

EVERYTHING ABOUT PVC FROM MANUFACTURING TO RECYCLING



PVC FROM A TO Z



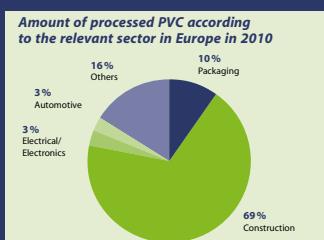
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PVC – WHAT YOU SHOULD KNOW

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 numerous 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 sound ecological and social investments.

ECONOMIC IMPORTANCE

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

PVC processing¹ in Europe is at 4.9 million tonnes per year. Thus, PVC is one of the most important plastic materials after the polyolefins polypropylene and polyethylene, which have a 50% of the market share. The outstanding importance of PVC is documented in the chart on the right.

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 materials² as well as of PVC (see chart on page 4).

PVC processing has increased comparatively slower in Europe. A high degree of market penetration has already been achieved in this sector. Nevertheless, growth has been registered even at this high level: this is an indication of the major importance of this high-performance plastic material.

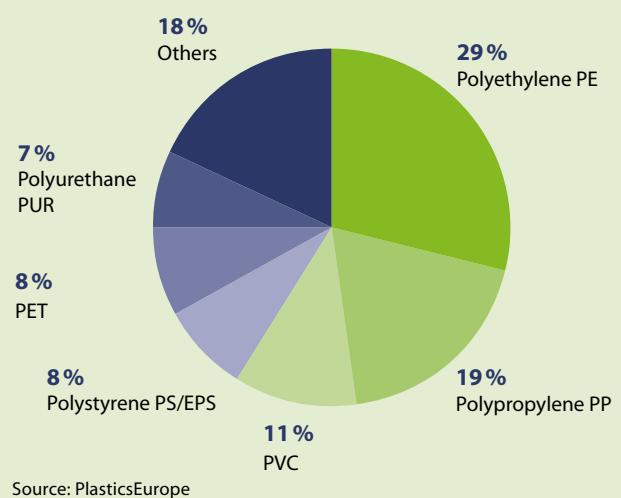
Large Manufacturers supply the Market

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 Western Europe, the five largest providers supply 64% of PVC. Taking into consideration the capacities of the largest manufacturers worldwide in 2009, Shin-Etsu is at the top, followed by Formosa Plastics, Solvay, and LG Chemicals. In terms of PVC specialities for paste processing, the situation is somewhat different. Here, the Europeans claim the top three positions,³ held by Vinnolit, Vestolit, and Solvay/SolVin.

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 processors lead the worldwide market with their products. In particular, these products consist of window profiles and rigid

Distribution of the plastics market in the EU 27+2 for 2009 in percentage



¹ PlasticsEurope Market Research Group, 2010.

² PlasticsEurope Market Research Group/Consultic Marketing & Industrieberatung GmbH, 2010.

³ Josef Ertl et al. Polyvinyl chloride – Special K 2010 I in "Kunststoffe" 10/2010.

films, as well as medical applications, membranes, and non-rigid films. Approximately 1.6 million tonnes of PVC was processed in Germany in 2009.

Important Economic Factor

In 2010, the German plastics industry earned 95 billion euros. The 415,000 employees in the plastics industry work in approximately 7,100 different companies.⁴

