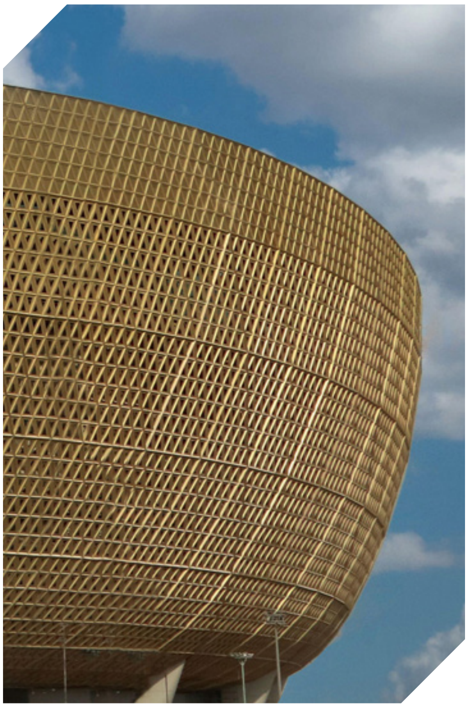
Navigating the PVDF landscape

A market in transition

AkzoNobel

Introduction



The world's supply of the specialty resin Polyvinylidene Fluoride (PVDF) to make high-performance industrial coatings is shrinking. Prices are rising.

High-performance coatings protect the exterior of metal components and finishes of commercial buildings, high rise blocks and monuments. From metal roofs and steel structures to wall panels and windows. PVDF offers the best protection against corrosion and degradation, keeping buildings safe and beautiful for 30 to 40 years in harsh environments.

Over the last 50 years, the PVDF market has approximately tripled, and most of this growth has been due to the use of PVDF coatings in the construction and architectural sectors.

But in recent years demand has also come from electric vehicles (EVs) and renewable energy manufacturers that use PVDF to produce lithium-ion batteries. This has resulted in a sizeable price rise in the last two years, which is likely to only increase.

It is a perfect storm. Demand for PVDF has increased dramatically, driven by governments' desire for cleaner energy and consumers' desire for cleaner transport. While recent raw material shortages and supply chain issues have accelerated the problem. This is forcing architects, specifiers, and manufacturers – including suppliers of coil and extrusion coating systems – to think about alternatives to PVDF coatings while maintaining the quality and durability of their products and buildings.

For coil and extrusion manufacturers, the decision of when to use PVDF coatings or an alternative is a balance of performance, availability and cost. Experts with knowledge of how coatings perform in extreme or hostile environments will know how to create that balance. The challenge will be for customers to find those experts to help navigate them through the troubled waters ahead.

The science **behind PVDF**

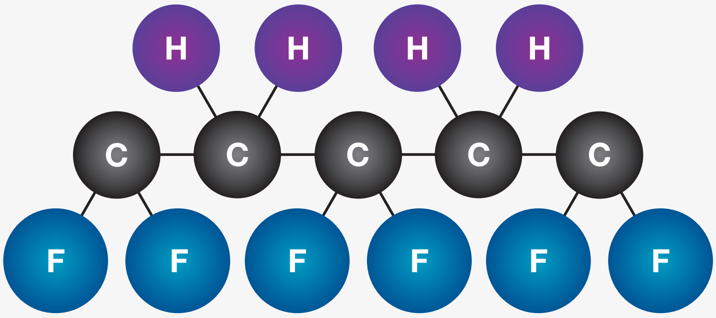
What is PVDF?
A resin with the strongest chemical bond found in nature

PVDF is a very stable fluoropolymer used in high-performance, highly durable exterior paint finishes. It was discovered over 60 years ago as DuPont scientists created Teflon, most commonly used in non-stick cookware.

Fluoropolymers are the most chemically inert of all polymers. PVDF's strength comes from carbon bonding with fluorine to produce one of the strongest chemical bonds in polymers and the molecule's spiral shape, which is structurally very stable.

Called thermoplastic or thermo-softening plastics, these polymers can be heated to be softened then cooled back to a rigid state. This process is repeatable and therefore makes them flexible during the coil and extrusion manufacturing process.

The unique molecular structure of these polymers provides its well known performance. PVDF remains stable in most chemical environments at high temperatures and is highly durable in extreme weather conditions.



