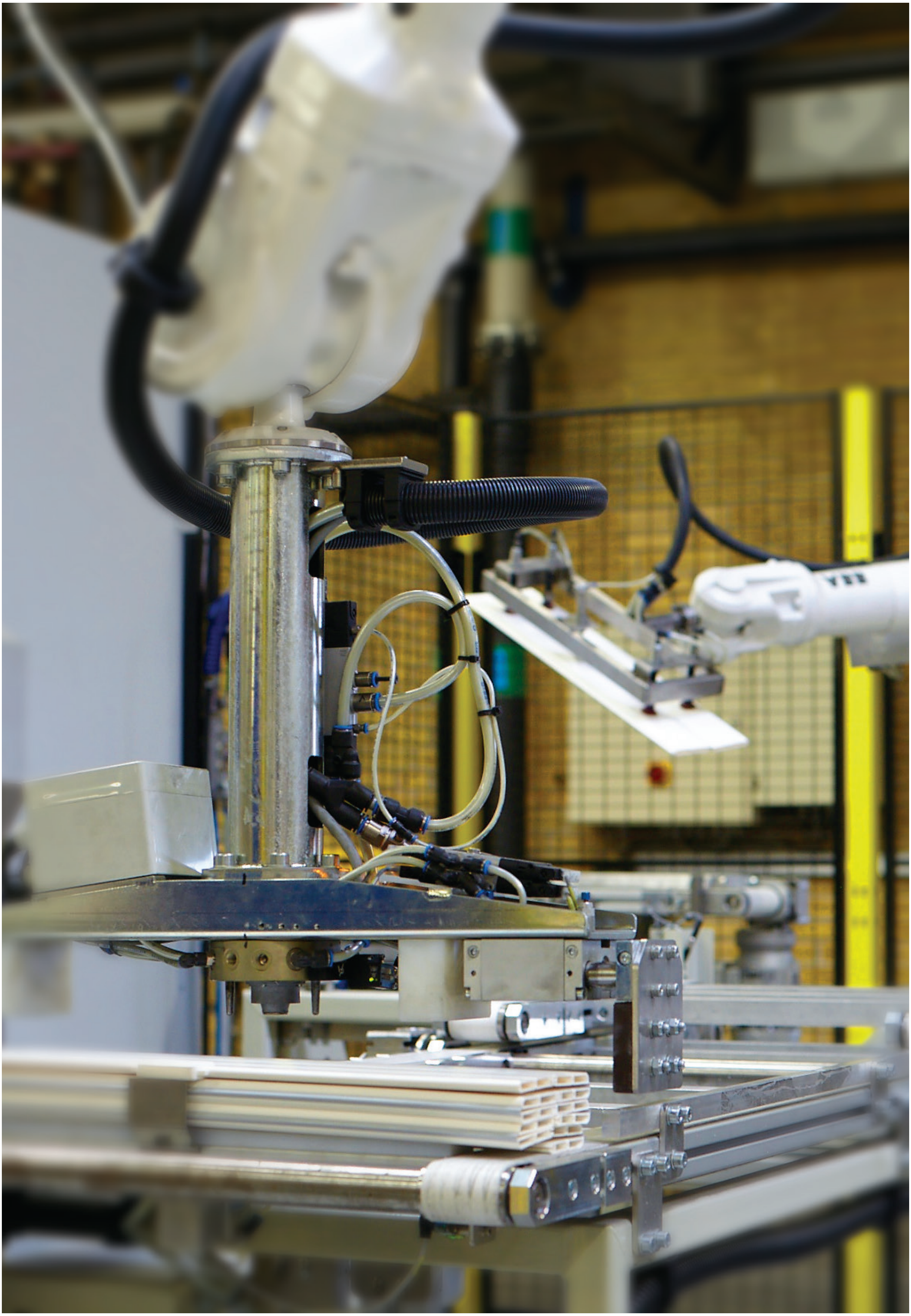
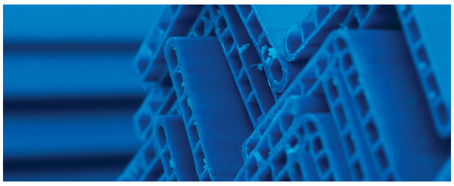
MATERIALS

Guide to raw materials for extruded plastic profiles



PASSIONATE ABOUT EXTRUSION



At Primo, we have more than 60 years of experience as manufacturers of high-quality extruded plastic profiles for various industries. We are dedicated not only to materials but also to develop new products and possibilities with our clients.

Innovative and more ingenious plastic profile solutions are the core of Primo's business. We work with transparency - and by sharing knowledge about materials, we pave the road to mutual success.

We extrude a broad range of plastics, and we produce unique composites for specialised profiles, for example, to the building segment. We supply a range of sectors from dedicated business areas such as medico to offshore, transport and energy.

All available information, including results of stress tests, thermal properties, environmental impacts such as CO_2 emissions, chemical composition, fire safety tests, and more, are shared by our material experts. This way, we lay the foundation for long-term collaboration and rapid time-to-market for our customers.

The characteristics of the raw materials define the properties of the profile. Thus, the extrusion process starts with the raw materials and is dependent on their properties and the right way of processing them. Today, product developers have more choices than ever when it comes to properties such as strength, durability, sustainable and cost-effective solutions.

This whitepaper is an introduction to polymer materials, their properties and areas of application.

Allan Larsen
Group Director, Technology

PRIMO

SHOULD I CHOOSE PLASTICS?

DECIDING WHAT OR WHICH MATERIAL TO USE FOR YOUR NEXT PROJECT IS AN IMPORTANT DECISION – AND PLASTICS ARE NOT ALWAYS THE OPTIMAL MATERIAL. HOWEVER, PLASTIC SCIENCE IS ADVANCING RAPIDLY, AND PLASTICS ARE REPLACING STEEL, ALUMINIUM, WOOD, AND OTHER MATERIALS IN MANY INDUSTRIES BECAUSE OF THEIR DURABILITY AND RECYCLING PROPERTIES.

When it comes to CO_2 footprint and long-term environmental impact, plastics have important properties. Plastics are light and easy to transport compared to e.g. metal and wood, and the extrusion process takes place at relatively low temperatures.

Furthermore, the properties of polymer raw materials are documented and can be used for certification and documentation of the profile.

When looking at properties such as the weight-to-strength ratio, plastics can easily compete with some metals. And the continuous development in polymer science and manufacturing processes means that plastic proves superior in more and more areas. But there are other reasons to choose extruded plastic.

When flexibility in material design and economy are added to the calculation, various plastics will prove superior in many more areas. The reason is that the extrusion process provides, fast and easy design options.

Furthermore, if you add properties such as ease of handling and sustainability, the scale again tilts in favour of a polymer-based material.

“The Plastic Properties database is a technical reference used to determine which polymer will be optimal for a project with a specific set of parameters.“

