million tonnes	2014 in million tonnes	2019 in million tonnes	Growth per year 2014 - 2019
PE-LD Polyethylene (Low Density) **PE-LLD** Polyethylene (Linear Low Density)	18.8	45.1	54.6	3.9 %
PE-HD Polyethylene (High Density)	11.9	39.8	47.3	3.5 %
PP Polypropylene	12.9	58.9	72.0	4.1 %
PVC Polyvinyl Chloride	17.7	40.5	49.0	3.9 %
PS Polystyrene	7.2	12.0	13.0	1.6 %
EPS Expanded Polystyrene (Foam)	1.7	6.3	8.1	5.3 %
ABS Acrylonitrile-Butadiene-Styrene Copolymer **ASA** Acrylic Ester-Styrene-Acrylonitrile Copolymer **SAN** Styrene-Acrylonitrile Copolymer	2.8	7.9	9.7	4.1 %
PA Polyamide	1.0	3.2	3.9	4.2 %
PC Polycarbonate	0.5	3.8	4.5	3.5 %
PET Polyethylene Terephthalate	1.7	18.9	24.2	5.1 %
PUR Polyurethane	4.6	14.3	18.1	4.8 %
Other Thermoplastics	2.8	9.4	11.4	3.9 %
Total	**~83.6**	**~260**	**~316**	**4.0 %**

Source: PlasticsEurope Market Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH

MANUFACTURING AND RAW MATERIALS

The European PVC industry has consistently improved its manufacturing processes in recent years. This is especially true for PVC-formulations. Thus, there have been considerable changes in the use of stabilisers and plasticisers.

Synthesis of Crude Oil and Rock Salt

Crude oil/natural gas and rock salt are the starting products for PVC manufacturing. Ethylene is the result of crude oil in the intermediate stage of naphtha through thermal "cracking". Chlorine, on the other hand, is produced from rock salt through chloralkali electrolysis. For this purpose, the modern energy-saving membrane process is commonly used today. From 2017, this will be the only method used within the EU. Sodium hydroxide and hydrogen are produced as important by-products. In turn, they are the raw materials for many other syntheses. Vinyl chloride (VC) is produced from ethylene and chlorine at a ratio of 43% to 57%. VC is the monomeric building block of PVC. The transformation of VC to PVC takes place through various technological processes to Suspension PVC (S-PVC), Emulsion PVC (E-PVC) and Mass PVC (M-PVC).

[4] PlasticsEurope Annual Report 2014

Additives

PVC products are derived from a white, odourless powder which is mixed with additives for the further processing of semi-finished and finished products. Such mixtures are not only found in practically all plastics, but also in other materials such as glass, steel, concrete, etc.

Basically, the following additives are used:

- stabilisers and co-stabilisers
- lubricants
- polymer agents to improve impact strength (modifier), heat and form stability, and processing performance
- fillers
- pigments
- plasticisers.

Additives facilitate processing and simultaneously determine the properties of end products. The choice of stabilisers and lubricants depends on processing technologies and requirements of the finished products. Specific material properties of semi-finished and finished products are achieved by the addition of modifiers, plasticisers and/or pigments. Depending on the choice and quantities of additives, PVC as a raw material can be converted to e. g. extremely thin flexible packaging film (cling film) for fresh meat or robust and thick-walled pipes for potable water. Additives, such as stabilisers and lubricants can be added as individual components or as so called one-pack mixtures. A very wide range of products and properties can be realised by these additives precisely adjusted to the end product performance requirements.

Stabilisers

The use of stabilisers guarantees sufficient heat stability for PVC during processing and protects the end product from change due to heat, UV-light, or oxygen. Especially inorganic and organic salts of the metals calcium, zinc, barium, lead and tin are added to PVC products. These salts are firmly anchored in the polymer matrix. They are not released during the use of these products. The use of stabilisers has undergone a significant change in recent years. One reason for this was that the European industry discontinued the sale and use of cadmium stabilisers in all EU member states.
In addition, the European Stabiliser Producers Association (ESPA) and the European Plastics Converters Association (EuPC) agreed to the voluntary commitment Vinyl 2010 in October 2001 to replace lead stabilisers. Several intermediate goals have therefore been established (basis: consumption in 2000):

- 15% reduction in 2005
- 50% reduction in 2010
- 100% reduction in 2015.[5]

The goal for 2010 was surpassed in 2008. The reduction of lead stabilisers was already at ca. 76% in 2010. At the same time, the research and development of alternative stabiliser systems in recent years has made enormous stride at great financial cost. In addition to systems based on calcium/zinc, whose market share in Western Europe increased from 5% in 1994 to over

The environment-friendly membrane electrolysis saves an enormous amount of energy and makes an important contribution to the reduction of CO_2 emissions.

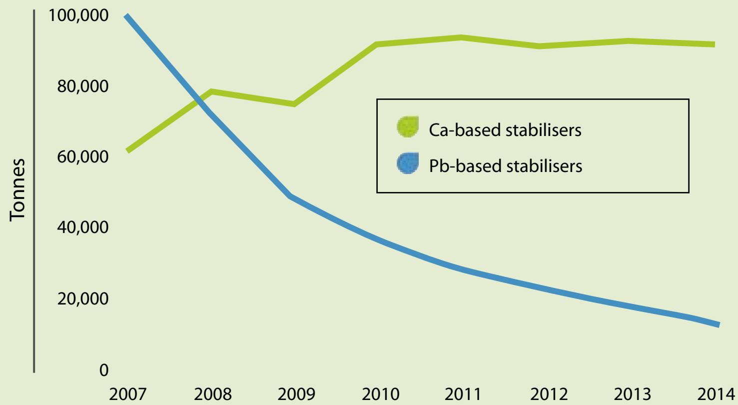
Photo: Vinnolit GmbH & Co. KG

50% today, tin also plays an important role. Moreover, new developments utilise metal-free organic stabiliser systems.
The amount of thermal stabilisers used in mixtures has been reduced in recent years through more effective additives and optimised processing.
Recycled materials might contain cadmium and lead due to the recycling of older products. This is permitted by law in order to create incentives for the use of recycled materials.[6] Directive 494/2011 by the EU Commission from 20 May 2011 regulated the use of recycled materials containing cadmium.[7]

Plasticisers

Approximately 70% of PVC produced is used in Europe to manufacture rigid products such as window profiles and pipes, which are distinguished by their longevity and weather resistance. The remaining 30% covers soft applications. Plasticisers provide PVC with special properties of use similar to those of

Stabilisers Consumption in the EU-28



Source: VinylPlus

[5] Also see details in the chapter "Voluntary Commitment of the European PVC Industry". The converters in the new members states followed, and by the end of 2007, all EU-27 members were on board.