The Van der Waals radius of F is larger than that of H thus the presences of F in the polymer chain induces more rigidity to bond rotation in the chain.

Fluoropolymers

Fluoropolymers are among the most chemically inert compounds due to their unique chemical structure.

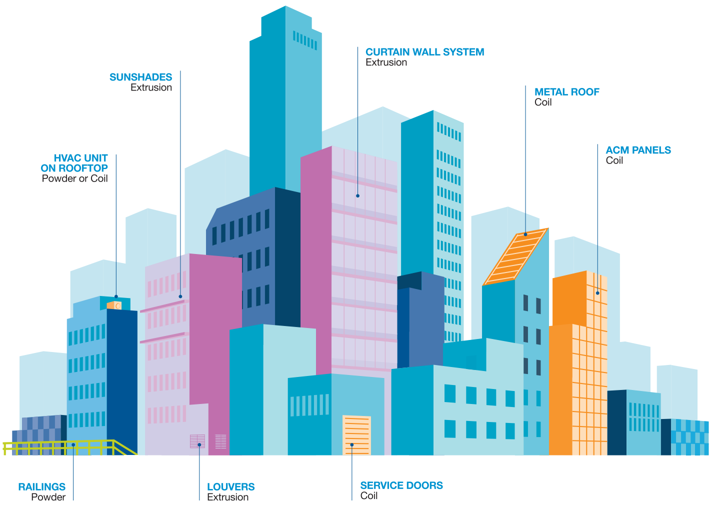
PVDF polymers contain three types of chemical bond: Carbon-Carbon (C-C), Carbon-Hydrogen (C-H) and Carbon-Fluorine (C-F).

'C-C' and 'C-F' bonds are very difficult to break and resist chemical degradation from occuring (e.g. with chemical pollutants or acid rain).

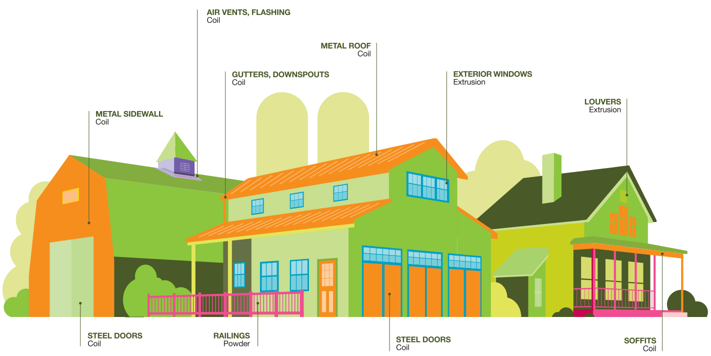
The 'C-F' bond is one of the strongest found in chemistry. The energy of the bond is 484 kJ/mol. More than the maximum 411 kJ/mol of ultra violet (UV) rays of the sun and so is not degraded by sunlight.

Due to the larger radius of F compared to H, the more F atoms added into the C-C backbone the more stiff the chain conformation. This has implications for the packing of the chains and hence the bulk properties of the material.

Application areas for Coil and Extrusion products



Window frames & curtain walls



Construction, domestic appliances, transportation, general industry

Why is PVDF so important?

PVDF plays a vital role in the construction industry. PVDF coatings provide excellent performance against harsh environments (UV, moisture, heat, chemical resistance, etc.) for high-rise buildings, metal roofing for commercial and residential buildings, and structural components of buildings. These structures are designed to withstand harsh weather environments such as heat, rain, snow, and humidity. PVDF coatings resist color fading and surface degradation caused by the sun's UV rays, keeping buildings looking newer for longer. It is tough enough to withstand abrasion, peeling, and film erosion by sea salt, and airborne chemical pollutants.

All of this allows buildings to look newer and cleaner over the building's lifetime. The protection provided by PVDF coatings means architectural landmark buildings can be created in even the most challenging locations such as deserts and coastal areas.

The various PVDF-based coating systems are also flexible, so that the integrity of the coating used on structural components is maintained, even when the components are 'flexed' or bent in manufacture. They also come with various warranties in relation to film integrity, chalk and fade.