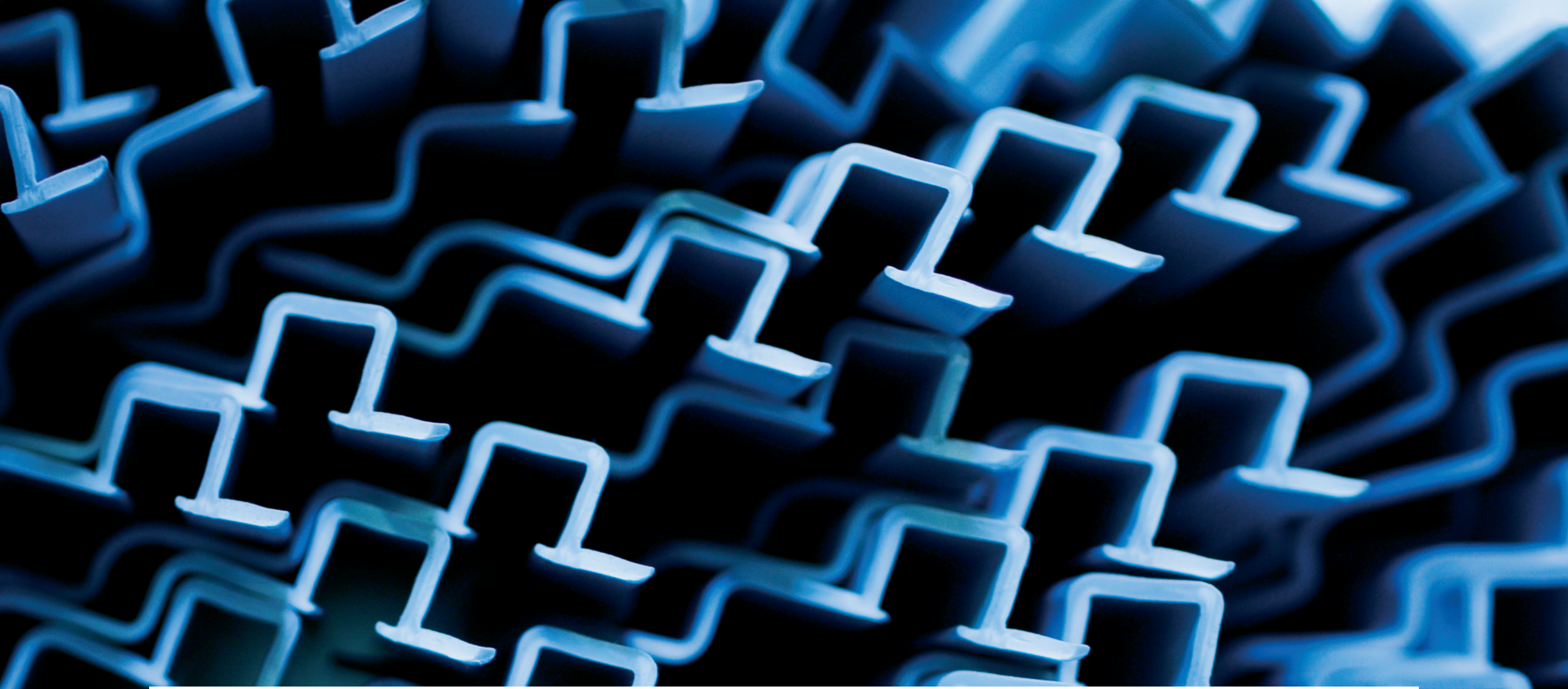
Polymers cannot yet compete with metals such as structural steel in the construction industry. However, more and more industries are optimising their products and manufacturing processes with plastic profiles. A good example is from the refrigeration industry. By replacing the industry standard aluminium profiles on commercial multideck refrigerators with plastic profiles, manufacturers can reach several targets. First of all, the plastic profiles lower overall manufacturing cost, but manufacturers can also build a more energy-efficient product. Plastics have thermal-insulating properties while aluminium, often used in the industry by default, is a thermal conductor.

When making the shift to plastic profiles, manufacturers of refrigerators also benefit from lighter profiles, which can be delivered with many features that will allow for easy assembly. Furthermore, plastics can provide properties and be made into shapes which is simply not possible in any other material and is therefore very difficult to substitute for an optimal solution.

PLASTIC PROPERTIES OVERVIEW OF TYPICAL, INDICATIVE VALUES

		Density **Specific Gravity**	Water uptake **Water Absorption**	Pull apart **Tensile Strength**	Stretchiness **Tensile Elongation**	Stiffness **Flexural Modulus of Elasticity**	Break under load **Flexural Strength**	Thoughness **Izod(/ charpy) Impact**
		The density of plastic compared to the density of water. A higher number indicates a denser plastic.	The % increase in weight of a plastic when it is immersed in water for 24 hours.	The load at which a plastic test specimen fails when it is pulled from both ends.	The dregree to which a plastic test specimen can be stretched under a tensile load prior to failure.	A measure of the flexural stiffness of a plastic prior to breaking or permanently derforming.	The Load at which a plastic test specimen fails in flexure.	The energy it takes to break a plastic test specimen. An indication of the thoughness of a material. (notched)
		g/cm3	**%**	**N/mm2**	**%**	**N/mm2**	**N/mm2**	**kJ/m2**
Rigid materials								
ABS	Acrylonitrile Butadiene Styrene	1,05	0,3	40	20	2200	60	no break
PC	Polycarbonate	1,2	0,2	> 70	> 100	2500	75	no break
PE-HD	High Density Polyethylene	0,95	< 0,05	22	> 800	800	25	no break
PE-HM	High Molec-ular weight Polyethylene	0,95	< 0,05	28	> 600	1200	40	no break
PE-LD	Low Density Polyethylene	0,92	< 0,05	8 tot 10	> 700	200 tot 400		no break
PET	Polyethylene terephthalate	1,27	0,15	52	> 100	2200	-	no break
PMMA	Polymethyl-methacrylate	1,19	0,5	74	5	3300	120	10
PP	Polypropylene	0,91	< 0,2	30	> 50	1150	28	7
PS	Polystyrene	1,04	0,06	36	40	1850	57	15
PVC-C	Rigid pvc Chlorinaded	1,55	0,2	60	15	3000	90	no break
PVC-HI	Rigid pvc High Impact	1,45	0,05	50	60	2800	50	no break
PVC-U	Rigid pvc	1,45	0,05	50	20	3000	80	no break
Flexible/ soft materials						**Hardness Shore A/D**	**Compres-sion set/"-sealability"**	**Tear strenght Mpa**
PVC-P	Platicized pvc	1,2 tot 1,3	0,3	10	170	60 -95A		8
TPE/TPE-s	Styrene block copolymer	1,05			> 400	50A - 50D		
TPO/TPE-o	Thermoplastic Polyolefin	0,95		> 20		50A - 50D		
TPU	Thermoplastic Polyurethane	1,26	0,05	> 35	> 500	60A - 70D	25% (70°C)	
TPV/TPE-v	Thermoplastic Vulcanizates	0,97			> 450	40A - 55D	28% (70°C)	27

Slipperiness **Coefficient of Friction**	Growth with heat **Coefficient of Linear Thermal Expansion**	Max heat **Max Continuous Service Temperature In Air**	Soft when heated **Heat Deflection Temperature**	Resistance **Chemical resistance / escr/ critical sensitivity**	Outdoor use **Weatherability & UV (White color)**	Re-use & waste **Recyclability**	Price **Cost index (eg. price/ kg)**
Degree to which a plastic resists sliding against anohter material. A lower number indicates more slippery.	Degree to which a plastic changes size due to temperature change. High number indicates more growth when heated.	An approximate temperature above which a plastic material will be more likely to fail.	The temperature at which a plastic test specimen will bend a specified distance under a specific load.		Resistance to Wheater coditions in Western Europe (5 = best, depending on composition)	Possibility to resuse the material in profiles or other applications	1 = lower 5= higher
	mm/m°C	**°C**	**°C**	**°C**			
0,6	0,075	90	80	Sensitive to solvents	2	yes	3
0,55	0,07	120	138	Resistant to oils, benzines, fuels, greases Not resistant to strong acids/bases.	5	yes	3
0,25	0,2	100	48	Good chemical resistance to most chemicals	4	yes	1
0,29	0,2	90	60	Good chemical resistance to most chemicals	4	yes	2
0,58	0,25	100	-	Good chemical resistance to most chemicals	4	yes	2
0,54	0,06	100	-	Resistance to alcohols, oils, greases and diluted acids.	5	yes, with special treatment	1
0,54	0,07	80	102	Sensitive to solvents	5	yes	4
0,3	0,16	125	65	Good chemical resistance to most chemicals	4	yes	2
0,46	0,1	90	-	Sensitive to solvents	3	yes	3
	0,07	110	103	Resistance to acids, salts, corrosives, bases, fats, and alcohols. Not resistance to solvents	5	yes	1
0,6	0,08	80	74	Resistance to acids, salts, corrosives, bases, fats, and alcohols. Not resistance to solvents	5	yes	1
0,55	0,08	65	82	Resistance to acids, salts, corrosives, bases, fats, and alcohols. Not resistance to solvents	5	yes	1
	0,15	50	-	Resistance to acids, salts, corrosives, bases, fats, and alcohols. Not resistance to solvents	5	yes	2
		60 -70	75	Resistance to acids, bases and accohol	5	yes	4
				Good chemical resistance to most chemicals	4	yes	2
0,4	0,2	110		Resistance to oils and greases, not to alcohols and solvents	5	yes	5
		130		Resistance to acids, alcohols, acetone	5	yes	5



The right choice

CHOOSING THE RIGHT MATERIAL

ENSURING THE OPTIMAL PROPERTIES OF YOUR PROFILE OR PRODUCT STARTS BY CHOOSING THE SUITABLE PLASTIC RAW MATERIAL. AT PRIMO WE OFTEN SAY THAT THE POSSIBILITIES ARE ENDLESS. THEY ARE - AND YOU MIGHT BE OVERWHELMED BY THE NUMBER OF DIFFERENT MATERIALS AVAILABLE AND THE COUNTLESS WAYS IN WHICH THEY CAN BE COMBINED, TAILOR-MADE AND CUSTOMISED.