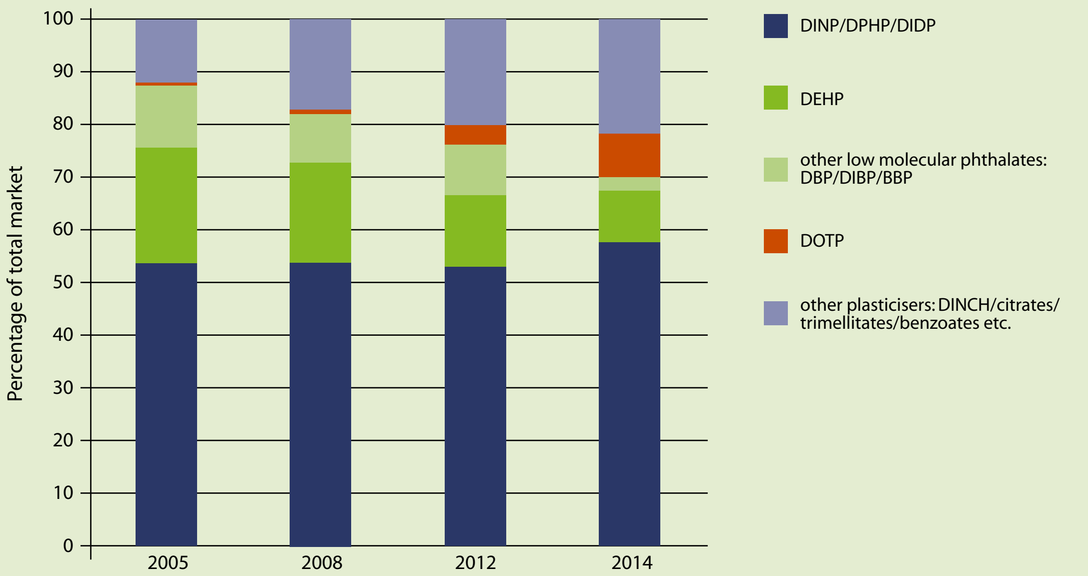
[6] Number 23 of the Resolution Recommendation on PVC from 3 April 2001.

[7] EU Directive 494/2011 from 20 May 2011.

rubber. This naturally hard material becomes flexible and elastic through plasticisers. At the same time, it retains its shape. Soft PVC can be applied to a wide range of products in various ways. Pastes made of a mixture of PVC and plasticisers expand the range of possibilities, e.g. by means of expressive vinyl wall-coverings or easy-to-clean flooring.
Soft PVC is distinguished by its outstanding properties of use which offer a versatile range of possibilities. Flexible products such as artificial leather, weather-resistant roofing membranes, or flame-retardant cables enhance our lives and make them safer and more comfortable. In medical care, soft PVC applications have stood the test of time for decades. Blood bags, tube systems, and wound dressings are essential components of patient care. PVC is the most used plastic material in medical applications. PVC products are even recommended for allergy sufferers due to their compatibility.
The most frequently used plasticisers are esters from phthalic acid. In terms of application, a change has taken place on the European market in recent years in favour of high-molecular weight plasticisers. The largest share is made up of DINP and DIDP.[8] These substances have extensively replaced low-molecular weight plasticisers on the market such as DEHP, DBP, and BBP.[9] Special plasticisers have also become important economically in the meantime. These include polymer plasticisers based on adipic acid, adipates, terephthalates, and other phthalate-free plasticisers such as DINCH.[10]

In public discussions, phthalates are repeatedly linked to harmful effects on humans and the environment. These generalisations are not justified. Many phthalates differ from one another considerably in terms of effect. The short-chained phthalates (DBP, DIBP, BBP, DEHP) have been classified as toxic to reproduction, i.e. they are suspected of having an influence on sexual function and fertility. As part of REACH, the new European legislation on chemicals, these phthalates have been listed as "substances of very high concern". Their production and application were subject to an authorisation process. As a result, these phthalates can still be used in the EU only by companies with the appropriate authorisation since February 2015.
In contrast, the high-molecular weight plasticisers DINP and DIDP have other properties. They are some of the most researched substances in terms of toxicology and ecology. Both plasticisers have undergone EU risk assessments and evaluations for many years. In January 2014, the European Commission published their conclusion for a re-evaluation of measures restricting the placing on the market of toys and childcare articles to be placed in the mouth of children under three years of age. The European Commission agrees with the results of The European Chemical Agency (ECHA), to keep the restrictions for these toys and childcare articles.[11] In contrast, for all other applications there was no risk identified, that further steps to reduce the exposition of DINP and DIDP will be necessary.
Since 1999 [12,13] the plasticisers DEHP, DBP and BBP are no longer allowed in toys and childcare articles in the EU.

Percentage of phthalates in the overall turnover with plasticisers in the EU28 plus East European countries



Source: ECPI

[8] DINP – diisononyl phthalate; DIDP – diisodecyl phthalate.
[9] DEHP – bis(2-ethylhexyl) phthalate; DBP – dibutyl phthalate; BBP - benzyl butyl phthalate.
[10] DINCH – 1.2-Cyclohexane dicarboxylic acid diisononyl ester.
[11] Guidance Document on the interpretation of the concept "which can be placed in the mouth" as laid down in the Annex to the 22nd amendment of Council Directive 76/769/EEC, European Commission, Enterprise and Industry Directorate-General.
[12] 1999/815/EC Directive Art. 9, 92/59/EEC
[13] 2005/84/EC

PROCESSING AND PRODUCTS

PVC can be converted into various products in a number of ways. The range extends from heat-insulating, energy-saving windows to robust pipes and easy-to-clean floorings. Approximately seventy percent of PVC materials are used in the building sector, many of which are long-life products.

