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ENVIRONMENT
& HEALTH

Analysis of Non-chemical Alternatives for IPBC

September 2024

Substance: 3-Iodo-2-propynyl butylcarbamate (IPBC)
CAS RN: 55406-53-6
EC RN: 259-627-5

Prepared for: Eurowindoor association

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1 Summary

Eurowindoor represents European window, door and façade manufacturers, with members of the association predominantly utilising (as downstream users) IPBC (Iodopropynyl butylcarbamate, CAS number: 55406-53-6) for the preservative treatment of wooden windows and doors, construction timbers and furniture in product type 8 (PT8) of the BPR. These products are used in both internal and external building projects across the European Union.

At time of writing, the current IPBC approval in the European Union (EU) is due to expire on 31st July 2025 in PT 8. It is currently classified as a skin sensitiser, and there is significant uncertainty as to its potential to have endocrine effects. With this latter classification in mind, IPBC is currently under assessment as an endocrine disruptor (ED) and is likely to become a Candidate for Substitution (one of the exclusion criteria of the Biocides Product Regulation (BPR)) due to its ED properties for human health and non-target organisms.

According to article 5 of the BPR, should an active substance fulfil the exclusion criteria, it may nevertheless be approved if it is demonstrated that the active substance – in this instance, IPBC – fulfils at least one of the conditions specified by Article 5 (2)(a–c), i.e., negligible risk, indispensability for controlling serious dangers to human or animal health or the environment, or disproportionate societal impact. Of note, Article 5 (d) specifies endocrine disrupting properties as an exclusion criterion. Should IPBC fall within the remit of the exclusion criteria then it will become a candidate for substitution and an analysis of alternatives will be needed. The availability of suitable and sufficient non-chemical alternative substances or technologies is a key consideration in that process and is outlined in this document.

An analysis of alternatives for IPBC and IPBC-based biocidal products in instances where the active substance is included in wood preservative formulations for the treatment timber in UC2 and UC3 situations (UC = use class) will be summarised in a later chapter. A description and explanation of different use classes is outlined in Section 3.1. The work performed in this report will be conducted with the aim of being used in public consultation and will adhere to the European Chemicals Agency (ECHA) guidance information where possible.

The main advantages achieved with using IPBC in wood preservation are:

- Sapstain, mould and fungal decay of timber products (with the exception of white rot fungi) are controlled.
- The resulting preserved wood is colourless, providing improved cosmetics and the option to colour the finished wood.
- Often used in conjunction with other active substances e.g. Propiconazole, Permethrin, Basic copper carbonate.
- Durability of the treated timber is improved.
- Treatment with IPBC does not negatively impact the physical or mechanical properties of the timber.

In addition to the main advantages listed above, the use of IPBC has many benefits when compared with other technologies e.g. cost effectiveness, treatment easily monitored/regulated via XRF, energy consumption is less compared with composite or thermally treated timber.

For timber treatment with IPBC, the consortium provided the following treatment types, and use class situations. These have been grouped according to end use of treated product, application type and use class and are summarised in the Table 1 and 2 below:

Table 1. Use class, timber type, and non-chemical alternatives overview to IPBC

Parameter		IPBC-treated	Non-chemical treated wood alternatives			
			Organowood	Accoya	Thermowood/Abodo/ Brimstone	Kebony
Used for	Decking	x	x	x	X	x
	Cladding	x	x	x	x	x
	Fencing	x	x		x	
	Flooring	x	x	No	x	No
	Windows	x	No	x	x	x
	Doors	x		x	x	x
Protects against	Fungi (white rot, Brown rot, Soft rot)	x	x		x	x

Parameter		IPBC-treated	Non-chemical treated wood alternatives			
			Organowood	Accoya	Thermowood/Abodo/ Brimstone	Kebony
	Insects	x (in conjunction with other active substances e.g. permethrin)	x	x	x	x
	Termites	x (in conjunction with other active substances e.g. permethrin)	Less likely to be attacked by wood-boring insects	Less likely to be attacked by wood-boring insects	Less likely to be attacked by wood-boring insects	Less likely to be attacked by wood-boring insects
Wood(s) used		Pine Spruce Douglas Fir Composite Ash Beech Oak	Pine	New Zealand radiata pine	Ash Pine Ayous Beech Oak	Radiata pine (Oceania) Maple US Southern Yellow Pine
Application method		High pressure Double vacuum Spray Brush Roller	Pressure treatment with sodium silicate	Acetylation under heat, pressure	High heat and steam	Impregnation with furfuryl alcohol under pressure

Parameter	IPBC-treated	Non-chemical treated wood alternatives			
		Organowood	Accoya	Thermowood/Abodo/ Brimstone	Kebony
Certifications	Supply chain able to seek various accreditations such as Nordic Swan etc.	FSC or PEFC certified Documented flame protection	Nordic Swan accredited BREEAM, LEED	Nordic Swan accredited PEFC	FSC certified Nordic Swan certified
Technical issues	IPBC degrades in hot temperatures	Requires maintenance Process only uses Pine wood	Issues with wood availability; issues with supply of acetic anhydride; still requires surface treatment against moulds; decreased MOR and MOE values relative to IPBC	Treated wood burns quickly; reduced flexibiity and strength, not advised to use in ground contact, load-bearing construction, or to protect against termites	Only one manufacturer
Safety issues with chemicals used	Skin sensitiser however use and risk is heavily mitigated along with automated processes and PPE.	Irritating to skin and eye Uses silicones	Flammable, corrosive to skin, acute toxicity (Cat 4) by oral and inhalation routes	None	Acutely toxic by oral, dermal, inhalation, irritant to eye; carcinogenic, toxic after repeated exposure
End of life	Can be recycled and disposed of according to local waste regulations	Can be recycled	Can be recycled	Can be recycled	Can be recycled

Parameter	IPBC-treated	Non-chemical treated wood alternatives			
		Organowood	Accoya	Thermowood/Abodo/ Brimstone	Kebony
In-use maintenance required	Yes, depending upon end-use and decorative coatings	Easy to clean Does not require oiling Gradually fades Brittle	Regular cleaning and maintenance twice yearly	Regular maintenance using wood oil, stain, paint or varnish with UV protection.	Easy to clean Does not require oiling Gradually fades Brittle

Table 2. Use class, timber type, and non-chemical alternatives overview to IPBC

Parameter		IPBC-treated	Alternative materials											
			Thermoset resins	uPVC	Vinyl monomer	Concrete	Aluminium clad timber composite	Glass	Fibre-reinforced plastic/polymer	Fibre-reinforced concrete	Wood-plastic composite	Steel	Bamboo	Mycelium based composites
Used for	Decking	x	Not developed at large scale	No	No	x	No	No	x	x	x	No	x	x
	Cladding	x		x	x	No	No	No	x	x	x	No	No	No
	Fencing	x		No	No	Yes - fence posts	Yes - composite panels with aluminium posts	No	x	x	x	x	x	x
	Flooring	x		Yes- PVC	x	x	No	x	No	x				
	Windows	x		x	x	No	x	x	No	x	x	x	No	No