In our experience, the optimal way to navigate this field is to begin with the basics. A good description of your new profile is the first step to determining what raw material to use. Together with our customers, we seek out what the fundamental properties should be. Why does the customer want the new profile? What is the purpose of your new profile, where will it be used, and how? Will it be exposed to chemicals or high voltage? We investigate the underlying needs and function of the profile to secure the best possible solution for our customers, based on years of experience and understanding the purpose of your new profile.

All of these variables will be taken into consideration when we decide which materials and processes are needed to produce the profile.

We do this drawing on our more than 60 years of experience and by consulting our material databases that describe the properties of a range of available raw materials.

Thermosets, thermoplastics and thermoplastic elastomers

DIFFERENT TYPES OF POLYMERS

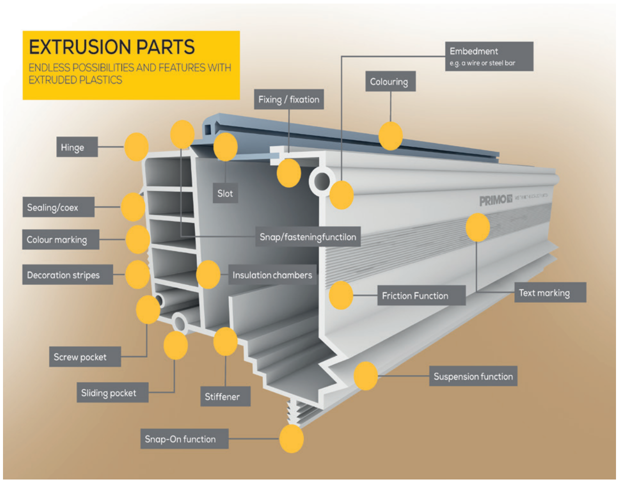
IN THE PLASTICS INDUSTRY, WE DIFFERENTIATE BETWEEN THREE OVERALL TYPES OF PLASTICS: THERMOSETS, THERMOPLASTICS, THERMOPLASTIC ELASTOMERS, AND. AS THE NAMES INDICATE, THEY BEHAVE DIFFERENTLY.

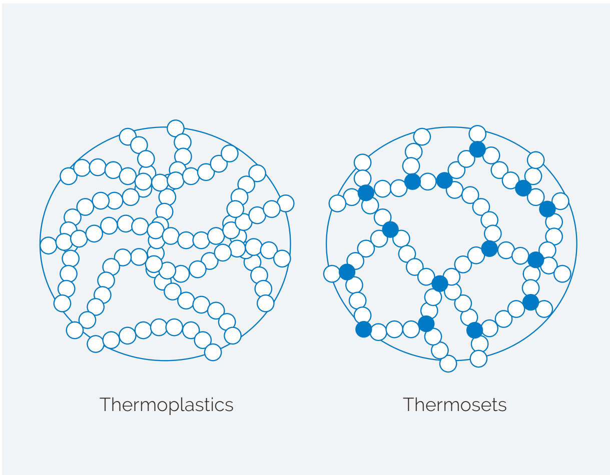
Thermosets are those polymers that become irreversibly chemically bonded on heating or by the addition of special chemicals. The curing process results in a permanent chemical change, and the thermoset molecule cross binding will not break again even when exposed to extremely high temperatures. Therefore, the polymer will degrade before melting when heated, which makes it difficult to recycle thermoset products - except as a filler material.

Common examples of thermoset plastics include epoxy, silicone, polyurethane, and phenolic. In addition, some materials such as polyester can occur in both thermoplastic and thermoset versions.

Thermosets are often stronger than thermoplastics. This is because the microscopic polymer molecules in thermosetting materials tend to cross-link, while thermoplastic molecules are linear.

Examples of thermosets are automotive tires, polyesters/epoxies for wind turbine blades and boats.





Thermoplastics can be remelted (plasticised) and processed again several times, generally without losing their properties, which also make them convenient for recycling. Thermoplastics is the most common type utilized in extrusion processes and people often associate the attributes of thermoplastic, when they think of "plastic"

Thermoplastic elastomers (TPE), sometimes referred to as thermoplastic rubbers, are either blends of two or more polymers or special types of block copolymers. These elastomers combine the performance benefits of rubber with the easy processability of thermoplastics but are more versatile than either material. The advantage of TPE is that the material has outstanding thermal properties and material stability when exposed to other materials. TPE is easy to handle in the manufacturing process.

HOW PLASTIC COMPONENTS ARE PRODUCED

IN GENERAL, SOLID PRODUCTS BASED ON THERMOPLASTICS ARE MANUFACTURED IN THREE DIFFERENT WAYS: INJECTION MOULDING, THERMOFORMING AND EXTRUSION.

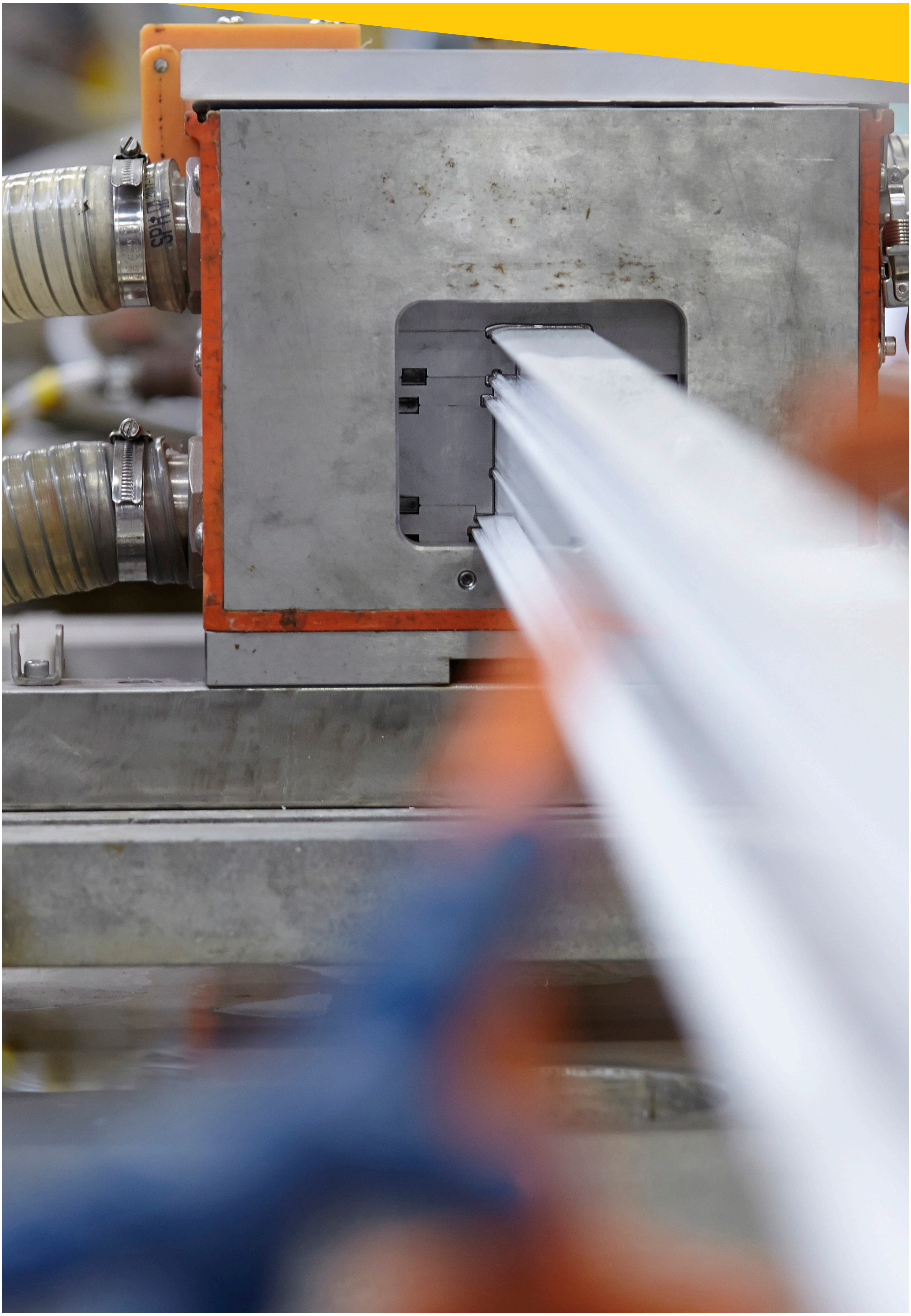
The three different methods can all form thermoplastics, so which one to choose is a matter of design and shape rather than material properties. Let us take a look at them.