A Shrinking Market

The coil and extrusion industry are / have been experiencing lengthy supply delays or much increased prices at least at some points during 2020-2022.

One of the largest PVDF producers, China, started to cut production of R142b, a key PVDF component, by 35% in relation to 1987 Montreal Protocol to reduce the use of ozone depleting substances. It is now in short supply.

At the same time global sales of EVs significantly increased every year since 2019, and governments are forging ahead with the switch to renewable solar and wind-powered electricity generation.

A sudden increase in demand by lithium-ion battery manufacturers which supply the EV and renewable energy markets has, in turn, caused significant price rises. In fact, the needs of these manufacturers, and their willingness to pay, means prices will continue to soar.

PVDF is used to coat anode and cathode binders in lithium-ion batteries – an essential part of battery cell construction, so battery manufacturers are prepared to pay premium prices. Makers of PVDF are switching to supply these higher-value customers. In November 2021, Arkema announced a substantial increase in its Kynar® PVDF fluoropolymer production capacity at its Pierre-Bénite site to address the fast-growing demand for materials for lithium-ion batteries.

Demand for these batteries will keep climbing with governments' policies for all new vehicles sold in Europe and half in the US to be electric by 2035.

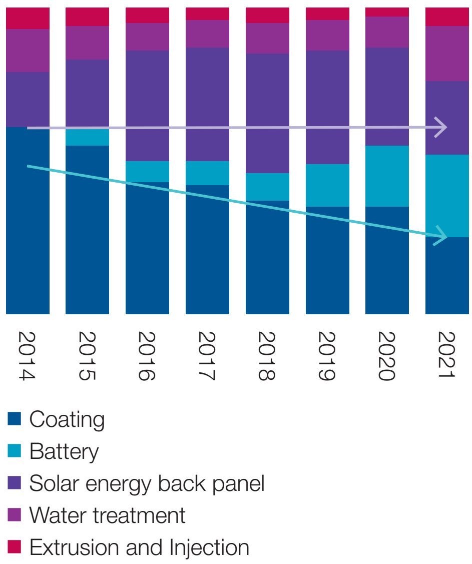
They are also switching to renewable energy, i.e., solar and wind power, as their countries' primary source of electricity.

Even if global PVDF production expands this won't necessarily fix the problem. China is one of the largest manufacturers of PVDF, but it is also one of the biggest manufacturers of EVs and batteries. Supplying into the EV and battery market is likely to be more attractive. So if there is a supply gap it is probable the coating industry will suffer, and exports to other markets such as the US will be restricted.

Coil and extrusion manufacturers are currently experiencing delays or much increased prices in 2020-2022 alone. Suppliers are expanding their PVDF production capacity, but it is hard for anyone to know how much more PVDF will be freely available to the architectural and construction sectors, nor what exactly will happen to prices.

There is still supply in the market. However to protect customers from the risks of delays, higher prices, and the uncertainty of cost-estimates, building component manufacturers can choose from a range of alternative and suitable coatings for a particular project. PVDF is necessary for extreme environments, but recent developments in Silicone Modified Polyester (SMP) products have improved color protection. And Fluoroethylene Vinyl Ether (FEVE) has similar properties to PVDF, albeit that it is more expensive and restricted in application. Polyester (PE) and Polyurethane (PU) can also be suitable alternatives.

PVDF Supply by Market Sector



Architectual Industry **Standards**

Specification Code	AAMA 2603	AAMA 2604	AAMA 2605
Typical coating types	High-solids Polyester, Acrylic	50% PVDF / Super Durable Polyester / Silicone Modified Polyester (SMP)	Fluoropolymers (70% PVDF and FEVE), some SMP
Typical usage	Interior, light commercial and residential	Exterior commercial, industrial high-end residential and high-traffic areas	Exterior high-performance architectural applications
Budget	$	$$	$$$
Weather exposure testing in South Florida	1 year testing	5 years testing	10 years testing
Color retention ASTM D 2244	1 year South Florida slight fade	5 years South Florida Fade = Delta E i.e. <5 hunter units fade	10 years South Florida Fade = Delta E i.e. <5 hunter units fade
Chalk resistance ASTM D 4214	Slight change	A rating of 8 on a scale from 1 (poor) to 5 years South Florida	A rating of 8 on a scale from 1 (poor) to 10 years South Florida
Gloss retention	Slight change	Maximum 30% loss in 5 years South Florida	Maximum 50% loss in 10 years South Florida
Humidity resistance ASTM B 2247	1500 hrs	3000 hrs	4000 hrs
Salt Spray resistance	1500 hrs Salt Spray, ASTM B117	1500 hrs Cyclic corrosion testing, ASTM G85, Annex A5	2000 hrs Cyclic corrosion testing, ASTM G85, Annex A5