The Swiss PVC industry contributes considerably to the success of the entire plastics industry. It achieves an annual revenue of approximately 14.4 billion Swiss francs with its 34,000 employees, i.e., more than 10 billion euros in some 850 companies. The Austrian plastics industry employs more than 26,000 employees in approximately 600 companies and generates an annual turnover of 5.8 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 - 2015					
Demand in million tonnes 1990 – 2015	1990 in million tonnes	2009 in million tonnes	2010 in million tonnes	2015 in million tonnes	Growth per year 2009 – 2015
PE-LD Polyethylene (Low Density)	18.8	39.0	40.3	47.9	3.5 %
PE-LLD Polyethylene (Linear Low Density)					
PE-HD Polyethylene (High Density)	11.9	31.0	32.2	40.4	4.5 %
PP Polypropylene	12.9	46.0	48.1	61.6	5.0 %
PVC Polyvinyl Chloride	17.7	32.5	34.8	43.6	5.0 %
PS Polystyrene	7.2	10.0	10.8	12.7	4.0 %
EPS Expanded Polystyrene (Foam)	1.7	4.8	5.2	6.4	5.0 %
ABS Acrylonitrile-Butadiene-Styrene Copolymer					
ASA Acrylic Ester-Styrene-Acrylonitrile Copolymer	2.8	7.9	8.5	11.2	6.0 %
SAN Styrene-Acrylonitrile Copolymer					
PA Polyamide	1.0	2.3	2.6	3.3	6.0 %
PC Polycarbonate	0.5	3.0	3.5	4.5	7.0 %
PET Polyethylene Terephthalate	1.7	14.8	15.5	19.8	5.0 %
PUR Polyurethane	4.6	11.3	11.9	15.1	5.0 %
Other Thermoplastics	2.8	7.4	8.3	10.5	6.0 %
Total	83.6	210	~222	~277	4.7 %

MANUFACTURING AND RAW MATERIALS

The European PVC industry has consistently improved its manufacturing processes in recent years. This is especially true for formulas. 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. Sodium

hydroxide and hydrogen are thereby 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.

⁴ Kunststoffindustrie Deutschland Eurostat/Arbeitskreis Marktforschung Wirtschaftsvereinigung Kunststoff_2011.

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 admixtures are not only found in practically all plastics, but also in materials such as glass, steel, concrete, etc.

Basically, the following additives are used:

- stabilisers and co-stabilisers
- lubricants
- polymer agents to improve tenacity, heat-and-form stability, and processing performance
- fillers
- pigments
- plasticisers.

Additives facilitate processing and simultaneously determine the properties of end products. The choice of additives depends on processing procedures and demands on the finished products. Depending on the choice of additives, PVC as a raw material is developed into sturdy, thick-walled pipes for drinking water or extremely thin, flexible film for packaging fresh meat. Additives thereby provide a wide range of product properties.

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 50% today, tin also plays an important role. Moreover, new developments utilise metal-free organic stabilising systems.

The amount of thermal stabilisers used in mixtures has been reduced in recent years through effective additives and more exact engineering processes.

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



Photo: Vinnolit GmbH & Co. KG

Visitors receive information about environmentally friendly membrane electrolysis which saves an enormous amount of energy: it is an important measure in the reduction of CO₂ emissions.

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 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 wallpaper 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 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

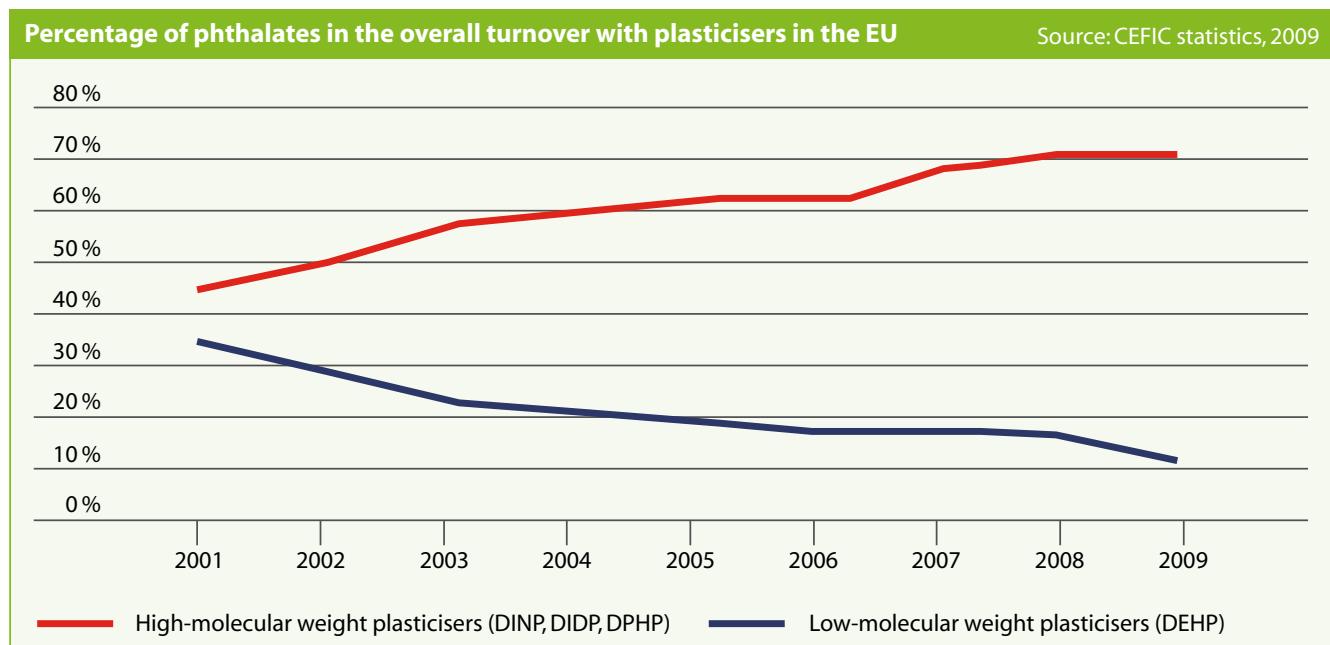
⁵ Also see details in the chapter "Voluntary Commitment of the European PVC Industry". The converters in the new members states followed, and by the end of 2007, all EU-27 members were on board.