Extrusion
Extrusion is a continuous process and the method Primo has specialised in. Extrusion makes it possible to produce long, and hypothetically, endless profiles. Extrusion is used for pipes, cables, window and door profiles, gaskets, and all kinds of plastic products where a uniform, long 3D shape is usable. The extrusion process also allows for co-extrusion, where two or more different polymers are extruded into the same profile.

A variation of traditional extrusion is foil extrusion. This process makes thin layers of polymer film for winding on rolls. " Rotational molding" and "Blow molding" are yet other techniques for producing plastic products.

Thermoforming
Thermoforming is another way to take advantage of the thermoplastic properties of specific polymers. In the thermoforming process, a plastic sheet is heated to a temperature sufficiently high for it to be formed into a certain shape. This is how a Polystyrene coffee cups are is made and numerous other products where a flat sheet is formed. Another example is skylight dome windows.

Injection moulding
Injection moulding is simply a manufacturing process for producing parts by injecting plasticised material into a mould. Plastic injection moulding utilises a heated screw to press the raw materials into a form. This is, for instance, how LEGOs are made – and billions of other large and small plastic products. Modern day injection moulding machines are controlled by a built-in computer. Acting on sensor fed information, it controls all the actions of the machine and ensures consistent output and shot to shot quality.



PERIODIC TABLE

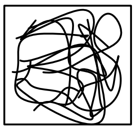
The Periodic Table of the elements by Mendeleev was a historic achievement in chemistry and enabled chemists to see the relationship between structure and properties of the essential elements. Polymers also have a strong relationship between structure and properties, and this 'Periodic Table of Polymers' is the first attempt to provide a simple codification of the basic polymer types and structures. The regular diversity of polymer types makes it impossible to include all of the variations in a straightforward table and this table only includes the most common polymer, and their crystal or semi-crystalline state.

Commodity

Amorphous

Increasing crystallinity

Random molecular orientation in both molten and solid phases.



General Characteristics
Soften gradually.
Generally transparent. Lower Tensile Strength and Tensile Modulus.
Lower Density.
Low Creep Resistance. High Dimensional Stability.
Low fatigue resistance.
Easy to bond using adhesives and solvents (high surface energy).

PS-HI
High Impact Polystyrene
TS: 19 - 33 MPa
EAB: 40 - 50%
TM: 1.8 GPa
LTST: 55 - 60iC
HDT: 60 - 80iC
Cost: ◆

PS-GP
General Purpose Polystyrene
TS: 40 - 50 MPa
EAB: < 3%
TM: 3.2 - 3.5 GPa
LTST: 70 - 85iC
HDT: 72 - 82iC
Cost: ◆

ABS
Acrylonitrile Butadiene Styrene (Copolymer)
TS: 40 - 60 MPa
EAB: 3 - 20%
TM: 2.0 - 2.6 GPa
LTST: 80 - 95iC
HDT: 90 - 100iC
Cost: ◆

SAN
Styrene Acrylonitrile (Copolymer)
TS: 47 - 72 MPa
EAB: 2.0 - 10%
TM: 2.3 - 4.1 GPa
LTST: 55 - 60iC
HDT: 84 - 95iC
Cost: ◆◆

PVC
Plasticised Polyvinylchloride
TS: 6 - 20 MPa
EAB: 50 - 460%
TM: 0.002 - 0.020 GPa
LTST: 50iC
HDT: 20iC
Cost: ◆

SBS
Styrene-Butadiene-Styrene (Copolymer)
TS: 35 - 40 MPa
EAB: 40%
TM: 1.8 - 2.0 GPa
LTST: 60iC
HDT: 67iC
Cost: ◆◆

SMA
Styrene-Maleic Anhydride (Copolymer)
TS: 40 - 52 MPa
EAB: 1.8%
TM: 2.0 GPa
LTST: 100iC
HDT: 105iC
Cost: ◆◆

ASA
Acrylonitrile Styrene Acrylate (Copolymer)
TS: 38 - 70 MPa
EAB: 15 - 45%
TM: 2.3 - 2.9 GPa
LTST: 82 - 120iC
HDT: 82 - 120iC
Cost: ◆◆

SM
Styrene-Butadiene (Copolymer)
TS: 26 - 30 MPa
EAB: 20 - 80%
TM: 1.8 GPa
LTST: 65 - 77iC
HDT: 70 - 77iC
Cost: ◆◆

PVC-U
Unplasticised Polyvinylchloride
TS: 45 - 55 MPa
EAB: 25 - 60%
TM: 2.50 - 3.02 GPa
LTST: 60 - 70iC
HDT: 64 - 70iC
Cost: ◆

CA
Cellulose Acetate
TS: 30 - 55 MPa
EAB: 5 - 55%
TM: 1.6 GPa
LTST: 45 - 70iC
HDT: 48 - 65iC
Cost: ◆◆

CAB
Cellulose Acetate Butyrate
TS: 26 - 50 MPa
EAB: 8 - 80%
TM: 0.7 - 1.5 GPa
LTST: 75 - 100iC
HDT: 62 - 70iC
Cost: ◆◆

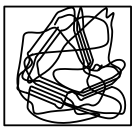
CAP
Cellulose Acetate Propionate
TS: 26 - 47 MPa
EAB: 30 - 100%
TM: 0.7 - 1.5 GPa
LTST: 75 - 100iC
HDT: 45 - 75iC
Cost: ◆◆

CP
Cellulose Propionate
TS: 30 - 45 MPa
EAB: 45 - 65%
TM: 0.8 - 1.5 GPa
LTST: 68 - 100iC
HDT: 61 - 73iC
Cost: ◆◆

PVC-U
High-Impact Unplasticised PVC
TS: 45 - 55 MPa
EAB: 25 - 60%
TM: 2.5 - 3.0 GPa
LTST: 60 - 70iC
HDT: 64 - 70iC
Cost: ◆

Semicrystalline

Random molecular orientation in molten phase, densely packed crystallites in solid phase.



General Characteristics
Sharp melting point.
Generally translucent or opaque.
Higher Tensile Strength and Tensile Modulus.
Higher Density.
High Creep Resistance.
Low Dimensional Stability.
High fatigue resistance.
Difficult to bond using adhesives and solvents (low surface energy).