Extrusion or Injection Moulding

PVC is one of the few polymers which can be processed thermoplastically and by means of paste technologies.[14] Thermoplastic processes take place primarily on extruders. The final products are pipes, profiles, sheets, tubes, and cables.[15] Film and floor coverings are created by means of calenders (rolling mills). Fittings and casings are produced in the injection moulding process and hollow articles such as bottles by blow moulding.

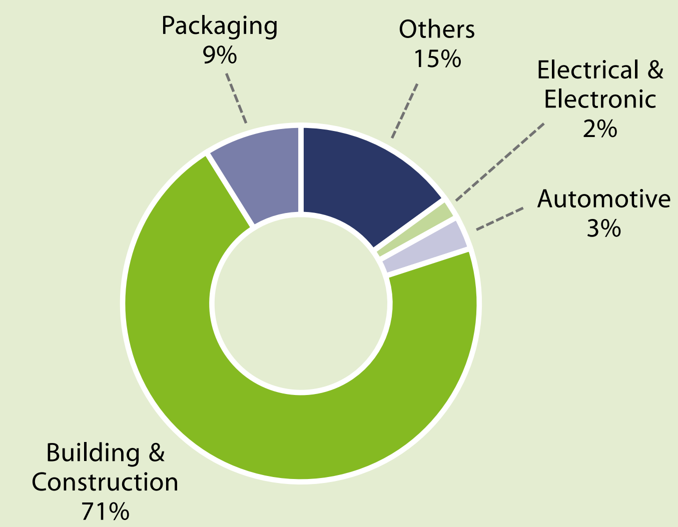
Emulsion and micro-suspension PVC is applied as a paste to various soft PVC products such as tarpaulins, flooring, coatings, and artificial leather. As an alternative, rotation moulding is used to shape dolls and balls.

A Wide Range of Products

PVC can be used in numerous products due to its outstanding properties and therefore is an integral part of our daily life.

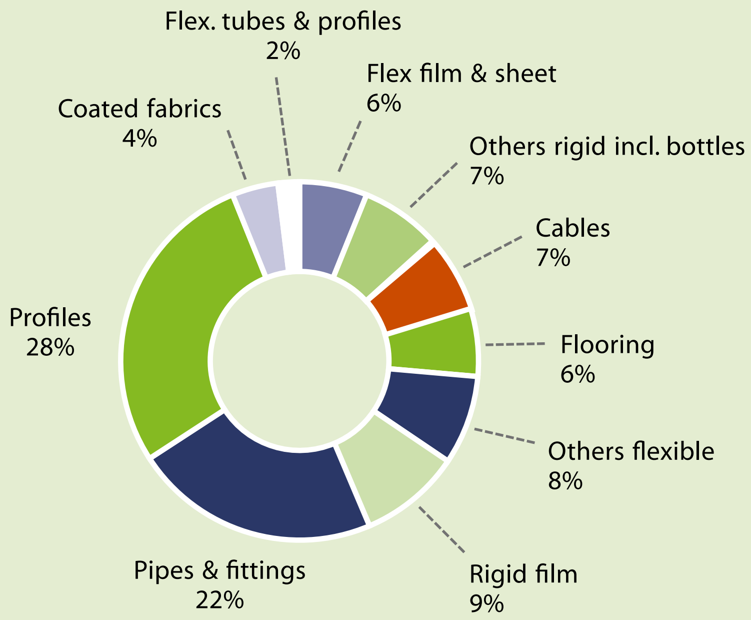
In Germany, approximately 70% of all PVC applications are intended for the construction sector. In particular, this includes window profiles, pipes, wall and floor coverings, as well as roofing membranes. PVC windows are weather resistant, durable, easy to clean, economical, and recyclable at the end of their life cycles. Robust pipes made of rigid PVC transport valuable drinking water, drain roofs, and dispose of sewage water. They can be easily, safely, and economically installed by means of structural and civil engineering. Building products made of PVC are distinguished especially by their longevity: this is a decisive criterion for selecting the appropriate material.

Amount of processed PVC according to the relevant sector in Europe in 2013



Source: PlasticsEurope

PVC applications in the EU, 2013



Source: ECVM

In the packaging sector PVC is found in special applications such as blister packs, adhesive tapes, hollow articles, and cups. Cables and wires with an insulation or sheathing made of soft PVC play a decisive role in the smooth operations of our daily lives in terms of energy supply, control functions, and communications. Protective underbody sealing, interior panelling, and cable harnesses inside vehicles and under the bonnet play an important role in the automotive sector. In addition, medical products such as blood bags or tubes, office articles, garden equipment and furniture, and tarpaulins are indispensable. These examples alone demonstrate the versatile possibilities of applications for PVC.

[14] "Technologiestudie zur Verarbeitung von PVC", Fraunhofer ICT, 2005, commissioned by PlasticsEurope Deutschland and AGPU can be downloaded at www.agpu.com.

[15] At www.agpu.com under the menu item "Infothek", product information is available on floor coverings, windows, pipes, cables, packaging, wall coverings, and medical and automotive articles made of PVC.

Versatile Material Properties

PVC is an all-around talent: it is hard and durable or soft and flexible as need be. Simple changes in the formulation allow for practically any desired material property. Therefore, PVC exists crystal-clear or coloured, electrically well-insulating or anti-static. This durable plastic is largely resistant to chemicals, weather and abrasion, and does not cause health risks. Moreover, the chlorine content makes the material highly flame-retardant. Further advantages of the material include efficient production and easy processing as well as the material-saving manufacturing of consumer goods.

Durable Applications Prevail

Detailed examinations on the length of use of PVC products in Western Europe reveal that long-term applications are dominant. This is especially true for Germany, Austria, and Switzerland. These countries have confidence in PVC products especially in the construction sector. In Switzerland, 80% of these material solutions are used in the building sector, and approximately 70% in Germany. This high quota can be traced back to the efficient, long-term properties of PVC: this is a further economic and ecological advantage since valuable resources are being saved.

LENGTH OF USE	SHARE OF OVERALL PVC CONSUMPTION
short, up to 2 years	15%
middle, 2-10 years	16%
long, 10-20 years	28%
very long, over 20 years	41%

RECYCLING

Used PVC products are too good to throw away. The European PVC industry has organised a recovery system for the most important PVC products in order to save valuable resources and has set ambitious goals for the future.