Parameter		IPBC-treated	Alternative materials											
			Thermoset resins	**uPVC**	**Vinyl monomer**	**Concrete**	**Aluminium clad timber composite**	**Glass**	**Fibre-reinforced plastic/ polymer**	**Fibre-reinforced concrete**	**Wood-plastic composite**	**Steel**	**Bamboo**	**Mycelium based composites**
	Doors	x		x	x	No	x	x	No	x door surrounds	x	x	No	No
Protects against	Fungi (white rot, Brown rot, Soft rot)	x		x	x	x	x	x	x Brown rot, White rot	x	x	x	No	No
	Insects	x (in conjunction with other active substances e.g. permethrin)		x	x	x	x	x	x	x	x	x	No	No
	Termites	x (in conjunction with other active substances e.g. permethrin)		x	x	x	x	x	x	x	x	x	No	No

Parameter	IPBC-treated	Alternative materials											
		Thermoset resins	uPVC	Vinyl monomer	Concrete	Aluminium clad timber composite	Glass	Fibre-reinforced plastic/ polymer	Fibre-reinforced concrete	Wood-plastic composite	Steel	Bamboo	Mycelium based composites
Wood(s) used	Pine Spruce Douglas Fir Composite Ash Beech Oak		-	-	-	composite	-	-	-	composite	-	bamboo	-
Application method	High pressure Double vacuum Spray Brush Roller		-	-	-	-	-	-	-	-	-	-	-
Certifications	Supply chain able to seek various accreditations such as Nordic Swan etc.		FENSA	-	BSI kitemark CE marking	FSC or PEFC certified	-	Fraunhofer FIT	BSI kitemark CE mark	FSC or PEFC certified	AISC certification	FSC certification	-

Technical issues	IPBC degrades in hot temperatures		Shorter service life Different manufacture process Aesthetics Non-biodegradable Environmental burden higher than timber Process uses fossil fuels	Shorter service life Different manufacture process High-production costs Difficult repair process Aesthetics Non-biodegradable	Manufacture process completely different Cosmetically does not meet customer requirements Construction using concrete in place of IPBC-treated wood is much more labour intensive Less cost-effective Relatively brittle, with low tensile strength Long curing time Cracks Non-biodegradable Cannot be used for all end-uses	High up-front costs to consumer Higher production costs Manufacture process completely different Fades over time. Cannot be repainted. Cannot be used for all end-uses required Layers can separate under stress Some composites are not fire resistant Disposal and recycling can be challenging	Higher production costs Manufacture process completely different Cannot be used for all end-uses required Disposal and recycling can be challenging Fragile Less cost-effective Relatively brittle, with low tensile strength Cracks	High up-front costs to consumer Higher production costs Manufacture process completely different Ages with time. Cannot offer the same service life. Cannot be used for all end uses needed. Low shear strength and elasticity Long-term temperature resistance is poor Cosmetically does not meet customer requirements – cannot be painted		Different manufacture process Still requires treatment with wood preservative to prevent decay. Cannot be used for all end uses High up-front costs to consumer Heat sensitive Different final texture and aesthetics to wood. Cannot be painted. Cosmetically does not meet customer requirements. Cannot be painted Recycling difficult UV-degrade The presence of fungal decay and discolorati	Different manufacture process Cannot be used for all end uses e.g. is a poor choice for complex roof designs compared with wood In contact with air/water for long periods, will corrode Susceptible to buckling Higher initial costs/less availability Aesthetics Fire-proofing costs Cosmetically does not meet customer requirements – cannot be painted	Different manufacture process High up-front costs to consumer Cannot be used for all end uses Aesthetics Can be more difficult to work with compared with other types of wood Very hard and dense making it a challenge to cut and shape Poor durability/service life without additional treatment Potentially invasive species Can emit VOCs due to the adhesives used in its manufacture	Low mechanical properties Different manufacture process High water absorption/poor weathering Poor service life Lack of standardised development methods Limited end uses compared with IPBC-treated timber Susceptible to mould growth

										on of wood-plastic composite decking in service has been known for decades (P. I Morris et al., 1998) with composites comprised of 50% or more of wood particles becoming degraded by brown and white rot fungi (P. Laks et al., 2002).			

Parameter	IPBC-treated	Alternative materials											
		Thermoset resins	uPVC	Vinyl monomer	Concrete	Aluminium clad timber composite	Glass	Fibre-reinforced plastic/ polymer	Fibre-reinforced concrete	Wood-plastic composite	Steel	Bamboo	Mycelium based composites
Safety issues with chemicals used	Skin sensitiser however use and risk is heavily mitigated along with automated processes and PPE.		Uses titanium dioxide, calcium carbonate and acrylate in resin mix to produce polyvinyl chloride	Uses ethylene, acetic acid and oxygen to produce polyvinyl acetate	Created using alkaline compounds such as calcium oxide	Uses titanium dioxide, calcium carbonate and acrylate in resin mix to produce polyvinyl chloride Adhesives	Raw materials used in production include ferric oxide, titanium dioxide, zirconium dioxides and chromium oxides	The fibers are usually glass, carbon, aramid, or basalt. Rarely, other fibers such as paper, wood, or asbestos have been used. The polymer is usually epoxy, vinyl ester, or polyester thermosetting plastics, and phenol formaldehyde resins are still in use.	Created using alkaline compounds such as calcium oxide The fibers are usually glass, carbon, aramid, or basalt. Rarely, other fibers such as paper, wood, or asbestos have been used.	Occupational exposure from use and incineration of preservative treated timber. Chemicals used in plastic manufacture	Occupational exposure from coke oven use; ammonium compounds, napthalene, sulphur.	Sodium hydroxide used in the manufacture	Composites chemically treated with formaldehyde and bavistin solutions

Parameter	IPBC-treated	Alternative materials											
		Thermoset resins	uPVC	Vinyl monomer	Concrete	Aluminium clad timber composite	Glass	Fibre-reinforced plastic/ polymer	Fibre-reinforced concrete	Wood-plastic composite	Steel	Bamboo	Mycelium based composites
End of life	Can be recycled and disposed of according to local waste regulations	No	Can be recycled	Can be recycled	Can be recycled	Can be recycled	Can be recycled	Can be recycled	Can be recycled	Can be recycled	Can be recycled	Not easily recycled	Can be recycled
In-use maintenance required	Yes, depending upon end-use and decorative coatings	No	Regular cleaning Should repair be required - difficult and costly.	Regular cleaning Should repair be required - difficult and costly.	Regular cleaning, coating with floor wax and sealer. Repair difficult and can be costly.	Cleaning	Regular cleaning (every 3-6 months). Repair difficult so often looking at replacement	Routine maintenance, cleaning	Regular cleaning, coating with floor wax and sealer. Repair difficult and can be costly.	Regular cleaning, coating with floor wax and sealer. Repair difficult and can be costly.	Can be prone to corrosion/ rust. Top-coat/sealant recommended.	Twice yearly cleaning, and maintenance with wood oil.	Not in large scale production as yet. Maintenance unknown.