PE-LD
Low Density Polyethylene
TS: 7.0 - 25 MPa
EAB: 50 - 400%
TM: 0.15 - 0.35 GPa
LTST: 40 - 70iC
HDT: 35iC
Cost: ◆

PE-LLD
Linear Low Density Polyethylene
TS: 8.0 - 20 MPa
EAB: 50 - 500%
TM: 0.2 - 1.0 GPa
LTST: 44 - 50iC
HDT: 37 - 44iC
Cost: ◆

PE-MD
Medium Density Polyethylene
TS: 14 - 25 MPa
EAB: 50 - 300%
TM: 0.25 - 0.70 GPa
LTST: 38 - 70iC
HDT: 38 - 43iC
Cost: ◆◆

PMD
Polymethyl pentene
TS: 25 - 28 MPa
EAB: 15 - 30%
TM: 1.0 - 2.2 GPa
LTST: 55 - 60iC
HDT: 40 - 50iC
Cost: ◆◆◆

EVA
Ethylene-vinyl Acetate (12% VA)
TS: 10 - 19 MPa
EAB: 50 - 750%
TM: 0.04 - 0.14 GPa
LTST: 50iC
HDT: 20 - 23iC
Cost: ◆◆◆

PE-Chlorinated
Chlorinated Polyethylene
TS: 12.5 MPa
EAB: 700%
TM: 0.002 GPa
LTST: 60iC
HDT: 25iC
Cost: ◆◆◆

PE-VLD
Very Low Density Polyethylene
TS: 34 - 400 MPa
EAB: 400 - 700%
TM: 0.10 - 0.20 GPa
LTST: 60iC
HDT: 75 - 95iC
Cost: ◆◆◆

EMA
Ethylene-methyl Acrylate
TS: 9 - 12 MPa
EAB: 750 - 800%
TM: 0.03 GPa
LTST: 55iC
HDT: 59iC
Cost: ◆◆◆

PP
Polypropylene (Homopolymer)
TS: 33 MPa
EAB: 150%
TM: 1.5 GPa
LTST: 100iC
HDT: 65iC
Cost: ◆

PP
Polypropylene (Copolymer)
TS: 25 MPa
EAB: 300%
TM: 1.2 GPa
LTST: 90iC
HDT: 60iC
Cost: ◆

PE-HD
High Density Polyethylene
TS: 10 - 50 MPa
EAB: 400 - 800%
TM: 0.18 - 1.6 GPa
LTST: 55iC
HDT: 46iC
Cost: ◆

Key to major polymer families:

- Styrenes
- Polyolefins
- Vinyls
- Cellulosics
- Polyesters
- Polyamides
- Acrylics
- Polycarbonates
- Acetals
- Polysulphones
- Imides
- Fluoropolymers

KEY

TS = Tensile Strength at Yield @ 23oC
EAB = Elongation at break
TM = Tensile Modulus @ 23oC
LTST= Long Term Service Temperature
HDT = Heat Deflection Temperature @ 1.8 MPa
Cost = Relative Cost

All properties are for the natural injection moulding grade resin only and do not include polymers with reinforcements or other functional fillers.

Increasing performance

Engineering

Performance

PMMA
Polymethylmethacrylate (Acrylic)
TS: 56 - 70 MPa
EAB: 3.0 - 3.5%
TM: 3.0 GPa
LTST: 90iC
HDT: 85 - 95iC
Cost: ◆◆◆

PPO (Modified)
Polyphenylene Oxide
TS: 40 - 90 MPa
EAB: 10 - 60%
TM: 2.0 - 5.4 GPa
LTST: 80 - 260˚C
HDT: 129˚C
Cost: ◆◆

PC
Polycarbonate
TS: 55 - 75 MPa
EAB: 110 - 120%
TM: 1.6 - 2.4 GPa
LTST: 95 - 154iC
HDT: 135 - 140iC
Cost: ◆◆

PAR
Polyarylate
TS: 68 - 71 MPa
EAB: 50 - 100%
TM: 2.0 - 2.2 GPa
LTST: 130 - 150iC
HDT: 165 - 175iC
Cost: ◆◆◆

PSU
Polysulphone
TS: 70 - 76 MPa
EAB: 10 - 80%
TM: 1.5 - 2.7 GPa
LTST: 150 - 180iC
HDT: 160 - 174iC
Cost: ◆◆◆

PES
Polyethersulphone
TS: 70 - 95 MPa
EAB: 40 - 80%
TM: 2.4 - 2.6 GPa
LTST: 180 - 220iC
HDT: 200 - 210iC
Cost: ◆◆◆

PPSU
(Block copolymer)
TS: 83 MPa
EAB: 40 - 80%
TM: 2.65 GPa
LTST: 180iC
HDT: 204iC
Cost: ◆◆◆◆

PEI
Polyetherimide
TS: 100 - 105 MPa
EAB: 40 - 60%
TM: 2.7 - 4.5 GPa
LTST: 170 - 215iC
HDT: 200 - 215iC
Cost: ◆◆◆◆

PAI
Polyamideimide
TS: 90 - 150 MPa
EAB: 2.6 - 12%
TM: 2.5 - 8.8 GPa
LTST: 220 - 280iC
HDT: 275 - 280iC
Cost: ◆◆◆◆◆

PI
Polyimide
TS: 72 - 90 MPa
EAB: 6 - 8%
TM: 1.3 - 4 GPa
LTST: 260 - 300iC
HDT: 280 - 360iC
Cost: ◆◆◆◆◆

PBI
Polybenzimideazole
TS: 120 - 160 MPa
EAB: 2.6 - 3.0%
TM: 4.0 - 6.5 GPa
LTST: 260 - 400iC
HDT: 220iC
Cost: ◆◆◆◆◆

PET-G
Glycolised Polyethylene terephthlate
TS: 55 MPa
EAB: 300%
TM: GPa
LTST: 60iC
HDT: 70iC
Cost: ◆◆◆

PVC-UX
Crosslinked Unplasticised PVC
TS: 28 - 40 MPa
EAB: 150%
TM: 2.5 - 3.0 GPa
LTST: 70 - 95iC
HDT: 120iC
Cost: ◆◆◆

PVC-C
Chlorinated Polyvinylchloride
TS: 53 - 58 MPa
EAB: 25 - 45%
TM: 2.6 - 2.7 GPa
LTST: 90 - 110iC
HDT: 105iC
Cost: ◆◆◆

PA 6/3/T
Amorphous polyamide
TS: 60 - 100 MPa
EAB: > 50%
TM: 1.4 - 2.3 GPa
LTST: 125iC
HDT: 102 - 123iC
Cost: ◆◆◆

PPA
Polyphthalamide (Amorphous)
TS: 85 MPa
EAB: 2.6%
TM: 3.7 GPa
LTST: 140iC
HDT: 138iC
Cost: ◆◆◆◆

PARA
Polyaryl amide
TS: 60 MPa
EAB: 100%
TM: 24 GPa
LTST: 150iC
HDT: 150iC
Cost: ◆◆◆◆

PE-X
Crosslinked Polyethylene
TS: 18 MPa
EAB: 350%
TM: 0.6 GPa
LTST: 90iC
HDT: 60iC
Cost: ◆◆◆

PB
Polybutene-1 (Polybutylene)
TS: 12 - 17 MPa
EAB: 300 - 380%
TM: 0.21 - 0.26 GPa
LTST: 110iC
HDT: 54 - 60iC
Cost: ◆◆◆◆

PE-UHMW
Ultra-high Molecular Weight Polyethylene
TS: 35 MPa
EAB: 500%
TM: 0.5 GPa
LTST: 55iC
HDT: 42iC
Cost: ◆◆◆

PA 11
Polyamide 11 (Nylon 11)
TS: 20 - 60 MPa
EAB: 30 - 400%
TM: 1.0 - 2.0 GPa
LTST: 74 - 147iC
HDT: 38 - 55iC
Cost: ◆◆◆

PA 12
Polyamide 12 (Nylon 12)
TS: 50 MPa
EAB: 200%
TM: 1.2 - 1.6 GPa
LTST: 70 - 80iC
HDT: 55iC
Cost: ◆◆◆