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

⁷ EU Directive 494/2011 from 20 May 2011.

⁸ DINP – diisononyl phthalate; DIDP – diisodecyl phthalate.

⁹ DEHP – bis(2-ethylhexyl) phthalate; DBP – dibutyl phthalate; BBP – benzyl butyl phthalate.



In recent years, the European PVC industry has increasingly used high-molecular weight plasticisers, while the use of low-molecular weight plasticisers has decreased considerably.

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 Hexamoll® 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), which are low-molecular weight plasticisers or LMWs, 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 are subject to an approval process.

In contrast to LMWs, the phthalates DINP and DIDP, which are high-molecular weight plasticisers or HMWs, have other properties. These substances are not subject to labelling and may be used for all present applications. DINP and DIDP are some of the most researched substances in terms of toxicology and ecology. The two plasticisers have undergone EU risk assessments and evaluations with no objection. This ended a ten-year process of extensive scientific evaluations by supervisory agencies and legislators. In the Official Journal of the European Commission from 13 April 2006, it was expressly confirmed that no risks are expected from these substances for human health and the environment.

In December 1999, the European Commission first issued a three-month limited ban on the use of certain phthalates in soft PVC for children's toys which children under three years of age place in their mouths according to their research.¹¹ This temporary measure resulted in a permanent legal regulation (2005/84/EC) in January 2007. Accordingly, the plasticisers DEHP, DBP, and BBP are neither allowed to be used in children's toys nor in any other items used for babies. However, DINP, DIDP and DNOP¹² may be used in children's toys and baby products which children do not place in their mouths. The technical description is found in the guidelines of the European Commission on the interpretation of the concept "which can be placed in the mouth".¹³ The European Parliament made the decision to limit the use of these phthalates exclusively on the basis of the precautionary principle, not on the basis of toxicological properties.

¹⁰ Hexamoll® DINCH – 1,2-Cyclohexane dicarboxylic acid diisononyl ester.

¹¹ 1999/815/EC Directive Art. 9, 92/59/EEC.

¹² DNOP – di-(n-octyl) phthalate.

¹³ 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.

PROCESSING AND PRODUCTS

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

Extruder or Injection Moulding

PVC is one of the few polymers which can be processed thermoplastically and by means of pastes.¹⁴ Thermoplastic processes take place primarily on extruders or so-called screw presses. 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 bodies by blow moulding.