2 Aims

At time of writing, the current IPBC approval in the European Union (EU) is due to expire on 31st July 2025 in PT 8, with classification of the substance as a skin sensitiser, and uncertainty as to its classification as an endocrine disruptor. With this latter classification in mind, IPBC is currently under assessment as an endocrine disruptor (ED) and is likely to become a Candidate for Substitution if its ED properties for human health and non-target organisms are proven.

If an active substance meets any of the criteria for substitution listed in Article 10(1) of the BPR, then the evaluating competent authority may identify the substance as a potential candidate for substitution. Should this be the case, ECHA will launch a consultation to collect information on potential alternatives to the substance (in this instance, IPBC) in accordance with article 10(3) of (EU) 528/2012.

In addition to being a candidate for substitution, an active substance might meet the exclusion criteria outlined in article 5(1) of the BPR e.g. carcinogens, mutagens and reproductive toxic substances, endocrine disruptors, persistent, bioaccumulative and toxic and very persistent, very bioaccumulative and very toxic. Should an active substance fulfil the exclusion criteria, it may nevertheless be approved if it is demonstrated that the active substance – in this instance, IPBC – fulfils at least one of the conditions specified by Article 5 (2)(a–c), i.e., negligible risk, indispensability for controlling serious dangers to human or animal health or the environment, or disproportionate societal impact. Article 5 (d) of the BPR specifies endocrine disrupting properties as an exclusion criterion. Should IPBC fall within the remit of the exclusion criteria then it will become a candidate for substitution and an analysis of alternatives will be needed. The availability of suitable and sufficient alternative substances or technologies is a key consideration in that process.

It is the aim of this report to assess the applicability and suitability of the non-chemical alternatives to IPBC in the end-use situations provided by the members of the Eurowindoor association with a view to IPBC's continued use.

The applicants, Eurowindoor apply for continued use of IPBC for its treatment of timber products, paints etc. Section 3 details the use scope.

The aim of this assessment is to robustly assess the technical feasibility of non-chemical alternatives to IPBC that are available at the moment or anticipated during the review period.

3 Scope

3.1 Background

IPBC is a water-soluble preservative used globally in the paints and coatings, wood preservatives, personal care and cosmetics industries and is a member of the carbamate family of biocides. IPBC is used as an antifungal preservative (biocide) and film preservative added to many personal care products, paints and coatings, construction products and cleaning products (NCBI, Nordic Council of Ministers and REACH). The uses of IPBC encompass paints, primers, wood preservatives, lacquers and varnishes, adhesives and binding agents, sealants and fillers, surface treatment products, corrosion inhibitors, lubricants and adhesives – often used in these products at concentrations ranging from 0.1–15 % with the majority below 1 % (AICIS, 2022). Due to its broad scope of uses, IPBC is currently approved under the EU Biocidal Products Regulation (BPR), (EU) 528/2012 for three product types (PT): preservative for products during storage (PT6), wood preservatives (PT8) and working or cutting fluid preservatives (PT13 (ECHA, 2024)).

IPBC is a carbamate ester of 3-iodo-2-propynol, bearing a butyl substituent on the nitrogen atom. In the environment, IPBC biologically degrades to carbamic acid, butyl-, 2-propynyl ester or propargyl butylcarbamate (PBC). Its fungicidal mode of action is alteration of cell membrane permeability in fungi

('Fungicide Resistance Action Committee, FRAC code list 2024', 2024). Further information on the classification of IPBC is provided in Table 3 below.

Members of the Eurowindoor association use IPBC in a variety of situations ranging from wood preservation of windows and doors to prevent blue stain and mould, short-term protection of freshly cut wood from blue stain and mould, construction timbers, non-structural finishing wood e.g. cladding, fencing and decking and in the topcoat or paint of outdoor furniture. Although IPBC is used in a range of product types and across regulatory regimes, this analysis will only include those uses outlined below in Table 4and are applicable to PT8 wood preservatives only. In addition, this review at the request of Eurowindoor does not include the assessment and comparison of the risks associated with potential non-chemical alternatives, technical and economic feasibility, and availability.

Table 3. Information on IPBC

Substance	Intrinsic properties[1]	Date of intention for ED assessment	Latest update to ED assessment
IPBC (3-iodo-2-propyl-butylcarbamate)	Acute Tox. 4 (H302) Eye Dam 1 (H318) Skin Sens. 1 (H317) Acute Tox 3 (H331) STOT RE1 (H372, larynx) Aquatic Acute 1 (H400) Aquatic Chronic 1 (H410) Broad-spectrum fungicide	1st October 2020	24 June 2024

[1] Harmonised classification – Annex VI of Regulation (EC) No 1272/2008 (CLP)

Table 4. Summary of use cases, efficacy, wood species, application method for IPBC-treated wood provided by Eurowindoor members.

Use Case #	Name	Description	Use category	Efficacy	Wood species	Use Class	Solvent	Application method	Compatibility	Insecticide property
1	Windows and doors - Industrial	Industrial manufacturing of wooden windows and doors. Most parts of the production is automatized.	Industrial	Blue stains + mold + wood rot fungi	Pine, Spruce, Fir	UC 2, UC 3.1 and UC 3.2	Waterborne	Flow coating, spray tunnel, dipping and pressure treatment	No corrosion with hardware and screws. No colour modification to topcoat or paint	In scope for relevant countries (e.g. France) Hylotrupes bajalus, termites
2	Windows and doors - Professionals	Manufacturing of wooden windows and doors handcrafted by professionals. Most parts of the production are semi-automated	Professional	Blue stains + mould + wood rot fungi	Pine, Spruce, Fir,	UC 2, UC 3.1 and UC 3.2	Waterborne, solvent borne	Brush, roller, manual dipping, spraying (Applied as pigmented or non pigmented primer and top coat)	No corrosion with hardware and screws. No colour modification to topcoat or paint	In scope for relevant countries (e.g. France)
4	Construction wood – DIY/Consumer use	First application or renovation for example carports, terraces, sidings, cladding, balconies, roof construction etc. applied by amateurs. Decorative coatings with PT 08 approval	DIY and Professional	Blue stains + mould + wood rot fungi	Pine, Spruce, Fir	UC 2, UC 3.1 and UC 3.2	Waterborne, solvent borne	Brush, paint roller (Applied as pigmented or non pigmented primer and/or as top coat)	No corrosion with hardware and screws. No colour modification to topcoat or paint	In scope for relevant countries (e.g. France)

Use Case #	Name	Description	Use category	Efficacy	Wood species	Use Class	Solvent	Application method	Compatibility	Insecticide property
5	Construction wood - Professionals	First application or renovation for example carports, terraces, sidings, cladding, balconies, roof construction etc. applied by professionals. Decorative coatings with PT 08 approval	Professional	Blue stains + mould + wood rot fungi	Pine, Spruce, Fir	UC 2, UC 3.1 and UC 3.2	Waterborne, solvent borne	Brush, roller, manual dipping, spraying (Applied as pigmented or non pigmented primer and/or as top coat)	No corrosion with hardware and screws. No colour modification to topcoat or paint	In scope for relevant countries (e.g. France)
6	Construction Wood - Industrial pressure treatment	Industrial treatment of construction wood. Most parts of the production is automated	Industrial	Blue stains + mould + wood rot fungi	Pine, Spruce, Fir	UC 2, UC 3.1 and UC 3.2	Waterborne	Pressure treatment	No corrosion with hardware and screws	In scope for relevant countries (e.g. France)
7	Construction Wood - Industrial dipping	Industrial treatment of construction timbers usually by dipping	Industrial	Brown rot + mould	Pine, Spruce, Fir	UC 2, UC 3.1 and UC 3.2	Waterborne	Flow coating, spray tunnel, dipping	No corrosion with hardware and screws. No colour modification to topcoat or paint	In scope for relevant countries (e.g. France)
8	Anti-sapstain (Industrial)	Industrial treatment of construction wood against mould and blue stains	Industrial	Blue stains + mould	Pine, Spruce, Fir	Short-term efficacy only	Waterborne	Automated Dipping, Spraying	No corrosion with hardware and screws	In scope for relevant countries (e.g. France)