PPA
Polyphthalamide
TS: 85 MPa
EAB: 2.6%
TM: 3.7 GPa
LTST: 140iC
HDT: 138iC
Cost: ◆◆◆

PA 4/6
Polyamide 4/6 (Nylon 4/6)
TS: 100 MPa
EAB: 40%
TM: 3.3 GPa
LTST: 130iC
HDT: 190iC
Cost: ◆◆◆

PEK
Polyetherketone
TS: 52 - 214 MPa
EAB: 1.3 - 330%
TM: 1.5 - 18.6 GPa
LTST: 90 - 334iC
HDT: 93 - 334iC
Cost: ◆◆◆◆

PEEK
Polyetheretherketone
TS: 90 - 110 MPa
EAB: 2.5 - 100%
TM: 3.1 - 8.3 GPa
LTST: 154 - 315iC
HDT: 154 - 295iC
Cost: ◆◆◆◆◆

PBT
Polybutylene terephthlate
TS: 30 - 105 MPa
EAB: 250%
TM: 1.5 - 5.2 GPa
LTST: 65 - 120iC
HDT: 70iC
Cost: ◆◆

PA 6
Polyamide 6 (Nylon 6)
TS: 40 - 50 MPa
EAB: 150 - 250%
TM: 1.2 - 2.8 GPa
LTST: 80 - 120iC
HDT: 60 - 90iC
Cost: ◆◆

PA 6/6
Polyamide 6/6 (Nylon 6/6)
TS: 40 - 86 MPa
EAB: 4.8 - 300%
TM: 0.7 - 5.5 GPa
LTST: 60 - 200iC
HDT: 50 - 150iC
Cost: ◆◆◆

LCP
Liquid Crystal Polymer (Aromatic copolyester)
TS: 55 - 165 MPa
EAB: 1.3 - 2.8%
TM: 2 - 20 GPa
LTST: 230iC
HDT: 200iC
Cost: ◆◆◆◆

PFA
Perfluoroalkoxy
TS: 15 - 30 MPa
EAB: 300%
TM: 0.60 GPa
LTST: 260˚C
HDT: 48 - 60˚C
Cost: ◆◆◆◆◆

PCTFE
Ethylene-chlorotrifluoroethylene
TS: 42 - 48 MPa
EAB: 200%
TM: 1.4 GPa
LTST: 140 - 166˚C
HDT: 63 - 67˚C
Cost: ◆◆◆◆◆

PCTFE
Polychloro-trifluoroethylene
TS: 30 - 40 MPa
EAB: 175%
TM: 1.3 GPa
LTST: 140 - 150˚C
HDT: 67 - 75˚C
Cost: ◆◆◆◆◆

PTFE
Polytetrafluorethylene
TS: 17 - 21 MPa
EAB: 140 - 400%
TM: 0.35 - 0.75 GPa
LTST: 250 - 260˚C
HDT: 50 - 60˚C
Cost: ◆◆◆◆

PET
Crystalline Polyethylene-terephthlate
TS: 57 - 75 MPa
EAB: 50 - 200%
TM: 2.47 - 3.0 GPa
LTST: 63 - 100iC
HDT: 63 - 100iC
Cost: ◆◆

PA 6/10
Polyamide 6/10 (Nylon 6/10)
TS: 50 - 60 MPa
EAB: 70 - 150%
TM: 1.5 - 2.8 GPa
LTST: 60 - 110iC
HDT: 65 - 85iC
Cost: ◆◆◆

PA 6/12
Polyamide 6/12 (Nylon 6/12)
TS: 17 - 60 MPa
EAB: 4 - 600%
TM: 0.29 - 5.5 GPa
LTST: 42 - 190iC
HDT: 50 - 90iC
Cost: ◆◆◆

POM
Polyoxymethylene (Acetal Copolymer)
TS: 62 - 70 MPa
EAB: 20 - 75%
TM: 2.8 - 3.1 GPa
LTST: 104iC
HDT: 110iC
Cost: ◆◆

EVOH
Ethylene-vinyl Alcohol
TS: 37 - 205 MPa
EAB: 100 - 330%
TM: 1.9 - 3.5 GPa
LTST: 80 - 100iC
HDT: 70 - 90iC
Cost: ◆◆◆◆

PPS
Polyphenylene Sulphide
TS: 69 - 124 MPa
EAB: 1 - 5%
TM: 2.2 - 5.5 GPa
LTST: 190 - 260iC
HDT: 174iC
Cost: ◆◆◆

FEP
Fluorinated ethylene-propylene
TS: 15 - 21 MPa
EAB: 240 - 350%
TM: 0.35 - 0.50 GPa
LTST: 60 - 204iC
HDT: 48 - 60iC
Cost: ◆◆◆◆◆

ETFE
Ethylene-tetrafluoroethylene
TS: 35 - 45 MPa
EAB: 200 - 500%
TM: 1.00 GPa
LTST: 160˚C
HDT: 90˚C
Cost: ◆◆◆◆◆

PVDF
Polyvinylidenefluoride
TS: 30 - 55 MPa
EAB: 50%
TM: 1.3 GPa
LTST: 150˚C
HDT: 75 - 82˚C
Cost: ◆◆◆◆

POM
Polyoxymethylene (Acetal Homopolymer)
TS: 67 - 85 MPa
EAB: 15 - 70%
TM: 2.9 - 3.6 GPa
LTST: 85iC
HDT: 124iC
Cost: ◆◆

TANGRAM TECHNOLOGY Consulting Engineers.

High-tech composite plastic profiles

COMPOSITES – REINFORCED PLASTIC

POLYMER COMPOSITES ARE PLASTICS THAT ARE REINFORCED WITH FIBRES, FILLERS, PARTICULATES, POWDERS, OR OTHER MATRIX REINFORCEMENTS TO PROVIDE IMPROVED SPECIFIC PROPERTIES.

Fibre-reinforced polymers (FRP) are used in several industries. For instance, Primo has developed a composite material based on ABS for exterior doors that is superior to steel and wood on several parameters. The reinforced ABS composite has, besides the thermal characteristics and unique structural strength, properties that will allow for regrinding and reusability at the end-of-life cycle.

All scrap and cut-offs from the reinforced ABS production are shredded into small parts and used in the production again for new window and door profiles. This new environmental dimension is another good argument for using more innovative, FRP materials.

The potential here is that doors and windows can be returned to Primo after the end-of-life phase to be used for new profiles.

FRPs are used a lot in the automotive and marine industry and increasingly in the aviation industry. For instance, 80 pct. of the Boeing 787 Dreamliner is made of FRP composites according to https://www.sciencedirect.com/science/article/pii/B9780124096059000015. FRP provides lighter planes and consequently lowers energy consumption and carbon emissions. FRPs are widely used, mainly because of the strength-to-weight ratio.

New raw materials for a greener future

ENVIRONMENT-FRIENDLY USE OF PLASTICS

THERMOPLASTIC PROPERTIES MAKE EXTRUDED PLASTIC PROFILES PERFECT FOR RECYCLING SINCE PROFILES CAN BE MELTED AND REUSED, USUALLY WITHOUT CHANGING THE MATERIAL PROPERTIES.

When deciding for a new material and manufacturer, consider the environmental aspects and the offered services. The plastic industry is committed to eliminating plastic pollution. For instance, industry leaders have joined forces in the program Operation Clean Sweep. This program aims to reduce the loss of plastic pellets, flakes, and powder from plastic production to zero in the sea.

Bioplastics

Bioplastic or rather bio-based plastic is produced from renewable biomass sources in opposition to petrochemical plastics. Bioplastic can be made from a range of natural products such as vegetable fats and oils, corn starch, straw, woodchips, sawdust, recycled food waste, etc.

Bio based plastic can have long-lasting properties, but some types of bio-based plastics are biodegradable. Biodegradable plastics degenerate fast, which means a short product life cycle. Biodegradable plastic is, therefore, used in a limited number of industries and applications. Primo produce biodegradable and compostable plant clips for grafting plants to grow in the correct direction. They fall off during the growth and ploughed over in the soil until complete decomposition.