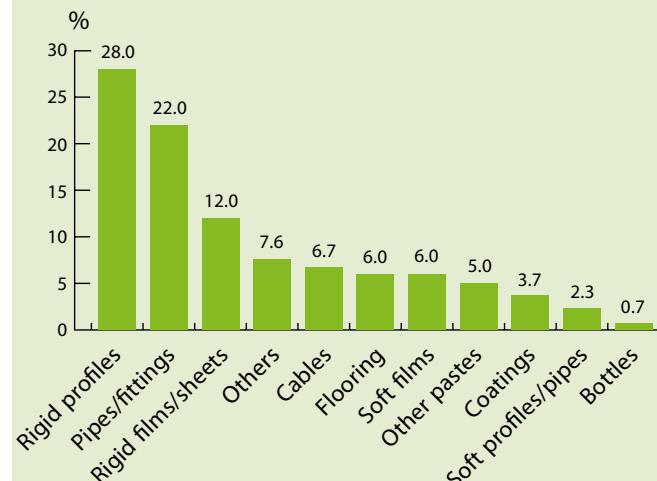
Emulsion and micro-suspension PVC is applied as a paste to various soft PVC products such as tarpaulins, flooring, coverings, and artificial leather. As an alternative, rotation moulding is used to shape dolls and balls.

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 lives. In Germany, approximately 70% of all PVC applications are intended for the construction sector. In particular, this includes window profiles, pipes, floor coverings, and roofing membranes. PVC windows are weather resistant, durable, easy to clean, economical, and recyclable at the end of their life cycles. Sturdy 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.

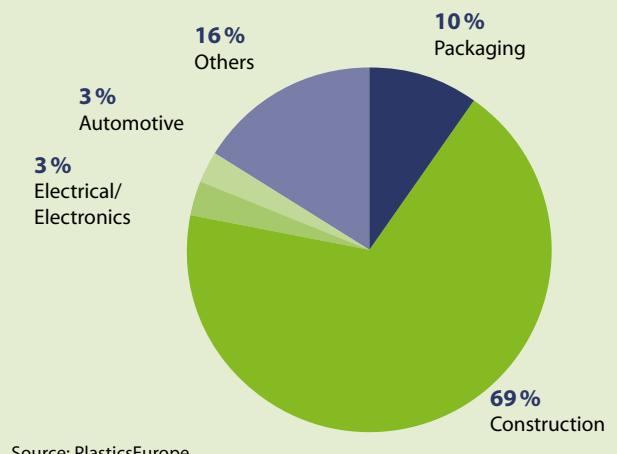
In the packaging sector PVC is found in special applications such as blister packs, adhesive tapes, hollow bodies, and cups. Cables and wires with an insulation or coating made of soft PVC play a decisive role in the smooth operations of our daily lives in terms of energy supply, control functions, and communications. Protective undercoating, interior panelling, and cable harnesses inside vehicles and under the bonnet play an

Distribution of amounts of PVC in 2010 based on products in Europe



Source: PlasticsEurope

Amount of processed PVC according to the relevant sector in Europe in 2010



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.

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 formula 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 harmless to human health. 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.

¹⁴ "Technologiestudie zur Verarbeitung von PVC", Fraunhofer ICT, 2005, commissioned by PlasticsEurope Deutschland e.V. and the Arbeitsgemeinschaft PVC und Umwelt e.V. 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.

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 Arbeitsgemeinschaft PVC und Umwelt e.V. has commissioned the Consultic Marketing und Industrieberatung GmbH at regular intervals to compile data about PVC waste in Germany. In 2007, the amount of PVC waste was approximately 563,000 tonnes (505,000 tonnes in 2005). 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 403,000 tonnes (360,000 tonnes in 2005). Approximately 77,000 tonnes (60,000 tonnes in 2005) of this amount were recycled mechanically and by feedstock recycling. If production waste is included in these statistics, the amount of recycled materials totals approximately 221,000 tonnes (180,000 tonnes in 2005). 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 production waste), the recycling quota is approximately 36%. 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).

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. 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-Bodenbelag Recycling (AgPR) and RoofCollect – the successor organisation



The collection and recycling of replaced PVC window systems is common practice today. At the end of the process, modern heat-insulating windows are manufactured which save energy and improve internal climate conditions.

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. It works closely with its recycling partners Tönsmeier Kunststoffe and VEKA Umwelttechnik. Since the beginning of 2005, Rohr-Recycling in Westeregeln – a subsidiary of the Tönsmeier-Gruppe – and Kunststofffrohrverband (KRV) have established an alliance to increase the amount of materials to be recovered. The new 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 remnants 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. Additional facilities are being planned.

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.agpu.com.

The PVC industry has contributed greatly towards a sustainable 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 differentiates between processes with and without the limitation of chlorine. The recovery process without the limitation of chlorine is especially suitable for soiled 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 furnace oven 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 separates when 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.