Use classes are defined by the European Standard EN 335: 2013 (Durability of wood and wood-based products. Use classes: definitions, application to solid wood and wood-based products). This standard defines the 5 use classes that represent different service and service-life situations to which wood and wood-based products can be exposed – helping the user to choose the wood products that meet their end-use requirements and based on the environment the timber is to be used. The products life span and the structural safety of the application could be compromised if the right level of treatment is not used. According to EN 335: 2013 use classes for timbers are defined as follows (Table 5).

Table 5. EN 335. 2013 use classes for timbers

Use Class	Use	Examples	Biological hazards	Service life
1 Internal: permanently dry	Internal use, dry. Moisture content 20% maximum	furniture, parquet flooring, panelling, interior fittings.	Wood destroying insects and termites	60 years
2 Internal: occasional risk of wetting	Internal use, moisture content occasionally >20%	tiling battens, framing and roof timbers, internal floor joists, sole plates	Wood-destroying insects and termites Wood decaying fungi tends to be limited to the surface of the wood due to occasional wetting	60 years
3.1 (Coated) External coated: above ground. Exposed to frequent wetting	External use, no ground contact, protected, moisture content frequently >20%	windows and other exterior woodwork, decking, cladding, gates	Fungi and mould where the moisture >20% Wood destroying insects and termites	15 - 30 years depending upon treatment retention
3.2 (uncoated) External uncoated: above ground. Exposed to frequent wetting	External use, no ground contact, not covered, moisture content frequently >20%	fence rails and boards, agricultural timbers not in soil	Fungi and mould where the moisture >20% Wood destroying insects and termites	15 - 30 years depending upon treatment retention
4.1 In contact with ground. Permanently exposed to wetting and/or providing exterior structural support	External, with ground contact, moisture content permanently >20%	garden fence posts, retaining walls, playground equipment, decking posts	Fungi and mould where the moisture >20% Wood-destroying insects and termites	15 - 30 years depending upon treatment retention
4.2 In contact with ground or fresh water. Permanently exposed to wetting and/or providing exterior structural support	External use, heavy duty with ground contact, with water contact, moisture content permanently >20%	beams, poles, water body constructions, poles supporting overhead lines, sleepers	Fungi and mould where the moisture >20% Wood-destroying insects and termites	15 - 30 years depending upon treatment retention
5	Use in salt water, moisture content permanently >20%	marine piling, piers and jetties	Marine borers & fungal decay	10 years

In addition, making it possible to use wood in inhospitable environments, preservative treatment provides natural wood with additional durability – this is based upon the loading and penetration of the preservative tailored to meet the desired use class, service life and end-use. In wood protection there are mainly two methods to preserve wood: wood preservation (chemical protection) and wood modification (modifying protection). While chemical protection is performed with preservatives, modification is performed via activation of chemical components present in wood cell walls using high temperatures. In wood preservation, traditional wood preservatives and methods employ chemicals that are considered toxic and can adversely affect human health and environment.

To achieve the various levels of loading and retention, there are various types of treatment process ranging from high-pressure vacuum, double-vacuum low pressure, fully automated and manual dipping, flow-coat, along with painting with both bush and roller.

High-pressure vacuum impregnation enables the preservative to penetrate deep into the wood with the help of vacuum and pressure providing an assured long-term protection against all forms of wood decay and insect attack (this treatment tends to be used for Use class 3 and above applications). With the double-vacuum low pressure process, the wood is first subjected to a short and relatively weak initial vacuum, after which the treatment vessel is flooded with preservative solution and reduced to normal pressure. Preservative intake is greatly reduced compared to vacuum pressure process and provides an envelope of durability/treatment around the timber.

The non-pressure automated and manual dipping process enables the preservative to penetrate into the wood through capillary action and diffusion due to the hydrostatic pressure of the impregnation solution in the impregnation vessel, or due to temperature differences in the impregnation fluids (LABC, 2024).

3.2 Use scope

In comparison to other building materials, wood has numerous advantages, such as suitable thermal insulation, high strength to weight ratio, easy machinability, and attractive aesthetics. Wood as a valuable building and industrial material requires protection due to its biodegradable properties especially when it is submitted to harsh conditions. Wood durability can be improved through the use of wood preservatives and modification systems. Wood protection should be safe to use, efficient, cost-effective, permanent, and should not corrode metal or degrade wood components.

As mentioned in the previous section, the members of the Eurowindoor associations product portfolio contains a wide range of construction, end-use and decorative products within the PT8 (wood preservatives) category. The diversified portfolio relies on treating and manufacture of components with various dimensions and end-uses. The ability to offer these services to long-standing, new customers or members of the supply chain is essential to the various companies' existence and ensures competitiveness.

Wood and timber items are susceptible to degradation when subjected to factors such as moisture, temperature extremes, microorganisms, UV radiation, and harsh chemicals, leading to potential safety risks for residents and financial setbacks. The longevity of wood-based products is largely influenced by the inherent durability of the wood, its design, and the adopted protective and preservative measures. With appropriate treatment, wood can endure substantially, as demonstrated by ancient structures, practical and decorative artifacts, musical instruments, and various wooden goods.

Final products within the Eurowindoor product portfolio share common requirements related to the key functionalities achieved with IPBC treatment, with IPBC-product retention, species of timber used, method of application and end-use dictating the overall Use Class (UC) and service life of the IPBC-treated wood product.

For simplicity, these products have been divided into 8 separate use cases as outlined in Table 6 which have then been further grouped into 3 over-arching end-uses, treatment type, use class and users e.g. Industrial, professional or consumer. Please see Table 6 below.