Sources

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ifscoatings.com/content/news/blog/an-architects-guide-to-aama-2603-2604-and-2605-in-laymans-term/

To help decide which coating is suitable in any given environment, it is worth looking at the performance rating of the Fenestration and Glazing Industry Alliance (FGIA). There are three specification codes.

AAMA specifications are a mix between meeting accelerated and real world testing that takes place in the harsh South Florida environment. It's toughest specification (AAMA 2605) requires 10-Year testing for Color retention, Chalk resistance, and Gloss retention.

AAMA 2603 specification is for high-solids polyester and acrylic coatings. These are mainly used for interior façades, retail points of sale, or commercial storefronts in shopping malls. They are not exposed to harsh weather conditions, so the need for exceptional performance in outdoor weather is unnecessary.

AAMA 2604 specifies the performance of Silicone Modified Polyester. They cost a little more than standard polyesters yet are five times more protective. Their weathering performance over five years is equal to one year for ordinary polyesters. SMP coatings are often applied to storefronts, windows, doors, and low-rise curtain walls. Although the ratings are for five years, they are usually supplied with a 10-year guarantee.

AAMA 2605 is designed to test the performance of superior paint specifications. 70% PVDF and FEVE coatings are primarily used in extreme weather conditions to protect exterior curtain walls, façades, windows and doors of buildings, stadiums, and high-value residences. These polymers provide long-lasting protection for buildings' structural and aesthetic qualities with warranties of 20 years for color and gloss on aluminum. Whilst there are other local Standards across the world AAMA remains the leading one even outside of the US.

What are
TRINAR® coatings?

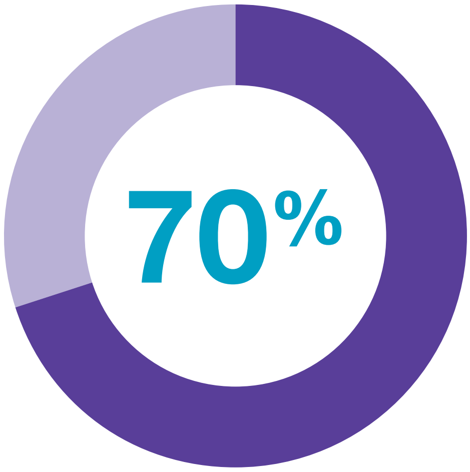
TRINAR coatings are a 70% minimum fluoropolymer-based paint system manufactured by AkzoNobel. The resin is 70% PVDF, to which AkzoNobel adds acrylic resin, solvent, pigment, and other high performing additives. It is primarily used for commercial and monumental projects.

The fluoropolymer coating is flexible which means when producing coils and panels the appearance of micro-cracks and abrasions are extremely limited. It also has a durable color and gloss retention in high-risk, extreme weather areas.

Both coil and extrusion coatings need formability, i.e., flexibility, adhesion, and damage resistance, which allows the surface coating to remain intact as metal products are bent or drawn through manufacturing to form various shapes. TRINAR has more recently improved scratching and marring during the forming and cutting processes, during transportation, throughout installation, and over the products' life. Its adhesive qualities prevent de-lamination of the coating system and protect against corrosion from water, heat, and chemical pollution.

There are other similar fluoropolymer coating systems on the market. Like TRINAR they rely on PVDF. Previously PVDF coatings were among the most economical ultra-high performing coating solutions. They are relatively less economical today. So, coil and extrusion manufacturers need to balance performance with higher costs and potential supply challenges.

Many architects, specifiers, and coil and extrusion manufacturers are considering how to supply an alternative product without compromising on quality for their customers. So what are their options?



TRINAR coatings are a 70% PVDF coating system manufactured by AkzoNobel.