Recyclable plastics

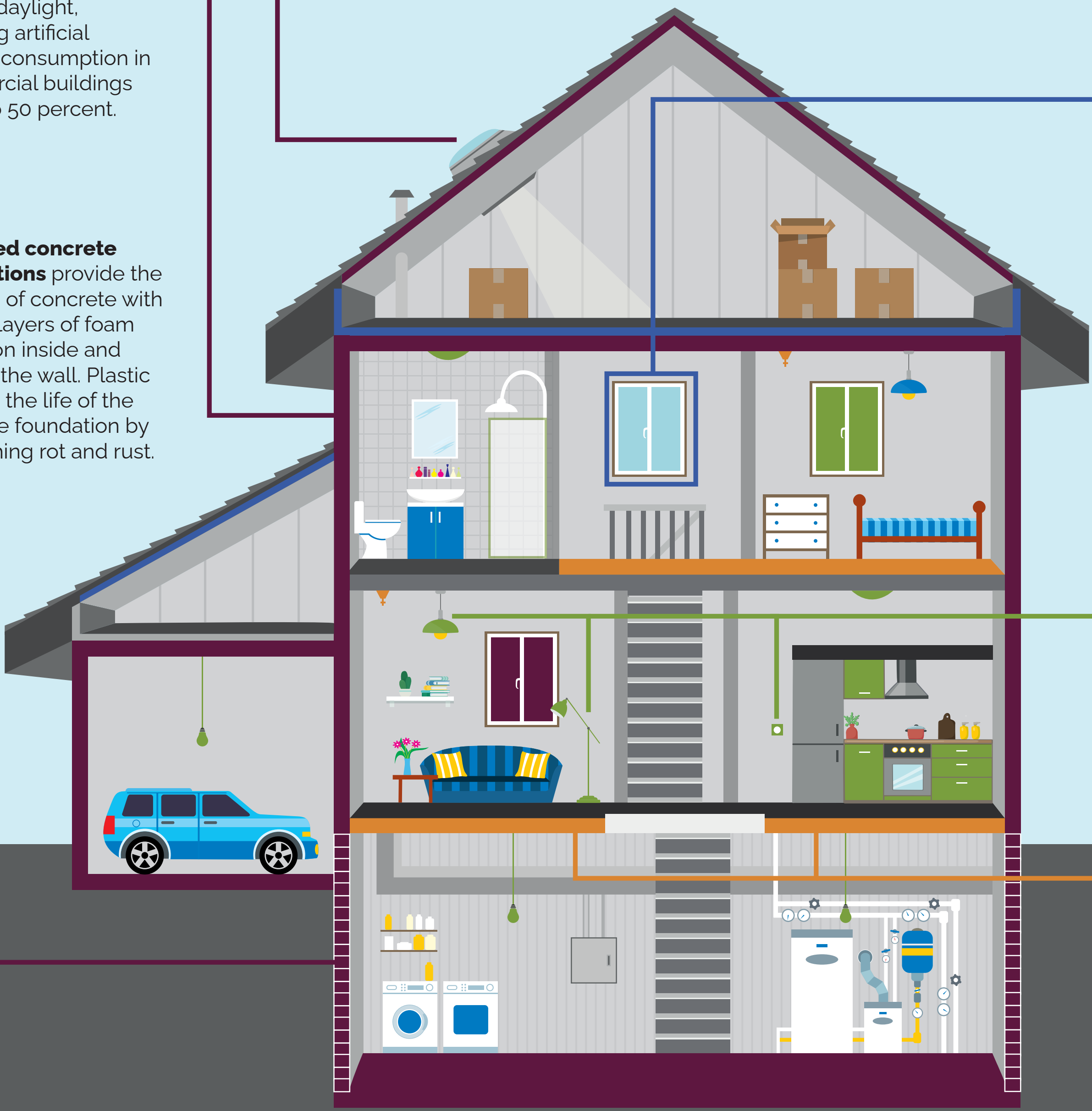
Recycling plastics is a process that involves the conversion of waste plastic into useful materials. The process includes collecting the recyclable plastics, sorting them according to their respective polymers, and then crushed in to smaller parts that can be used to make new plastic components. All thermoplastics have excellent properties for recycling since they can be melted and reformed multiple times without compromising their original properties. Challenges occur when bulks of waste plastic contain different types of plastic or even other types of waste.

ENERGY USE REDUCTIONS

Polycarbonate or acrylic skylight glazing can capture natural daylight, reducing artificial lighting consumption in commercial buildings by up to 50 percent.

Plastic vapor barrier and sealants can reduce the infiltration of outside air into the average home by 10 to 50 percent reducing energy needs.

Insulated concrete foundations provide the benefits of concrete with built-in layers of foam insulation inside and outside the wall. Plastic extends the life of the concrete foundation by diminishing rot and rust.



BUILDING WITH THE POWER OF PLASTICS

Today's plastics can help architects, owner/managers and specifiers to meet sustainability goals for new and retrofit building solutions in commercial, residential and infrastructure construction. Advanced continuous insulation, sealants, windows, doors, siding, flooring, roofing, foundations, decking, and piping made with advanced plastics can dramatically improve energy efficiency, reduce waste and CO_2 emissions and help us to do more with less. This is building with the power of plastics.

CO_2 REDUCTION

- **Vinyl window frames** require three times less energy to manufacture than aluminum window frames.
- **Spray foam (SPF)** roofing systems can reduce the time and labor of old-roof tear-offs, reducing landfill waste and the energy and emissions needed to remove and haul the debris.

MATERIAL USE REDUCTION

- **Polystyrene beads** in concrete reduce weight and improve poured concrete's flexural strength, helping to resist crack propagation.
- **Plastic insulated electrical and communications wiring** can be inherently fire retardant plastic. The durability of plastic electrical compo-nents helps products last a long time.
- **Plastic** can be an effective and continuous air and vapor retarder, reducing material deterioration and structural damage.

WASTE REDUCTION

- **Recycled content in roofing, decking, flooring and carpeting and padding** create material efficiencies and reduce energy use and waste with equal product performance and maintenance

* Savings vary. Find out why in the seller's fact sheet on R-values. Higher R-values mean greater insulating power.

GENERAL PROPERTIES OF THE MOST USED THERMOPLASTICS AND ELASTOMERS IN EXTRUSION

ABS - STYRENE COPOLYMERS ABS/ASA/SAN

Profile property
- 'Universal' plastic
- Glossy
- Good scratch resistance
- Medium rigidity, good impact strength
- Sensitive to solvents
- Temperature resistant up to approx. 90°C (Commodity ABS)
- In-between engineering and commodity thermoplastics

Examples of applications
- Technical parts
- Covers
- Casings
- Toys

HI PS (HIGH IMPACT PS)

Profile property
- Higher impact strength than GP PS
- Less stiffness and hardness than GP PS
- Milky
- Sensitive to solvents
- Good processing
- Temperature resistant up to approx. 70°C

Examples of applications
- Housings
- Packaging

PC-POLYCARBONATE

Profile property
- High transparency (Translucency 80-90%)
- Excellent impact strength, high rigidity
- Resistant to oils, benzenes, fuels, greases
- Not resistant to strong acids/bases
- Weather resistant depending on the formulation
- Temperature resistant up to approx. 125°C

Examples of applications
- Translucent parts
- Optics
- Medical technology
- CDs, DVDs
- Electrical equipment and electronics

PE-HD

Profile property
- Less branched polymer chains, therefore, higher crystallinity and density
- Harder than LDPE but relatively easy to scratch
- High toughness and elongation at break
- Good chemical resistance
- Excellent mechanical workability
- Temperature resistant up to approx. 90°C

Examples of applications
- Plastic lumber
- Pipes
- Coverings
- Reusable water bottles
- Bottles for chemicals
- Coating for wires

PE-LD

Profile property
- Strongly branched polymer chains, therefore, low crystallinity and density
- Soft, feels waxy, easy to scratch
- High toughness and elongation at break
- Good chemical resistance
- Temperature resistant up to approx. 60°C

Examples of applications
- Ziploc bags
- Packaging foam
- General-purpose containers
- Plastic wraps and film
- Playground slides