Table 6. Overview summary of end-use, users, use class and treatment type of IPBC-based preservatives treatments used by Eurowindoor members

End-use	Users	Use Class	Treatment type
Windows & Doors	Industrial	UC2, UC3.1, UC3.2	Flow coating, spray tunnel, dipping and pressure treatment
	Professional	UC2, UC3.1, UC3.2	Brush, roller, manual dipping, spraying
Construction	Industrial	UC2, UC3.1, UC3.2	Pressure treatment, flow-coat, automated dipping
	Professional	UC2, UC3.1, UC3.2	Brush, roller, manual dipping, spraying
	Consumer	UC2, UC3.1, UC3.2	Brush, roller
Anti-sapstain	Industrial	Short-term protection	Automated dipping, manual dipping, spraying

4 Key functionalities provided by IPBC-treated timber

A set of key performance requirements (key functionalities) that are fulfilled by the use of IPBC can be found in Table 77 below. The key process functionalities described in this section refer to the general minimum requirements related to the production process (e.g. process treatment time, service life of end product etc) that must be fulfilled by a non-chemical alternative and will therefore, be used in the assessment of short-listed alternatives (please see Section 7).
For example, the rich starch contained in wood provides the necessary nutrients for the growth and reproduction of mould and stain fungi ((Scurlock, Dayton and Hames, 2000) and (Yang *et al.*, 2019) (Dales *et al.*, 1991). Mould and blue stain fungi may reduce the quality of wood and bamboo products, especially in exterior applications. In addition, the presence of mould spores in the air may cause allergic reactions, asthma or infections (Matan and Matan, 2008) (Mousavi *et al.*, 2016) (Matan, et al. 2008, Mousavi et al. 2016 and Dales et al, 1991). The addition of biocidal agents in the production of wood-based products is a common treatment method, which can effectively prevent infection by mould and stain fungi, thereby extending their service life (Lee *et al.*, 2022). Due to IPBCs strong inhibitory effect on various fungi and algae such as mould, stain fungi e.g. blue stain, and yeast (Han *et al.*, 2022) it has been widely used in the protection of wood, bamboo and composite materials for mould and stain fungi control since the 1980s (Hansen, 1988) (Zhang *et al.*, 2020). IPBC is one of the two most widely used Biocidal Products Regulations–approved fungicides (Vallières, Alexander and Avery, 2021). The antifungal mechanism of IPBC is still unclear, but it is considered that it may be related to the iodo group at the end of the molecular chain. Some IPBC-based preservative formulations yield an odourless, treated product that can be painted if dried after treatment – this is a key aspect for numerous members of the Eurowindoor association and is in response to consumer demand.

Developing new biocides involves high costs and takes time given the regulatory hurdles, which does not encourage such investment. An alternative route for the industry could be development of new blends of existing biocides or the consideration of alternative materials. For example, the combination of IPBC and 2-n-octyl-4-isothiazolin-3-ones (OIT) is used in current commercial preservatives, for water-borne dry film interior coatings (Vallières, Alexander and Avery, 2021). The review and assessment of non-chemicals alternatives to IPBC-treated timber will be reviewed in Section 7.

4.1 Wood treatment specification/desired service life

The level of preservative treatment required for the end use of the timber, depends not only on the risk of attack but also on the expected life of the wood in service. Table 77 below outlines the WPA's recommendations for treatment levels in order to achieve the desired service lives of 15, 30 and 60 years that would be expected depending upon end-use of the product.

Table 77. Overview of service life and timber type. Sourced from (WPA, 2021)

Component	Use class	Desired service life (years)					
		15		30		60	
		Permeable wood	Resistant wood	Permeable wood	Resistant wood	Permeable wood	Resistant wood
Internal joinery	1	No treatment required					
Roof timber (dry)	1	60 year service life is always required				NP1	NP1
Roof timbers (dry) insects	1	60 year service life is always required				NP1	NP1
Roof timbers (risk of wetting) + insects	2	60 year service life is always required				NP1	NP1
External walls (sawn wood)	2	60 year service life is always required				NP1	NP1
Sole plates above damp proof coursing	2	60 year service life is always required				NP2	NP2
External joinery (coated) e.g. cladding, facias	3c	NP2		NP2		-	-
Fence rails, deck boards, external joinery	3u	NP5		NP5		-	-
Fence and deck posts, deck substructures, raised beds	4	NP5		NP6		-	-
Poles and fence posts	4	NP5	NP4	NP5		-	-
Sleepers	4	NP5		NP6		-	-
Wood in fresh water	4	NP6		NP6		-	-
Wood in salt water	5	NP6		-	-	-	-

Service life within a use class relies on many factors; for preservative treated wood, these include the preservative efficacy and quality of the treatment. Other important factors include wood quality (e.g.

sapwood content), the end use of the treated wood and subsequent design, quality of construction, quality and regularity of maintenance and exposure conditions in which the IPBC-treated wood is used.

4.2 Treatment specification

In order to achieve the service life and use class specification for the end-use of the IPBC-treated wood, preservative penetration and retention values for treatment are recommended based upon a combination of process control parameters specific to each treatment installation accompanied by chemical confirmatory analysis. The required retention is the amount of preservative to be found in the analytical zone as defined by the penetration class (Figure 1) – NP1 commonly referring to surface treatment such as anti-sapstain/blue stain prevention processes, and NP5 for pressure treatment of timber. It should be noted that the treatability of wood varies between species (WPA, 2021).

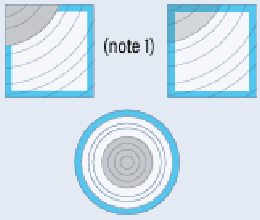
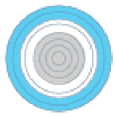
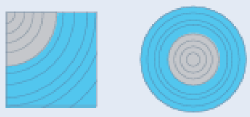
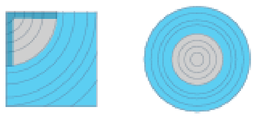
PENETRATION CLASS	PENETRATION REQUIREMENTS (note 1)	ANALYTICAL ZONE	TYPICAL COMPONENT PENETRATION (note 4)
NP1	None	3mm from lateral faces	
NP2	Minimum 3mm lateral into sapwood	3mm lateral into sapwood	 (note 1)
NP3	Minimum 6mm lateral into sapwood	6mm lateral into sapwood	
NP4 (note 2)	Minimum 25mm	25mm lateral into sapwood	
NP5	Full sapwood	Full sapwood	
NP6 (note 3)	Full sapwood and minimum 6mm into exposed heartwood	Full sapwood and minimum 6mm into exposed heartwood	

Figure 1. Overview of penetration class of timber and level of treatment (WPA, 2021)

4.3 Treatment types and process

The European performance standard for wood preservatives, BS EN 599-1: 2013 Efficacy of preventive wood preservatives as determined by biological tests, provides specification according to use class, defines the biological tests and the results needed to demonstrate preservative effectiveness. In addition, BS EN 351-1: 2023 Durability of wood and wood-based products sets out a framework for specifying preservative treatment based on a combination of penetration and retention of preservative (as outlined above).

There are a number of different processes for applying/treating wood with preservatives largely depending upon the wood type and the intended use, use class and service life.
There are two main processes for the preservative timber treatment: low pressure (or double vacuum) and high-pressure. Low pressure treatments are typically for timbers specified for use classes 1-3 and coated. The predominantly water-based treatment provides an effective 'envelope' protection around the timber. Both these, and the other methods of treatment utilised by the members of the Eurowindoor association are outlined in more detail in Section 4.

4.3.1 Preservative application on timber surface

4.3.1.1 Brushing

This timber preservation method involves the use of a brush to manually apply preservatives to the wood surface. All sides of the timber are properly coated with the preservative.

4.3.1.2 Dipping

The piece(s) of timber is dipped in a container filled with a preservative – in this case containing IPBC – and left for a limited period of time to allow the preservative to fully cover the surface of the timber. This can be both a manual and automated process.