Increase in Recovery Quotas

The AGPU and other associations have commissioned the Consultic Marketing und Industrieberatung GmbH at regular intervals to compile data about PVC waste in Germany. In 2013, the amount of PVC waste was approximately 647,300 tonnes (563,000 tonnes in 2007). This corresponds to 1-2% of the overall volume of household waste and industrial waste similar to household waste. The share of post-consumer waste from this amount was at 520,300 tonnes (403,000 tonnes in 2007). Approximately 140,000 tonnes (77,000 tonnes in 2007) of this amount were recycled mechanically and by feedstock recycling. If production waste (post-industrial) is included in these statistics, the amount of recycled materials totals approximately 243,000 tonnes (221,000 tonnes in 2007). In actuality, the recycled amount is even higher. "In-house recycling" is not included in these statistics. During this process, the production waste generated in converting machines is comminuted and then immediately recovered. Based on the overall amount of waste (post-consumer and post-industrial), the recycling quota is approximately 37%. Additional PVC waste undergoes energy recovery through state-of-the-art, cutting-edge technology – primarily in waste incineration plants. Since PVC has a calorific value similar to that of brown coal (approximately 19 MJ/kg), the material contributes positively to energy balance when incinerated in household waste (approximately 11 MJ/kg).

Photo: Rewindo Fenster-Recycling-Service GmbH

Nowadays the collection and recycling of old PVC windows is common practice. From the obtained recycling material new PVC profiles for energy-saving windows are being produced by co-extrusion.

Mechanical Recycling

Mechanical recycling has been used in PVC production and processing for many decades. The largest part of unmixed waste flows directly back into production. Since the beginning of the 1990s, the PVC industry has developed a number of initiatives for the recovery of post-consumer waste which are now established on the market.
PVC construction materials make up the largest amounts in waste management. The Arbeitsgemeinschaft PVC-Boden-

belag Recycling (AgPR) and RoofCollect – the successor organisation of the Arbeitsgemeinschaft für PVC-Dachbahnen Recycling (AfDR) – handles this waste in Germany. Rewindo Fenster-Recycling-Service GmbH has established a broad-based, take-back system for windows in Germany in close cooperation with their recycling partners. Since the beginning of 2005, Rohr-Recycling in Westeregeln – a subsidiary of the Tönsmeier-Gruppe – and Kunststoffrohrverband (KRV) have established an alliance to increase the amount of materials to be recovered. This initiative takes back PVC pipes throughout Germany and arranges for the recycling of used products. Furthermore, the PVC industry in Germany cooperates with the European initiative Recovinyl established by Vinyl 2010.

In Austria, the industry initiatives ÖAKF for plastic windows (Österreichischer Arbeitskreis Kunststoff-Fenster) and ÖAKR for plastic pipes (Österreichischer Arbeitskreis Kunststoff-Rohre) organise the return and recycling of used PVC materials. The amounts collected in this manner are processed primarily by Reststofftechnik GmbH in Salzburg.

Furthermore, the dissolving process VINYLOOP® developed by Solvay allows the recycling of previously difficult-to-treat composite materials (such as PVC/copper made from cable scraps or PVC/polyester from used tarpaulins). Innovative VINYLOOP® technology was launched after completion of a ten-kiloton plant in the Italian city of Ferrara at the beginning of 2002.

Recycling possibilities are also available for packaging, cables, credit cards, and mixed PVC waste. These offers and numerous recycling products are listed in the PVC-Recycling-Finder of the AGPU at www.pvcrecyclingfinder.com.

The PVC industry has contributed greatly towards a sustainable and resource efficient economy with its forward-thinking, take-back and recovery systems for used products.

Feedstock Recycling

Hydrogen chloride in pure form is obtained by thermally treating PVC products. The hydrocarbon part in PVC is used to generate heat and electricity in the same process. Hydrogen chloride then goes back into PVC production.

Feedstock recycling can be divided into processes with and without the limitation of chlorine. The recovery process without the limitation of chlorine is especially suitable for contaminated and PVC-rich mixed plastic material fractions. The PVC industry has been researching suitable forms of technology for the feedstock recycling of PVC-rich waste streams since 1992.

The rotary kiln at the recovery plant at DOW/BSL in Schkopau is technologically suitable for PVC-rich waste streams in feedstock processes. PVC waste in solid and liquid form can be recovered at this plant, which started operations at the end of 1999. Through the thermal treatment of waste, the hydrogen chloride is separated and also the released energy is used. Processed into hydrochloric acid at the plant, it can be used again as a raw material for the production of PVC.

In the production of calcium carbide at Alzchem Trostberg GmbH in Hart, high calorific plastic fractions with a chlorine content of up to 10% can be used. These waste materials are used to increase the amount and calorific value of the resulting carbide furnace gas.

Photo: Nicocyl GmbH

Second Life: These durable industrial floor panels are made from used PVC cable insulations.

Ecoloop, a subsidiary of Fels-Werke GmbH, employs a new technology for the energy-efficient conversion of organic and carbon-rich materials such as used wood or plastic into purified syngas as an energy source. In the process, raw materials with a chlorine content of up to 10% can be used.

Energy Recovery

Currently in Germany there are about 73 plants for the thermal treatment of mixed municipal waste. They have an approved total capacity of approximately 18 million tonnes at their disposal.

In the past, it was assumed that PVC contributed approximately 50% towards the chlorine input in waste incineration plants. Today, this amount is estimated at about one-third (30–35%). This reduction can be traced back to the recovery activities in the packaging sector, among other things.

The chlorine content in PVC is converted completely to HCl during incineration and removed from the flue gas far below the legally permitted emission limits as defined by prescribed flue gas cleaning. The scrubber liquid is neutralised primarily with burnt lime. The resulting calcium chloride is deposited. Some waste incineration plants do not work with limestone scrubbers. They neutralise with sodium hydroxide. This results in a valuable brine.

In order to reduce the chlorine input, hydrogen chloride can be separated from the flue gas as hydrochloric acid and used again in chemical production. Five waste treatment facilities in Germany – e.g. in Hamburg, Böblingen, Kiel, and in Kempten – work according to this principle.