PET

Profile property
- Crystal-clear, odourless, and tasteless
- Rigidity increasing by stretching
- Good breaking strength
- Temperature resistant up to approx. 80°C
- Correlation to fibre market

Examples of applications
- Textiles
- Bottles
- Foils
- Packaging
- Films

PMMA

Profile property
- Very high transparency
- Reasonable impact resistance
- High hardness (resistant to scratching)
- Sensitive to alcohol and solvents
- Good weather resistance
- Resistant to oils, benzenes, fuels, greases, bases
- Good UV resistance
- Susceptible to stress corrosion cracking
- Temperature resistant up to approx. 90°C

Examples of applications
- Light covers
- Optics
- Medical technology

PP

Profile property
- Harder than HDPE with higher rigidity
- Increased rigidity by compounding with reinforcements (glass fibre, talcum, etc.)
- Good toughness
- Homopolymer becomes brittle in frost
- Good chemical resistance
- Excellent mechanical processing
- Temperature resistant up to approx. 90°C

Examples of applications
- Automotive industry
- Industrial applications
- Consumer goods
- Furniture market

PS - GP-PS (GENERAL PURPOSE PS)

Profile property
- Crystal-clear
- Rigid, stiff, brittle, sensitive against impacts
- Sensitive to solvents
- Good processing
- Temperature resistant up to 75°C
- Foamed as an EPS

Examples of applications
- Foils
- Packaging
- Spectacle frame
- Absorption / Insulation (EPS)

PVC-P (SOFT)

Profile property
- Rubber-like due to plasticiser
- Flame resistant, self-extinguishing
- Excellent weather resistance depending on the formulation and known for good cold resistance
- Temperature resistant up to approx. 50°C

Examples of applications
- Sealing
- Gaskets
- Cables and wires
- Garden hoses
- Imitation leather
- Toys

PVC-U (RIGID)

Profile property
- Impact strength vs stiffness modifiable
- High rigidity
- Flame resistant, self-extinguishing
- Excellent weather resistance depending on the formulation

Examples of applications
- Construction elements
- Water and waste pipes
- Bank cards
- Flooring
- Window frames

TPE

Profile property	Examples of applications
• Rubber-like	• Footwear • Gaskets • Seals • Grips

TPO

Profile property	Examples of applications
• High impact resistance, low density, and good chemical resistance • Toughness and durability • Rigid	• Seals and gaskets • Automotive bumpers and dashboards

TPU

Profile property	Examples of applications
• Resistance to acids, salts, corrosives, bases, fats, and alcohols • High elongation and tensile strength • Excellent abrasion resistance • Low-temperature performance • Excellent mechanical properties combined with a rubber-like elasticity • High transparency • Good oil and grease resistance	• Gaskets • Seals • Mobile Phone cases • Caster wheels • Hoses and tubes • Power tools • Footwear • Sports equipment

TPV

Profile property	Examples of applications
• High temperature resistance • Wide range of hardness's • Resistance to chemicals and weathering • Good recovering characteristics • Flex fatigue resistance • Lightweight • Good colourability	• Automotive seals • Pipe seals • Gasket • Glazing seals • Construction

CASE STORY

DEVELOPING NEW POLYMER SOLUTIONS FOR THE MARINE INDUSTRY

MOTORBOAT MANUFACTURERS AND SHIPBUILDERS HAVE INTEGRATED THE RECENT DEVELOPMENTS IN POLYMER SCIENCE IN ORDER TO BENEFIT FROM NEW INNOVATIVE MATERIALS AND DESIGNS FOR MARINE PROFILES.

A few years ago, nearly every manufacturer in the marine industry used the same standard protective profiles. Rub-rail profiles were not an area the industry used to differentiate itself from the competition. This has all changed.

"Together with the main players in the industry, we saw new possibilities. Why not improve the standard product with known technologies from other industries? Then we realised that almost all manufacturers had a range of wishes and specific requirements for new rub-rail profiles for their leisure boat model ranges," says André Sandberg, Business Area Manager.

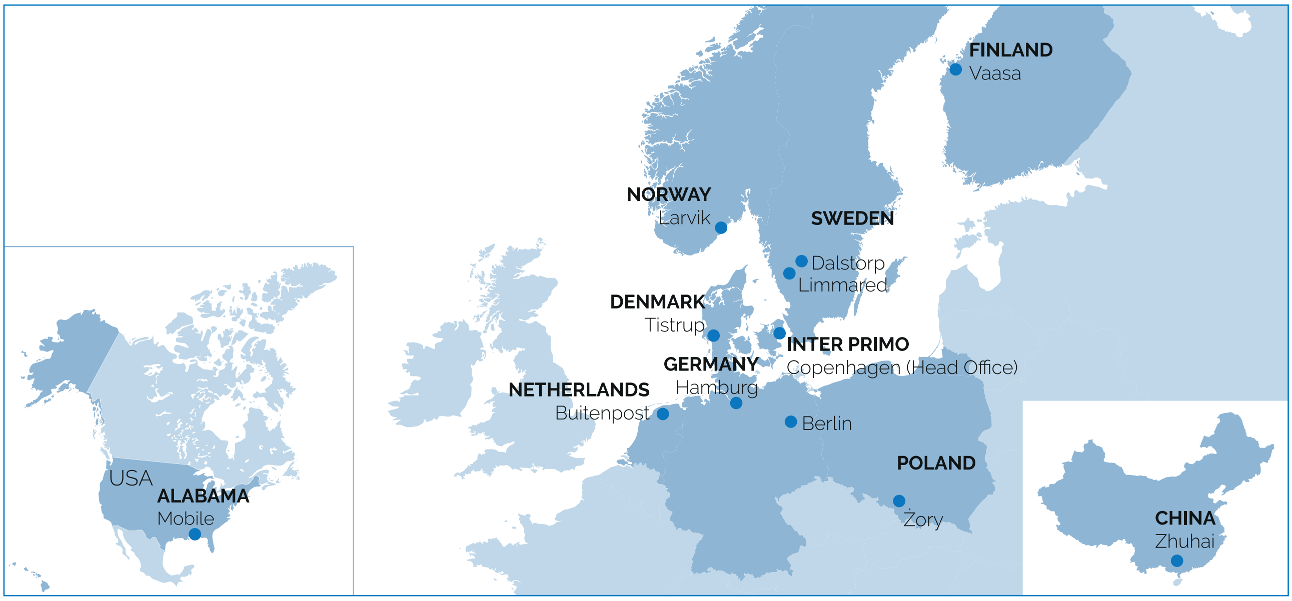
A range of colours and shapes

Primo began to offer different colours for bumper profiles and different shapes instead of the usual rounded, one-size-fits-all profile. This gives the boat and yacht designer greater freedom, and today the standard products are almost replaced by custom solutions.

For instance, the composition of materials is explicitly developed for durability on the sea and to withstand sunlight, saltwater, as well as stability and functionality over an extensive range of temperatures. Moreover, Primo's rub-rail profiles are typically tailored and cut for a specific project, so they are easy to install.

"Now, we have established an entire business area for the marine industry with specialised product lines. Pioneering in this field also means that we have developed special compositions of raw materials optimised for the leisure boat industry," André Sandberg says.

SUBSIDIARIES



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PRIMO GROUP

PRIMO DESIGNS AND MANUFACTURES TOMORROW'S PROFILES TO OPTIMISE PERFORMANCE AND SAVE RESOURCES.

Primo is an international extrusion specialist, supplying a multitude of industries with tailored polymer profile solutions, such as: Building, HVAC, Energy, Lighting, Offshore, Medico, Electronics, Transport and many more. Quality, customer satisfaction, environmental matters and safety are of paramount importance to our operations.

Driven by our care for a better tomorrow and based on our extensive experience, know-how and proven process, we continuously seek to design and extrude the profiles of tomorrow that will optimise performance and save resources. Thanks to the private ownership of Primo, we have the agility, ability, and willingness to invest in the future. We treat our customers as long-term partners and steadily work to improve our footprint.

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