4.3.1.3 Spraying

A sprayer machine is used to spray the preservative solution on the wood surface. It is quicker and more efficient than brushing and again, can be fully automated.

4.3.1.4 Flow-coat

Flow-coat is an automated method used to apply liquid coatings, wood preservatives, primers and intermediate coats on wooden components, when both assembled or as single parts. The coating process involves a liquid coating poured/sprayed onto wood, with the coating flowing under controlled gravity (and due to the viscosity of the coating) over the timber. Excess coating is collected, filtered and mixed with new coating and replenishing solvent for recycling, making the process more efficient and reducing waste. Its particularly useful for coating complex shapes and ensuring an even coating without much manual labour.

4.3.2 Penetrating preservative application

A penetrating process, one which includes features or procedures intended to overcome the natural resistance of wood to penetration by a wood preservative in its ready for use form, is required.
Process parameters must be selected to achieve the required penetration and retention requirements. Processes (typically involving requirements for wood moisture content, preservative solution concentration and vacuum and pressure phases) are not defined in specifications based on penetration and retention of a preservative. The treatment cycles and concentration of preservative used for treatment will vary depending upon the species being treated, the desired service life and the Use Class. Generally speaking, there is an increased biological risk of wood deterioration the higher the Use Class number and the longer the service life. In such cases, more severe treatment cycles which result in increased penetration are frequently necessary to meet these more demanding requirements, often in conjunction with higher preservative retention.
Because of this high-pressure treatment is particularly effective for use in use class 3 and 4 applications, especially for in ground contact as higher levels of protection can be achieved.

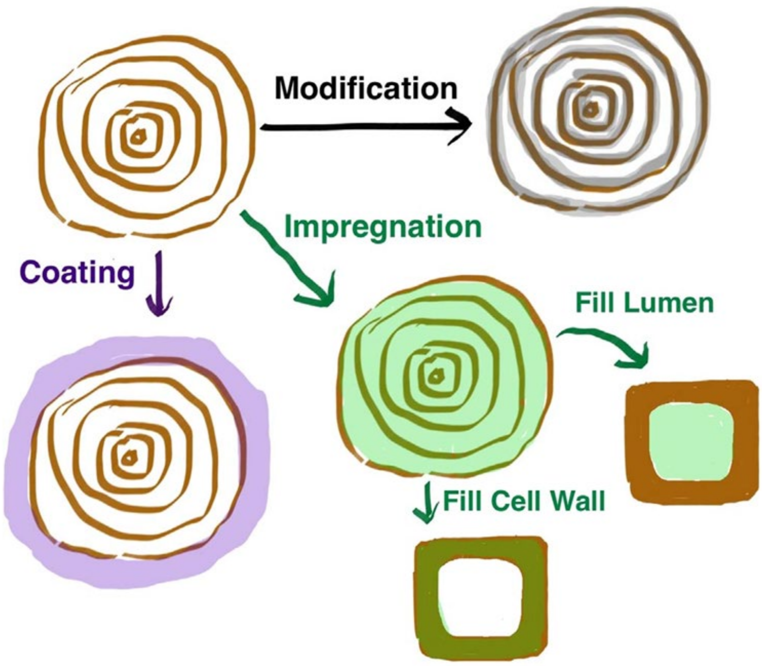


Figure 2: Illustration of different wood treatments. Wood treatments normally use one of three strategies: modification of the cell wall, impregnation, and coating. ((Ramage *et al.*, 2017)

4.3.2.1 Vacuum-pressure impregnation

This is a process for the impregnation of permeable wood with preservative. The wood must have a moisture content <30% to be ready for treatment. Largely the process can be summarised into three stages: initial vacuum (where air is removed from both the treatment vessel and the wood), flooding of the vessel under vacuum with preservative (the pressure forces the solution deep in the wood under high pressure) and lastly, the final vacuum (ensuring that the wood can be removed from the treatment plant without dripping).

Of note, wood species are very different in their permeability levels. This means that longer vacuums and pressure phases must be used for spruce than for pine.

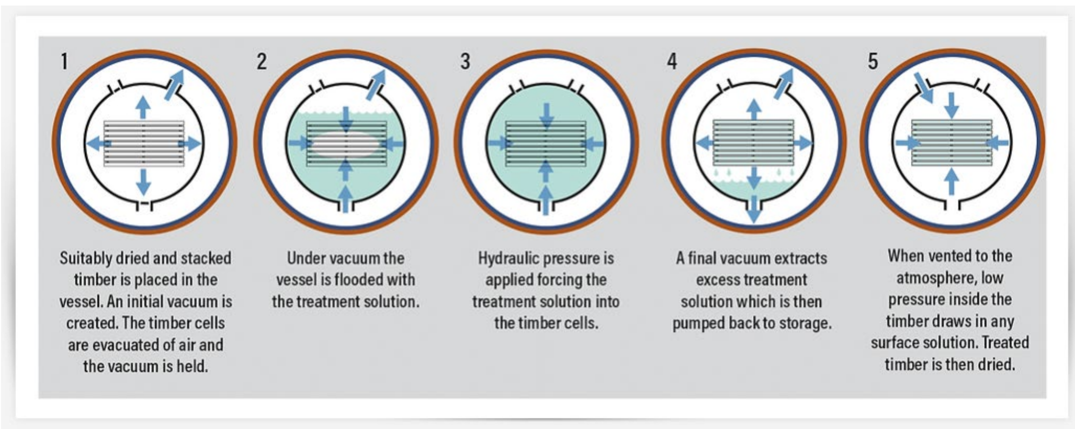


Figure 3: Illustration of the basics of the vacuum pressure process (WPA, 2021).

4.3.2.2 Double vacuum process

In this low-pressure process, the wood is first subjected to a short and relatively weak initial vacuum, after which the treatment vessel is flooded with preservative solution and reduced to normal pressure. Preservative intake is therefore greatly reduced compared to the vacuum pressure process. In the final vacuum, excess solution is removed to give the wood a relatively "dry" final surface.
Though exclusively solvent-based wood preservatives used to be used in this process, there has recently been an increase in the use of water-borne preservatives to reduce pollution caused by solvents.
This process is particularly used for the impregnation of dry timbers that must retain dimensional accuracy for use in use class 3 as windows and door frames etc. In addition, construction timber, cladding, wooden balconies etc are also treated using the double vacuum process.

4.4 Prevention of sapstain/bluestain, fungal and insect attack

In terms of both its physical and chemical properties, wood is an exceptionally difficult substrate to degrade. One of the principal reasons is that wood contains very low levels of nitrogen, which is needed to produce the enzymes that degrade the main structural polymers of wood - cellulose (about 40-50% of the dry weight of wood), hemicelluloses (25-40%) and lignin (20-35%). The lignin component also presents a barrier to wood decay because lignin is a complex aromatic polymer that encrusts the cell walls, preventing access of enzymes to the more easily degradable cellulose and hemicelluloses.
There are three types of wood rot that treatment with preservatives such as IPBC protect against: soft rot fungi, brown rot fungi and white rot fungi.