Ecoloop, a subsidiary of Fels-Werke GmbH, employs a new



Photo: "Vinyl 2010"

Built from recycled PVC materials, this yellow-framed platform at the bus stop makes getting on the bus easier.

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.

Waste Incineration

Currently in Germany there are about 68 plants for the thermal treatment of mixed municipal waste. They have an approved total capacity of approximately 19 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 of the DSD (Duales System Deutschland / "Der grüne Punkt", etc.) 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 saline solution.

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 Kempten – work according to this principle.

Another possibility is offered by the 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 so doing, 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 m³ of exhaust gas, based on EU Directive 2000/76/EC.

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 food remnants 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/m³. 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 harmful to human health and the environment. Heavy metal stabilisers may in fact reach the seeping 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 toxicologically relevant deterioration of the seeping 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



Photo: PVCplus

Bags made from used lorry tarpaulins are not only modern; they also save valuable resources by ideally making use of the longevity of the material.

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.

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.

REACTION TO FIRE

Even PVC products can catch fire. The following information provides 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 carbon black arise as well as gases which flare up 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 examinations 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, hydrochloric acid (HCl) forces one to flee due to its pungent odour, even in the smallest, harmless concentrations.

Smoke Gases

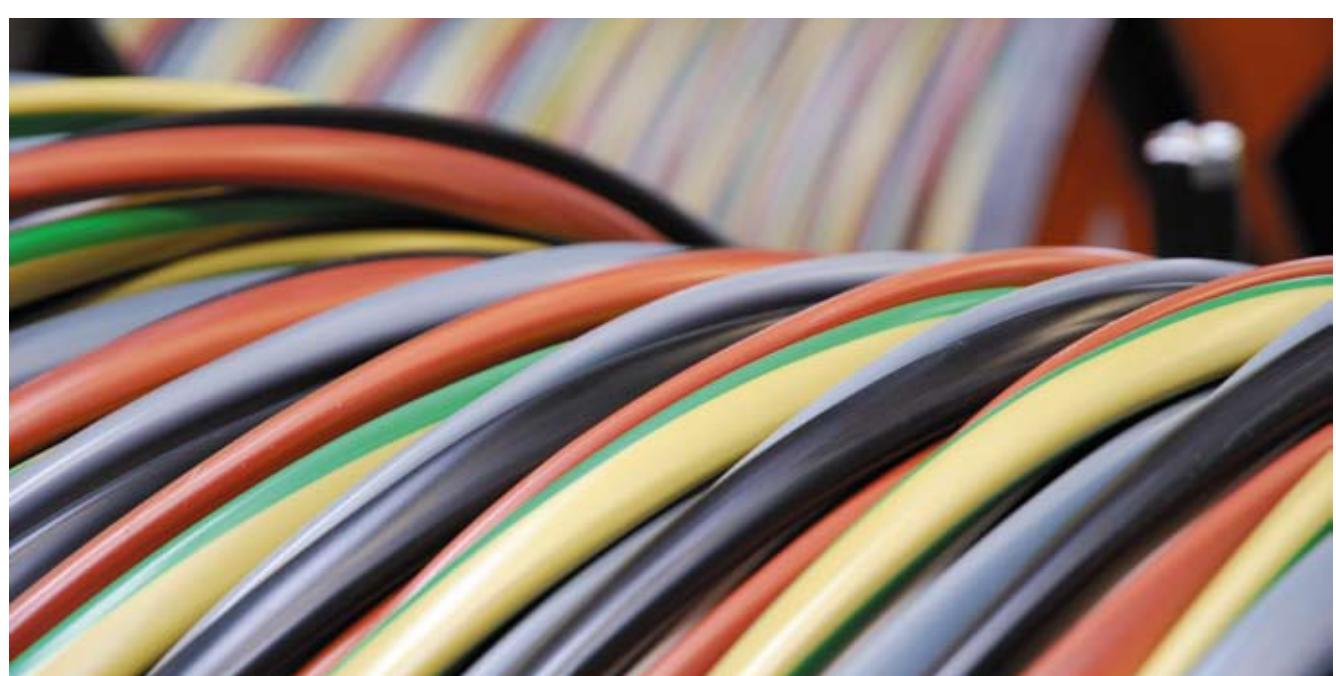
There are numerous discussions about carcinogenic smoke gases besides the acute toxic fire gases (CO, HCN, acrolein, HCl, etc.). They also are produced by every fire. Some of the most important of this kind are PAHs (polycyclic aromatic hydrocarbons) and fine dust particles.