Another possibility is offered by the SOLVAir® (former NEUTREC®) process from SOLVAY. Sodium chloride is recovered and purified with the help of sodium bicarbonate in the flue gas purification of incineration plants. Facilities used for the treatment of reaction products containing sodium are in operation in Italy and France.

The HALOSEP® process also offers the possibility of recovering chlorine from waste incineration in the form of salt. Waste from the flue gas purification of two major Danish waste incineration plants was treated as part of a pilot program. In doing so, more than 99% of the chlorine was recovered.

Dioxins and furans (PCDD/F) result from almost every incineration process involving organic materials. The amount of these undesired compounds depends heavily on the construction and operation of the waste incineration plants.[16] Remaining emissions are minimized through steps towards flue gas purification (adsorption filter). Since 2000, all European waste incineration plants must emit less than 0.1 ng TEQ dioxin per m^3 of exhaust gas, based on EU Directive 2000/76/EG.

Bags made from used truck tarpaulins are not only modern. They also save valuable resources by ideally making use of the durability of the material.

Photo: AGPU Media GmbH

Numerous investigations show that the PVC portion of household waste does not effect the amount of dioxin formation and thereby dioxin emissions.[17] The complete sorting of PVC products from waste does not alter the dioxin concentration in exhaust gas. The reason is the salt content which is always present in waste, for which residues of food among other things are responsible.

No matter whether with or without PVC: there is no change in compliance with the threshold value of 0.1 ng/m^3. Thermal and other control parameters in incineration have the greatest influence on dioxin emissions. It would be better to discuss exhaust gas rather than dioxins. Its toxicity is much higher due to other pollutants. This is the case with the carcinogenic substances PAHs (polycyclic aromatic hydrocarbons such as benzo[a]pyrene) or fine dust particles. A holistic approach to adverse effects is especially important for uncontrolled thermal processes as seen in the following section.

PVC and RDF

The PVC industry arranges for a substantial portion of used PVC to be recovered through various recycling initiatives (among others to be found in the "PVC-Recycling-Finder" of the AGPU at www.pvcrecyclingfinder.com) before the waste reaches refuse-derived fuel (RDF) processing. In this manner, the chlorine content of the fractions is reduced considerably for RDF processing. The PVC share of "PVC-rich" fractions, which is sorted out during RDF manufacturing, is usually only 5-15%.

Landfills

PVC products stored in landfills are not posing a risk to human health and the environment. Heavy metal stabilisers may in fact reach the leakage water of landfills in small amounts, but are more or less insignificant in comparison to heavy metals from other sources in municipal waste. It is similar with plasticisers which can migrate from soft PVC through micro-organisms. They are broken down and do not lead to a toxically relevant deterioration of the leakage water. This conclusion was reached by an extensive international research project on the long-term behaviour of PVC products in landfills and under ground. It was conducted by the Technical University Hamburg-Harburg, the University of Linköping, and Chalmers University in Göteborg from 1996-2000.

In principle, valuable materials such as plastics do not belong in landfills. The depositing of untreated plastics and other organic materials is outdated and is no longer permissible in some European countries. Since January 2000, all organic waste in Switzerland must be thermally treated in waste incineration plants before reaching landfills. In Germany, a corresponding regulation in the form of a ban on depositing organic waste such as wood, paper, and plastics has been in effect since 2005 (source: DepV – Landfill Ordinance, Technical Guidelines – Municipal Waste). In Austria, the topic was dealt with in the same way through the Landfill Ordinance of 2008.

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[16] "The most important steps towards reducing PCDD/F formation during incineration are the reduction of overall air surplus and improvement of combustion, i.e., reducing CO and C_{org} emissions and the unburned parts in the fly ash and slag … good combustion must be seen … as the necessary condition for a high rate of destruction and a minor redevelopment of PCDD/F."– Christian Hübner, Rolf Boos, Georg Bohlemann, Monographie 160, Umweltbundesamt, Wien, 2000.

[17] Sources: American Society of Mechanical Engineers: "The Relationship between Chlorine in Waste Streams and Dioxin Emissions from Waste Combustor Stacks", Washington, 1995; Umweltbundesamt: "Handlungsfelder und Kriterien für eine vorsorgende nachhaltige Stoffpolitik am Beispiel PVC", 1999, p. 47.

FIRE BEHAVIOR

Even PVC products can catch fire. The following information provide a short overview about how PVC reacts in the event of fire.

If it Burns

Plastic materials and natural products can only catch fire if sufficiently large ignition sources and oxygen are available. In the process, aerosols and soot arise as well as gases which enflame and react to oxygen.

Fire Gases

The toxic properties of gases from burnt plastic materials are comparable to those which result from the burning of natural materials such as wood and paper. Numerous investigations have shown that approximately 90-95% of deaths during fires can be traced back to carbon monoxide (CO) poisoning. This gas arises during every fire and kills without warning. In contrast, hydrogen chloride (HCl) forces one to flee due to its pungent odour, even in the smallest, harmless concentrations.

Smoke Gases

There are numerous discussions about carcinogenic smoke gases besides the acute toxic fire gases (CO, HCN, acrolein, HCl, etc.). They also are produced by every fire. Some of the most important of this kind are PAHs (polycyclic aromatic hydrocarbons) and fine dust particles.

When materials containing chlorine such as PVC, or other plastic and natural substances, catch fire, dioxins and furans may result. These substances, however, bond strongly to the soot particles created during a fire and therefore are not bioavailable to people, animals, and plants. In examining people exposed to fire in contrast with those not exposed to fires, higher levels of dioxins could not be determined. The same conclusions were reached after PVC fires, e.g. in October 1992 in Lengerich/North Rhine-Westphalia, where several hundred tonnes of PVC went up in flames.

Corrosion

Every smoke gas is corrosive due to high temperatures, humidity, etc. If this gas contains additional acids (e.g. NOx, SOx, HCl, acetic acid), that can increase the effect. When PVC catches fire, a special corrosive smoke gas arises based on its chlorine content – HCl. Recent studies show that corrosion – contrary to the opinion of certain experts – in the case of fire does not play a role in the feared outage of safety electronics because it happens comparatively slowly over a long period of time. Important reasons for the outage of safety electronics are short circuits which result from electrically conducted soot residue.