Soft-rot fungi grow on wood in damp environments. They are the characteristic decay fungi of fence posts, telegraph poles, wooden window frames, the timbers of cooling towers, and wood in estuarine or marine environments. They have a relatively simple mode of attack on wood, Their hyphae grow in the lumen of individual woody cells, usually after entering through a 'pit' (depression) in the wall. Then they produce fine penetration branches that grow through the thin, lignin-coated S3 layer of the wall, to gain access to the thick, cellulose-rich S2 layer. When the penetration hyphae find a longitudinal plane of weakness in the S2 layer, they produce broader T-shaped hyphae which grow along the plane of weakness and secrete cellulase enzymes. The diffusion of these enzymes creates a characteristic pattern of decay, seen as rhomboidal cavities within the cell wall. These persist even when the fungi have died, leaving the characteristic 'signature' of a soft-rot fungus. The soft-rot fungi have little or no effect on lignin, which remains more or less intact. All the soft-rot fungi need relatively high nitrogen levels for wood decay, typically about 1% nitrogen content in the wood. If this is unavailable in the wood itself, then nitrogen can be recruited from the environment, such as the soil at the bases of fence posts, etc.

The fungi that cause soft rots include several Ascomycota and mitosporic species, such as Chaetomium and Ceratocystis in terrestrial environments and species of Lulworthia, Halosphaeria and Pleospora in marine and estuarine environments.(Deacon, 2024). Brown-rot fungi are predominantly members of the Basidiomycota, including common species such as *Schizophyllum commune*, *Fomes fomentarius* (the 'hoof fungus' of Scottish birch woods; and the 'dry-rot fungus', *Serpula lacrymans*. Many of the brown-rot fungi produce bracket-shaped fruitbodies on the trunks of dead trees, but the characteristic feature of these fungi is that the decaying wood is brown and shows brick-like cracking – a result of the uneven pattern of decay, causing the wood to split along lines of weakness. The term 'brown rot' refers to the characteristic colour of the decayed wood, because most of the cellulose and hemicelluloses are degraded, leaving the lignin more or less intact as a brown, chemically modified framework.

White-rot fungi are more numerous than brown-rot fungi and include both Ascoymta such as *Xylaria* spp, and Basidiomycota e.g. *Coriolus versicolor* (also called *Trametes versicolor*). This latter species is commonly used in testing standards due to its ubiquitous nature and ability to degrade wood particularly in warm to hot temperatures. The most remarkable feature of white-rot fungi such as Coriolus spp. is their ability to completely degrade lignin – the only known organisms able to do this. Lignin is a complex polymer composed of three types of phenyl-propane unit (six-carbon rings with three-carbon side chains) bonded to one another in at least 12 different ways. If lignin were to be degraded by conventional means it would require a multitude of enzymes. Instead, lignin is degraded by an oxidative process. The details of this are complex, but essentially the white-rot fungi produce only a few enzymes (lignin peroxidase, manganese peroxidase, H2O2-generating enzymes, and laccase) and these generate strong oxidants, which virtually "combust" the lignin framework (Kirk & Farrell, 1987).

Lumber from virtually all wood species, both freshly sawn and kiln dried, is susceptible to discolourations as a result of microbial and/or non-microbial factors. Previous research has indicated that a number of factors, including wood species, can greatly influence extent of mould growth on wood substrates (Gobakken and Lebow, 2010) and (Lie *et al.*, 2019). The most prevalent fungi in stored logs and lumber are those which mainly affect the sapwood with the resulting damage called 'sapstain'. Blue stain is probably the most common of these, and is causes objectionable discoloration and darkening of the wood as the name suggests (Cassens, 1991).

Blue stain attack starts from the sapwood towards the heartwood. In a study carried out by Sofiaturizkiyah et al, (2023) comparing mould and blue stain variation among different species of wood, in the first week, pine, rubber, and jabon already demonstrated signs of blue stains on the sapwood and heartwood. While in sengon and gmelina, the heartwood was not attacked by blue stain until the sixth week. This is because sapwood has cells that are still alive and have higher moisture content than heartwood. The high moisture content of wood is optimal for fungal growth. In addition, sapwood contains living cells and food storage such as starch. The growth of blue stain is highly dependent on the availability of water and nutrients in the wood. Wood must contain enough food storage, free water, and oxygen for mycelium growth (Sofiaturizkiyah and Priadi, 2023).

Wood with durability class IV-V is susceptible to attack by wood destroying organisms, including wood staining fungi. Wood with high permeability, such as pine wood, is more susceptible to fungi attack because it allows the fungi to grow well (Agussalim, 2018).

Discoloration due to fungal attacks is a problem for using wood as a raw material for furniture, especially if it wants to display the natural colours and patterns of wood. The economic losses caused by fungal attacks in the United States and Finland each year reach 150 and 570 billion rupiahs [(Ţura, Wasser and Zmitrovich, 2018). Meanwhile, losses caused by blue stain attacks on rubber wood in Indonesia reach 220 billion rupiahs annually (Sofiaturizkiyah and Priadi, 2023)

In several studies, it was reported that different wood species (and different softwoods and hardwoods respectively) vary in their susceptibility to blue stain and fungal attack. For instance, Kasim et al., (2005) discovered that pine and rubber have higher starch content, especially in the sapwood than other hardwood varieties. Starch is an important energy reserve for plants, which is stored in the parenchyma cells. Hardwoods tend to possess high content of tannins and other extractives, making them less susceptible to fungal stain attacks (Sofiaturizkiyah and Priadi, 2023) but not immune from either blue stain or wood rotting fungi.

Anti-sapstain/blue stain is a product which is used to protect timber against sapstain (also referred to as blue stain). Although these discolourations caused by these fungi mainly result in cosmetic, surface damage it is rarely acceptable to the consumer. Timber discolouration often results in downgrade and a loss in revenue (Sidhu, 2011). Dip treatment is a common method of applying anti-sapstain products to timber in bulk.

Discolorations on processed timber are generally prevented by either kiln drying the wood down to low moisture contents (below 19%) that do not support fungal growth or by surface application of chemicals that inhibit chemical and biological activity such as treatment with IPBC. Although kiln drying wood does remove one of the main fungal growth requirements, water, the timber will tend to discolour if it gets rewetted during storage and/or transportation.

The risk of infection by microorganisms is the highest when the conditions are warm and humid. Once the discoloration in the log is initiated it cannot be reversed with any type of post treatment. The lumber produced from the logs should be treated with anti-sapstain chemicals within 24 hours, otherwise many fungi may penetrate the wood beyond the reach of the chemicals during the anti-sapstain treatment. Wood discolorations that are a result of fungal infection can be divided into microbial and non-microbial, depending on their causes. The microbial discolorations are as a result of sapstain fungi, mould fungi and incipient decay. The non-microbial discolorations are due to many factors including: photochemical, biochemical, chemical and brown stain (Kreber, 1994).

5 Key process functionalities

The members of the Eurowindoor association have identified common minimum requirements (for both the treatment process and the end product) which must be fulfilled by an alternative to be considered as a technically feasible substitute of IPBC-treated timber. These requirements are outlined in Table 8 (key process functionalities) and Table 9 (key product functionalities) and are applied for the assessment of the alternative (please see Section 7).