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 carbon black 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. NO_x, SO_x, 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 coating 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. The Arbeitsgemeinschaft PVC und Umwelt 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 so doing, ecological observations are based on LCAs and risk assessments, for the entire life cycle of products of course.

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-inventory") on a standardised basis for the manufac-

turing and processing of important plastic materials and continuously updates this information. Qualified institutions compile LCAs for products based on these "ecological 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

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 so doing, 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 Transport, Building and Urban Development which developed the guidelines for sustainable government buildings (<http://www.nachhaltigesbauen.de/leitfaeden-und-arbeitshilfen.html>).

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.



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: they are an economical and sustainable solution.

¹⁸ PROGNOS-AG, Basel, "PVC und Nachhaltigkeit - Systemstabilität als Maßstab, ausgewählte Produktssysteme 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>.

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

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 so doing, 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 Commission²⁵ and the German Federal Environment Agency (UBA).

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 formulas to modern manufacturing methods. The wide range of products satisfy demanding requirements for modern, future-oriented solutions:



Photo: objectif for Art und Design Belags GmbH

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

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 coatings 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 sterilisable blood bags

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 CO₂ 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 CO₂ this would mean in purely mathematical terms doing without the compensation of approximately 150 million tonnes of CO₂ 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.

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.

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"

After many individual improvements, the European PVC industry has made important cooperative efforts in recent years to master future challenges in terms of sustainable development.

European PVC manufacturers agreed on an industry charter in 1995 under the auspices 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)
- EuPC (plastics converters)

signed the Voluntary Commitment of the European PVC Industry on Sustainable Development in March 2000. An amendment to this commitment followed in October 2001 entitled "Vinyl 2010".²⁷ The initiative involves key questions in the individual stages of the life of its products. The first part deals with the manufacturing of basic materials: PVC, plasticisers, and stabilisers. It describes continuous improvement in terms of environmental impact and the use of resources. The topic of the second section is the responsible and sustainable use of additives. The admixture of additives contributes considerably to the in-

novative development of PVC. The third section describes the contribution made by the industry to disposing of products responsibly at the end of their life cycles. The fourth section extensively presents how the PVC industry would like to maintain adherence to the various commitments. This is where the availability of respective funds is explained. In 2003, a supervisory body was brought together with representatives from the EU Commission, EU Parliament, trade unions, and, somewhat later, consumer associations. Representatives from environmental associations were also invited, but they did not wish to participate. Furthermore, a progress report was published annually, showing the most recent findings on the path to sustainable development. The final report for 2010 documented the tremendous progress made in the past ten years in waste management, recycling technologies, stakeholder engagement, and the handling of additives. All the goals of "Vinyl 2010" were reached or even surpassed.

"VinylPlus"

The completion of "Vinyl 2010" also marks the beginning of the new sustainability initiative "VinylPlus"²⁸ which was launched in the summer of 2011 and built on the success of the preceding program. "VinylPlus" was developed in conjunction with the international NGO The Natural Step (TNS) which is at the forefront of research and dialogue about sustainable development. The new initiative is based on five commitments with the following goals: a quantum leap in recycling rates of PVC and in achieving the development of innovative recycling tech-

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 Further information as well as the annual progress reports are found at www.vinyl2010.org.

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



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

nologies, 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 the entire PVC value chain. Transparency and open dialogue with internal and external target groups will be the focus of "VinylPlus". In the process, the new commitment places great emphasis on continuous dialogue with stakeholders. As with "Vinyl 2010", the PVC industry will publish an independently verified and audited report, documenting the progress of all goals established by "VinylPlus".

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 problematic 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

²⁹ New EPDs from 2008 are found on the internet at:
<http://www.plastics-europe.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.

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 processors 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 new "VinylPlus" agreement.

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 ("Duurzaam 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.



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