The amount of economic damage due to corrosion depends on the circumstances of the fire and the beginning of the renovation work; it may increase if the renovation work takes place at a later date. In the process, the overall economic costs show that the economic advantages of using PVC are greater than the possible damage from a fire. The replacement costs alone for PVC cables in Germany would amount to approximately one billion euros per year. These costs are therefore similar to renovation costs (not only due to corrosion) for all fires in Germany (source: Engelmann: "Kosten-Nutzen-Abschätzung: Halogenfreie oder PVC-Kabel", in: Vorbeugender Brandschutz, 1995).

Wires and cables with a heavily flame-retardant insulation or sheathing made of soft PVC are indispensable in energy supply, control functions, and communications.

SUSTAINABLE DEVELOPMENT

PVC products perform well ecologically as well as socially and economically. Essential for this success are low life-cycle costs, longevity, and the recyclability of these high-quality products.

Evaluation of Sustainability

Sustainable development must be evaluated from ecological, economic, and social perspectives. Assessments of individual areas can be misleading. AGPU has held extensive dialogues with experts from the economic sector, the sciences, environmental associations, as well as with journalists about PVC. One result of this process is the independent PROGNOS Study from 1999/2000 on the sustainability of selected PVC products and their alternatives[18]: it was the first study that dealt with the concept of "sustainable development" for individual products. The result was a balanced picture of PVC products with good results, but also with open questions and the possibility for improvements, which has led the way to a sustainable future for PVC.

Current information on the topic is summarised briefly below. In doing so, ecological observations are based on LCAs and risk assessments, for the entire life cycle of products of course.

Photo: VEKA AG

As shown in this housing complex in Thun (Switzerland), modern energy-efficient PVC windows significantly contribute to a comfortable living environment. In addition they save energy.

Ecological Factors

Part of the ecological quality of products and services can be determined by life-cycle observations. Risk assessments round off the ecological quality. In order to evaluate sustainable development reliably, social and economic factors must also be taken into consideration.

The European plastics industry is compiling essential life-cycle data (eco-profiles) on a standardised basis for the manufacturing and processing of important plastic materials and continuously updates this information. Qualified institutions compile LCAs for products based on these eco-profiles. In the process, additional information is taken into consideration, such as the local electrical power situation, recycling, waste disposal, etc. An important study which focuses on PVC products was conducted by H. Krähling.[19]

Photo: Funke Kunststoffe GmbH

PVC pipes, which reach a lifespan of more than 100 years, are easy to install because of their light weight. During this period of use, they require hardly any maintenance. Overall it's an economical and sustainable solution.

Perhaps the most extensive study on the life cycle assessments of PVC products was commissioned by the European Union in 2004 under the direction of PE Europe GmbH – Life Cycle Engineering. It shows that PVC products are very comparable to other products made from different materials in terms of life cycle assessment. [20]

However, for the reliable life cycle assessment of specific products one must still consider

- that it sometimes may be necessary to have varying amounts of materials for similar products made of different materials; and
- that processing, recycling, and recovery, etc. must be assessed. In doing so, life cycle assessments should correspond to ISO 14040/44.

The resource and energy efficiency of PVC products often proves to be especially advantageous for life cycle assessments. Recycling and material-saving designs provide additional possibilities for improvement. Careful planning and building in the construction sector in particular, especially (energy-efficient) savings in terms of use and low expenditures for care and maintenance, are far more important than the materials applied. This opinion is shared by the Federal Ministry of Building which developed the guidelines for sustainable government buildings.

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[18] PROGNOS-AG, Basel, "PVC und Nachhaltigkeit – Systemstabilität als Maßstab, ausgewählte Produktsysteme im Vergleich", Deutscher Institutsverlag Köln, 1999 (ISBN-Nr. 3-602-14485-2). An English translation has been authorised by PROGNOS.

[19] H. Krähling, "Life Cycle Assessments of PVC Products: Green Guides to Ecological Sustainability", LCA Documents, ecomed publishers, Vol. 6, ISBN 3-928379-58-5, 1999, 60 pages.

[20] "Ökobilanz-Studie zu PVC und prinzipiell konkurrierenden Materialien, 2004", http://europa.eu.int/comm/enterprise/chemicals/sustdev/pvc.htm, http://www.pe-consulting-group.com/downloads0.html?&L=1.

On the basis of life cycle assessment data, more easily readable evaluations are also compiled such as EPDs (Environmental Product Declarations). They summarize the numerous results of life cycle assessments through various ecological criteria such as energy consumption, climate effects, or acidification. Ecological profile data as well as EPDs for individual plastic materials is available on the website of PlasticsEurope.[21] It is considered the most reliable quantitative data for plastic materials worldwide. In comparing this data to the corresponding data of other materials, it must be taken into consideration that the methods of compiling the ecological profile data always vary to some extent. Therefore, exact comparisons are not possible.

Economic Factors

PVC products are distinguished by their longevity, low costs for maintenance, and recyclability. Their life-cycle costs are correspondingly low: this is a fact that has direct influence on their market success. Consumers choose the more cost-effective product with the same performance. They know that economic resources are limited, just like all other resources, and try to use them carefully for optimal benefits.

However, low life-cycle costs are also tied to ecological and social factors in qualitative and quantitative terms. These savings can therefore also be used for ecological and social objectives. We see two possibilities in assessing costs and ecology simultaneously in quantitative terms:

One possibility is to present the costs in addition to ecological results such as in the eco-efficiency model at BASF. In this example, ecological results are combined into one unit by standardisation and importance and compared to the standardised costs.

Another possibility is the direct combination of the two criteria, which means a “compensatory” method. In doing so, possible cost advantages between alternative products are used to finance ecological improvements, such as steps for saving energy or preventing climate effects. For example, a specific calculation is available for PVC windows and alternatives. By using approximately 1% of the product costs for a PVC window, 100% of the climate effect generated through this product can be compensated:[22] this is a small financial expenditure with great effect. This "compensatory" method has been used for years for "climate-neutral flights".

Low life-cycle costs also have a positive effect on the social sector: for example, the poor and many nations in the Third World are now more likely to be able to afford low-priced products e.g. in health and education.