AkzoNobel also supplies other PVDF containing coatings across the world under other trading names.

What are the **alternatives?**

PVDF is particularly good for long-lasting protection of vivid and dark colors. A choice of bright colors is restricted though, if a two-coat rather than a three-coat system is used.

The PVDF coating's flexibility supports the manufacture of metal building components. However, this flexible finish can be relatively soft and more susceptible to scratching and marring than other systems. With white coatings, more metal marking occurs than with other, tougher coating systems. Careful handling in production avoids these issues.

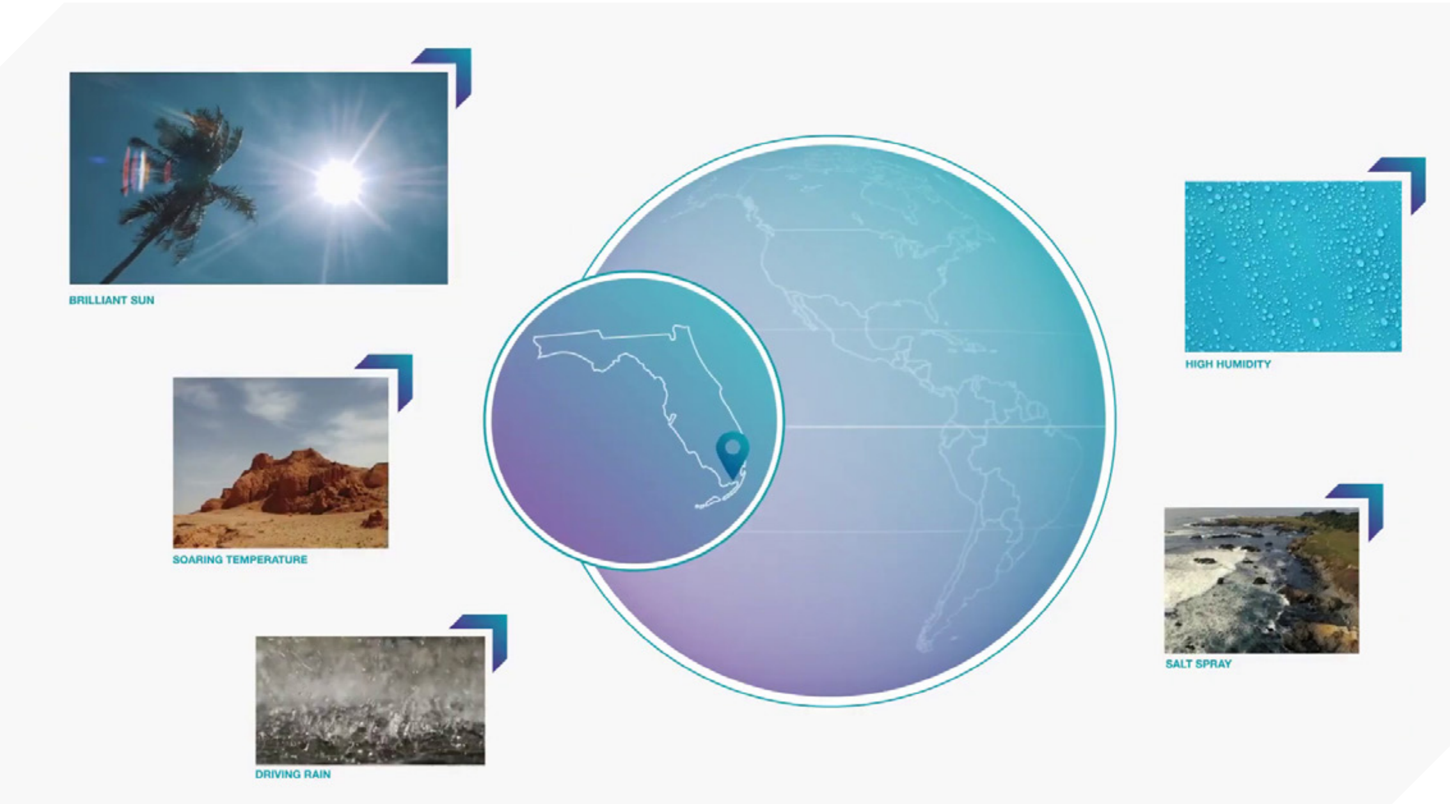
PVDFs are particularly suited to severe environments: industrial sites with high concentrations and quantities of acid rain and chemical pollutants; coastal areas with saltwater spray from the ocean; desert climates with the risk of wind and sand erosion; or climates with extreme heat, UV sunlight, and moisture or humidity (e.g. South Asia).

The vast majority of the Northern Hemisphere however, does not have such extremes. Here PVDF coatings will offer little additional protection over other high-quality coating systems.

The coating selection criteria varies by project. From our experience SMPs are a good substitute in more environments than you would think. Central and Northern U.S., Canada, North Asia are all examples of areas where PVDF may not be needed.

However, SMP will perform well in other extreme areas. Those in coastal areas or mountainous regions with swings in temperature, heavy rainfall, hail and snow. Although these environments might be considered extreme, SMP's toughness will weather these conditions well.

There are few locations across America and the globe which absolutely need PVDF or FEVE. There are good quality alternatives which will deliver the coating performance your building and your customers need.



The science behind SMP

Silicone Modified Polyester (SMP)

With the current constraints on supply and rising prices, it may become more economical and reliable to use silicone modified polyester (SMP) which costs less than PVDF.

SMP is a silicone-protected or siliconized polyester architectural coating system for coiled and flat metal sheet product. The SMP coating system blends polyester, silicon and ceramic pigments for color, gloss retention and weather resistance.

High silicone levels improve the gloss retention characteristics of coating systems. These products have been formulated and improved over decades with extensive research and performance testing. Today's SMP coatings are much closer to the durability of PVDF than previously thought.

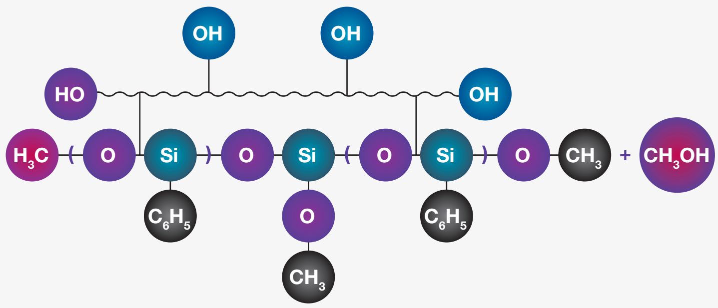
SMP offers more gloss options and textured finishes compared with PVDF coating systems, and differs slightly when comparing color fade in medium and dark colors. The coating can begin to chalk and fade slightly quicker than PVDF coatings, especially when bright or dark colors are used in extreme conditions. However lighter colors are inherently better at deflecting UV rays and SMP is a viable option.

SMP, once cured, is tougher than PVDF and has excellent scratch resistance which ultimately reduces corrosion of exposed metal during the life of the building. Because of more competitive prices and harder finishes, SMP coatings are the preferred alternatives for warehouses, industrial storage, agricultural structures, and other non-monumental commercial buildings.

These SMP coatings work well in all but the most extreme environments. Areas with intense sunlight such as deserts should be avoided, or heavy industrial areas with chemical pollutants and acid rain.

Given SMPs are not suffering the same supply and fluctuating price issues, they will often be a good alternative to PVDF.

Molecular Structure of SMP Resin



Hydroxylterminated Polyester + Silcone Intermediates + Methanol

Silicone Modified Polyester

Silicone Modified Polyester (SMP) resins are linear chains of ester groups. C-H, C-O and C-Si bonds. Although weaker than C-F bonds, C-Si bonds are still very strong and require significant energy to break.

However current SMP formulations are approaching the durability and efficiency of premium PVDF coatings, and some have fade warranties of up to 30 years.

The science behind **other alternatives**

Polyester (PE)

Polyester resins can be made from a wide variety of acids and alcohols resulting in a range offering different performance properties. Polyesters can offer an economical product with good performance across the board and in many cases are fit for purpose. The versatility of the resin allows chemists to produce very strong products that satisfy unique specifications. Polyester resins are consequently a popular choice for coil coatings.

Standard polyesters have limited flexibility and adequate durability however they can be adapted to improve flexibility or increase scratch resistance. They have moderate resistance to UV, good corrosion protection and good chemical resistance.