On the other hand, the refusal of some communities to use PVC means "more costs without any quantifiable ecological advantages". [23] The additional costs resulting from the refusal can in fact be calculated and no longer invested in sensible ecological and social gains.[24] PVC substitution without economic and ecological basis can even lead to a deterioration of the present situation, as determined by Enquête Commission[25] and the German Federal Environment Agency (UBA).

Modern PVC flooring with the natural look of wood is a favourite in kindergartens, hospitals, schools, and sports facilities. It is extremely easy to clean, resistant, and durable.

Photo: Gerflor

Social Factors

For decades, PVC products have stood the test of time in almost all areas of our daily lives. In the process, they have been extensively researched and continuously developed in order to offer high safety and quality standards: this extends from the selection of raw materials and improved formulations to state of the art manufacturing methods. The wide range of products satisfy demanding requirements for modern, future-oriented solutions: in health care, building technology, as well as everyday goods in the home and at work.

Many products are essential for the functioning of our complex daily lives and are distinguished by their tremendous social benefits. Wires and cables with sheathings or insulation made of soft PVC ensure a smooth data transfer and reliably supply us with energy. Disposable gloves meet high hygienic standards in medical care. The same holds true for easy sterilisable blood bags and tube systems for nutritional care. Pipes for drinking water provide permanent access to clean water without giving bacteria a chance to survive. Modern plastic windows provide pleasant indoor climate conditions and save energy. Safety products such as welding curtains and reflectors for work clothes increase safety at the workplace. In all these areas, this high performance plastic has proven to be a safe and reliable partner.

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[21] See www.plasticseurope.org, category "Plastics & Sustainability", Life-Cycle Thinking.

[22] E.-J. Spindler "Integration der monetären Kosten in Ökobilanzen", UWSF – Z. Umweltchem. Ökotox. 11 (5) 299-302 (1999).

[23] Summary of additional costs for PVC substitution.

[24] In an older study by the Hessian Ministry of Housing, the additional costs for a PVC-free flat were calculated at approximately €2,200. In the process, investments can be financed which save approximately 100 tonnes of CO_2 and the corresponding amounts of energy! In a 1994 study commissioned by the Hessian Ministry of the Environment, PROGNOS AG in Basel estimated that additional expenditures for the replacement of 70% of PVC products are approximately 3.3 billion euros per year; for the compensation costs of 20-25 €/t CO_2 this would mean in purely mathematical terms doing without the compensation of approximately 150 million tonnes of CO_2 per year if PVC substitution is required! This is nevertheless approximately 20% of the annual climate effect in Germany.

[25] Enquête Commission "Schutz des Menschen und der Umwelt", Drucksache des Deutschen Bundestages 12/8260, 1994; UBA-Studie "Produktökobilanzen und ihre Anwendungsmöglichkeiten im Baubereich: Ökologievergleich von PVC-Bauprodukten", 1996.

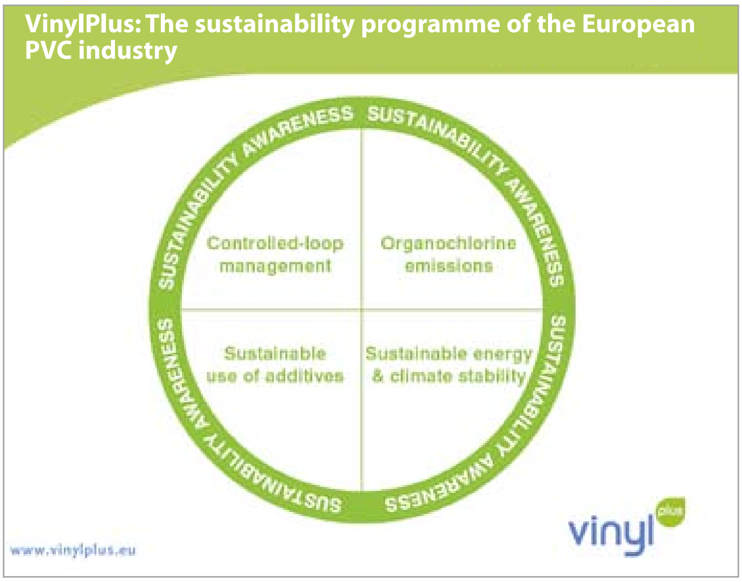
In the process, economic PVC products have a positive effect on society. Cost-effective, high-quality products are available to a number of people and affordable to lower-income people who thus have the pleasure of enjoying a higher standard of living. Savings from buying reasonably-priced products, on the other hand, can be used to help promote further ecological and social improvements; this is an effective contribution to sustainable development.
In addition, optimising manufacturing and processing methods guarantees good working conditions, which are also reflected in job safety and a low accident rate.[26]

VOLUNTARY COMMITMENT OF THE EUROPEAN PVC INDUSTRY

The European PVC industry has achieved all the objectives of its voluntary commitment Vinyl 2010 and thereby has made a considerable contribution to the sustainable development of its products. With the follow-up agreement VinylPlus, it will continue this active involvement.

Vinyl 2010

For more than 20 years, the European PVC industry is making a great effort together to master challenges in terms of sustainable development.
European PVC manufacturers agreed on an industry charter in 1995 under the umbrella of the European Council of Vinyl Manufacturers (ECVM). According to the charter, the signatories are obligated to continuously reduce impact on the environment in terms of "responsible care". The results of the agreement are specific emission limits in manufacturing S-PVC and vinyl chloride, which fall below legally stipulated values.
In addition, the four major European associations ECVM (PVC manufacturers), ECPI (PVC plasticiser manufacturers), ESPA (PVC stabiliser manufacturers) and EuPC (plastics converters) signed the Voluntary Commitment of the European PVC industry on Sustainable Development Vinyl 2010[27] in 2000, including specific objectives for the responsible and sustainable use of additives as well as the development of recycling technologies and its volumes. All the goals of Vinyl 2010 were reached or even passed.



Information on VinylPlus is available for download at www.vinylplus.eu.