Polyesters typically have a smooth surface finish, but with either the addition of polyamide particles or with a structured base layer, textured surfaces can be possible. Coupled with aesthetic benefits, these textured products are often highly scratch resistant too.

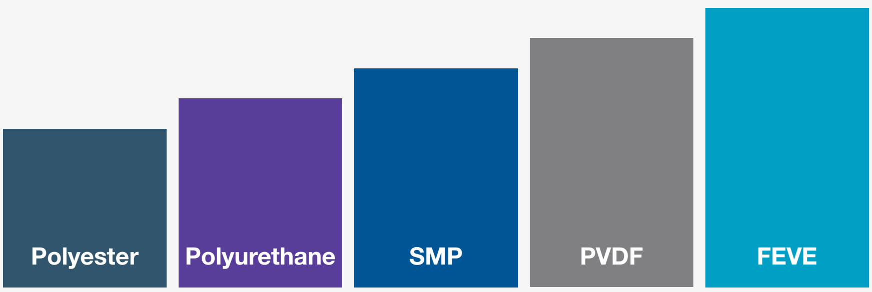
Polyesters are commonly used for both wall and roof cladding on buildings, particularly in moderate climates. This represents the most economical choice for these types of applications however durability can be limited.

Polyurethane (PU)

Polyurethane coatings are chemically similar to polyesters with the addition of isocyanates in the formulation. Compared to polyesters, polyurethanes can produce high-build coatings which tend to offer increased durability and the improved corrosion resistance. The amount of isocyanate effects the coating flexibility and isocyanate type effects the resistance of UV light.

Polyurethanes are capable of high levels of flexibility especially suitable for prepainted metal and they also have increased scratch resistance compared to polyesters. The use of polyurethane coatings for prepainted metal has grown recently because of these desirable properties. Consequently, polyurethanes generally cost more than basic polyesters so they are used where the benefits outweigh the cost differential.

The high-build products are widely used in roof and wall cladding because of their improved corrosion and UV resistance, coupled with the scratch-resistant properties of the polyamide-modified varieties. The other important property of polyurethanes is the improvement in the flexibility/scratch-resistance ratio.



Relative prices

Fluoroethylene Vinyl Ether (FEVE)

FEVE resins contain a strong fluorocarbon bond, giving them similar performance ratings to PVDFs. It has similar weather and UV resistance to PVDF and is relatively unaffected by chemical pollutants or acid rain.

FEVE can provide protection of bright, vividly colored panels and components for a similar length of time to PVDF and with a higher gloss option.

But FEVE systems are thermoset resins i.e. they will not re-melt under high pressures and temperatures once they are cured. This makes FEVE resins tough and resistant to scratches or marring. It also makes it less flexible than PVDF, which is a consideration when manufacturing products with sharp angles or bends.

FEVE is also less impact-resistant and could require careful handling to avoid spoiling the final look and protective qualities of the coating.

FEVE polymers are the most expensive resins. Although PVDF prices have approximately tripled in recent years, the relative price of FEVE is still higher than PVDF today.

FEVE coatings require considerable vetting to ensure proper performance.

Technical Support from AkzoNobel

While there is still so much uncertainty surrounding PVDF supply and prices, AkzoNobel will continue to work closely with suppliers to maintain the current PVDF supply where it is needed.

We are using our decades of experience in the industry to develop new coatings for our coil and extrusion customers. Our very experienced technical teams are here to support you in making those important choices about what is the most suitable coating for every project. Some will need to use PVDF. Many will be able to use alternative coatings.

> "AkzoNobel will continue to work closely with suppliers to maintain the current PVDF supply where it is needed."

For more information please visit
our Coil and Extrusion website:
coilcoatings.akzonobel.com

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AkzoNobel

We supply the sustainable and innovative paints and coatings that our customers, communities – and the environment – are increasingly relying on. That's why everything we do starts with People. Planet. Paint. Our world class portfolio of brands – including Dulux, International, Sikkens and Interpon – is trusted by customers around the globe. We're active in more than 150 countries and have set our sights on becoming the global industry leader. It's what you'd expect from a pioneering paints company that's committed to science-based targets and is taking genuine action to address globally relevant challenges and protect future generations.

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