VinylPlus

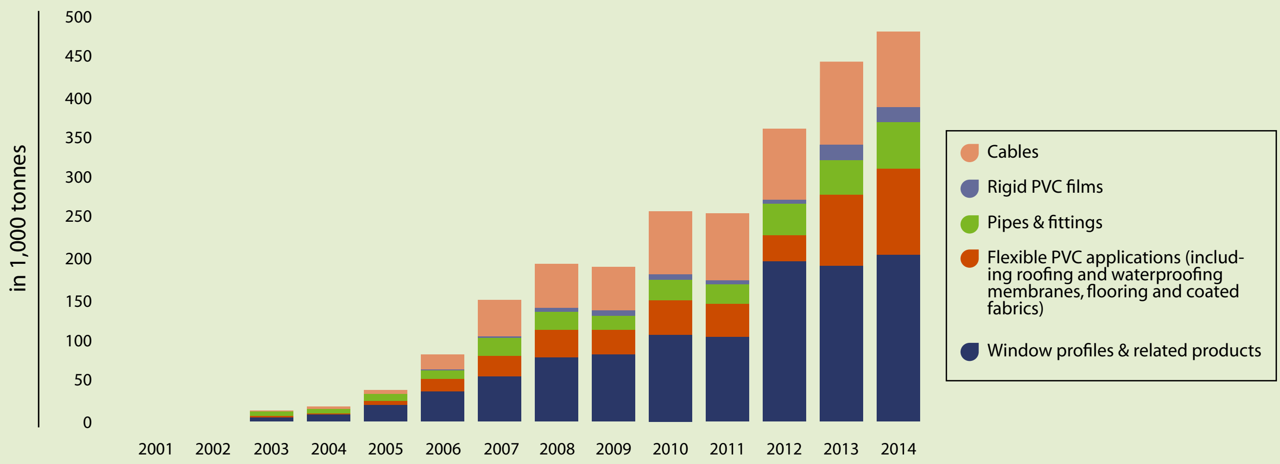
The completion of Vinyl 2010 also marks the beginning of the new sustainability programme VinylPlus[28] which was launched in the summer of 2011 and built on the success of the previous program. Vinyl 2010 has managed to establish an Europe-wide infrastructure for collection and recycling of more than 250,000 tonnes PVC per year, and to replace additives like cadmium-based stabilisers. In the second decade, VinylPlus has set the following targets for the European PVC industry: a quantum leap in recycling rates of PVC and in achieving the development of innovative recycling technologies to reach its goal of 800,000 tonnes recycled PVC anually by 2020; addressing concerns about organochlorine emissions, ensuring the use of additives based on sustainability criteria, increasing energy efficiency and the use of renewable energies and raw materials in PVC production, and promoting sustainability throughout

[26] This aspect of social sustainability is found in the method propagated by BASF (SeeBalance), as well as in other sustainability labels such as those for bio-fuels.

[27] Detailed information on VinylPlus can be found at www.vinylplus.eu.

[28] Detailed information on VinylPlus can be found at www.vinylplus.eu.

PVC recycling volumes registered within the Vinyl 2010 and VinylPlus frameworks



Source: VinylPlus Progress Report 2015

the entire PVC value chain. VinylPlus combines the majority of leading companies from the PVC industry in EU-28, Norway and Switzerland. The programme was developed together with the international NGO The Natural Step (TNS). Progress is reviewed by an independent Monitoring Committee with the majority of members being external stakeholders. The results are anually published in the "VinylPlus Progress Report" and presented at the international Vinyl Sustainability Forum to stakeholders from the industry, politics, public authorities and media since a couple of years now. With registered 481,018 tonnes of PVC waste recycled in 2014, VinylPlus continues to progress toward its 2020 recycling target. Also successful is the replacement of lead-based stabilisers with calcium-based stabilisers in the EU-28 by the end of 2015 in new products. The plasticisers market has also changed significantly. The use of DEHP has been reduced clearly to non-classified phthalates and other plasticisers.

Material of the Future

PVC is capable of playing an important role in sustainable development. One prerequisite is that political decisions are made based on proven criteria.

Considerable improvements in raw material and energy efficiency have been established in the current ecological profiles on manufacturing PVC.[29]

The low life-cycle costs of many PVC products allow for the financing of important ecological and social improvements. Progress in recycling and disposal has greatly resolved the problem of waste. Many formerly, fiercely-debated topics concerning risk (substitution of critical additives) could be defused. This has lead to a scientific and political re-evaluation of PVC.[30]

Our environmental, economic, and social policy is oriented towards the guiding principle of sustainable, future-oriented development. Cost-effective products such as those made of PVC are economically, ecologically, and socially "competitive".

PVC offers many positive prerequisites for sustainable development for our industrial society through:

- low-energy expenditure in manufacturing and processing
- the use of the practically unlimited resource of salt
- the combined production of chlorine and sodium hydroxide
- low emissions and waste during manufacturing and processing
- mechanical and feedstock recycling
- good price-performance ratio of products along with environmental costs
- immense ecological/social optimisation potential based on outstanding economical advantages.

In spite of the advantages of PVC and PVC products already achieved, manufacturers and converters are working resolutely in the future on

- further improvements on ecological properties of PVC
- further improvement on the economic competitiveness of PVC
- and the further improvement of social needs.

PVC is a modern, high-performance material, which will be urgently needed in the future as well. The low share of crude oil saves limited resources and increases the economic efficiency of this material. Longevity and resistance to environmental factors make PVC the material of choice for economic planning and sustainable construction. Furthermore, the European PVC industry will achieve even great environmental protection and more consumer safety with the VinylPlus agreement.

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[29] New EPDs from 2008 are found on the internet at: http://www.plasticseurope.org/plastics-sustainability/eco-profiles.aspx
Environmental Product Declarations of the European Plastics Manufacturers; **Polyvinyl chloride (PVC)** (emulsion polymerisation)
European Council of Vinyl Manufacturers (ECVM) & PlasticsEurope January 2008. **Environmental Product Declarations** of the European Plastics Manufacturers;
Polyvinyl chloride (PVC) (suspension polymerisation) European Council of Vinyl Manufacturers (ECVM) & PlasticsEurope January 2008.

[30] In this way, all German federal states, and also several municipalities, have revised earlier limitations on PVC. The Green Party is speaking in favour of modernisation instead of substitutions. The manual by the Dutch Ministry of Housing, Spatial Planning and the Environment ("Duurzam Bouwen") recommends the use of recyclable PVC products. The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (UBA) does not see any major disadvantages at least in terms of rigid PVC products.

PVC IS SMART

ANDROID APP ON Google play

Erhältlich im App Store