Table 8. Key process requirements outlined by Eurowindoor members

Key process functionalities	Short description	Minimum requirement (quantitative/qualitative)
Process reliability and reproducibility	Treatment/coating/painting process must be reliable (that is achieve desired preservative retention) to ensure service life requirements are met for the end product.	Service life requirements (depending upon use class) are met for the end product. Non-chemical alternatives need to be able to offer similar downstream processes e.g. dipping, painting, flow-coat etc
Substrate compatibility	The preservative treatment/coating process must be compatible with a variety of wood types and applicable to various sizes of components.	Non-chemical alternatives to IPBC need to match the wood products currently treated with IPBC-based preservatives, coating and paints in terms of longevity, compatiblity, service life, cosmetic appearance, and ability to paint/re-coat. Alternatives need to be economically equivalent to current IPBC-treatments.
Preparation	The preparation of the alternative must be compatible with current processes. For example, high-pressure vacuum impregnation process or automated dipping.	Alternatives to IPBC-treated timber need to offer similar if not the same process timelines, preparation and end properties.

Key process functionalities	Short description	Minimum requirement (quantitative/qualitative)
Process handling/Treatment	The treatment of the alternative must be compatible with current processes. For example, high-pressure vacuum impregnation process or automated dipping. Alternatives also need to be compatible with both high-throughput and volume processes in addition to lower volume processes such as consumer/professional use e.g. painting/rolling. Treatment times need to be comparable to those of current processes. Ranging from hours for pressure impregnation to high-volume flow-coat applications.	Supply chain needs to meet equivalent costs. Similar ease of handling. Scaling of alternative process needs to be considered/met.
Post-treatment processes	E.g. painting to change colour, flow coat etc Drying water or solvent based preservative treated timber	Must be compatible with down-stream processing, transport, end-use cosmetic and service life requirements.
Compatibility with other materials	Compatibility with adhesives, sealants, floor coverings, surface finishes, metal fasteners and fittings	
Service life	The end product must meet service life requirements as specified.	Meet or exceed both service life and fungal, blue stain (cosmetic) resistance requirements.

5.1 Production process and controls

Assessment and verification of constancy of performance (AVCP) is the phrase used in European Standards to describe procedures for declaring that a material conforms to a relevant specification. Compliance is achieved by meeting these retention and penetration requirements (in the case of penetration to an acceptable quality level) which involves a combination of process control parameters specific to each wood treatment installation with confirmatory chemical analysis on a mutually agreed basis.

There are different levels of AVCP ranging from a supplier's declaration to a full third-party assessment and validation. Note some older European standards use the term 'Attestation of Conformity'. Where a treater operates a quality management system which complies with BS EN ISO 9001 Quality Management Systems and can demonstrate that his process reliably achieves the requirements of the specification, analysis of each batch of wood is not necessary. Once a pattern of consistent specification compliance has been established, (known as the safe relationship), chemical analysis to demonstrate continuing compliance should be undertaken at 6 monthly intervals.

This process is used under the WPA Benchmark Approved Treater scheme. Individual treated wood products certificated under the scheme are verified as being compliant with this code of practice - for either 15 or 30 years desired service life. Details of this and other quality schemes operated by the WPA are at https://www.thewpa.org.uk/quality-schemes. Where a treater does not operate such a Quality Management System, specifiers may require analysis of each batch treated.

Unless otherwise required by the customer or specifier a batch should be considered to comply with specification if the requirements of BS EN 351-2 are met. When determining whether the penetration requirements appearing in Tables 5 and 6 have been met, some evidence of penetration at the limit of the penetration zone must be found. Unless acceptable quality levels (AQL) have been agreed between the supplier and customer, those levels given in BS EN 351-1 will apply (10% AQL for permeable species and round resistant species; 25% AQL for sawn resistant species).

The number of samples selected should be in accordance with Inspection level S3 (BS EN 351-2). Sampling units shall be selected from a charge immediately after appropriate post-treatment conditioning. As several sampling procedures are destructive, arrangements should be made to include additional material in a batch to be included for sampling purposes.

5.1.1 **Post-treatment processes**

5.1.1.1 Drying treated wood

a) Water based preservatives. High pressure impregnation with water-containing preservatives increases the moisture content of wood. After treatment this needs to be reduced to a level suitable for the end use of the wood. Drying may be accelerated by open stickering with through ventilation, by an increase in temperature, or by use of other means such as kiln drying. Low pressure impregnation with water-containing preservatives will raise moisture levels only in a superficial outer zone and this is normally fully reversible by air drying within a short time.

However, IPBC is a thermally unstable compound that may be decomposed under high-temperatures (Freeman, 2008). Thermal processing such as wood drying or hot pressing of boards during wood processing might decompose IPBC and reduce its final antifungal activity (Klement *et al.*, 2021) (Han *et al.*, 2022).

b) Organic solvent based preservatives The moisture content is not increased with treatments using organic solvent preservatives. The solvents evaporate quite quickly providing there is adequate ventilation and good airflow. Most treated wood can be used within 2 to 7 days of treatment depending on the uptake of preservative and the prevailing conditions. Occasionally a pack of treated wood will contain some pieces which have pockets of abnormally permeable sapwood.
Although undetectable before treatment, after treatment these can be seen as dark-coloured streaks. Such pieces, when identified, should be removed from the pack for prolonged drying before gluing, painting or installation.

6 Key product functionalities

The key product functionalities reflect the performance requirements of the resulting product e.g. service life, surface staining, wood rotting fungi etc required for IPBC-treated timber and thus the specifications needed for a non-chemical alternative to meet. A list of key product functionalities achieved by treating timber with IPBC- containing preservative is presented in Table 9 where they are further divided into two broader categories: core functionalities and product/customer-specific functionalities. A potential non-chemical alternative must fulfil all key product functionalities listed below in order to be considered a technically feasible substitute to IPBC-based preservation.

Table 9. Overview of key product functionalities of treating wood with IPBC-containing preservative

Type	Key product functionality	Technical Quantitative/qualitative minimum requirement	Test method
Core functionality	Anti-sapstain/ blue stain Anti-mould	Wood-staining fungi, in particular blue stain, attack the wood very soon after cutting and lead to an irreversible reduction in the wood's value. Fungal spores spread the infestation and can be a health risk. Treatment process would need to be applicable to the short-term anti-sapstain/blue stain (Aureobasidium pullulans, Sydowia pithyophilia) and mould (Sclerotinia, white-rot) protection of freshly cut wood as well as more long-term treatments such as pressure impregnation. (See below on service life). Users would need to include consumer (DIY), professional and industrial. Treatments would need to be compatible with current processes including types of preservative e.g. waterborne, solvent, oil-based and timber required e.g. Softwood (pine, spruce etc) and occasional hardwoods. Compatible with hardware, screws for downstream uses. Colour modification: no modification of top coat/colour paint once applied.	EN599-1: 2013 Durability of wood and wood-based products. Efficacy of preventative wood preservatives as determined by biological tests – specification according to use class. CEN/TS 839 outlines methods for the assessment of preservatives designed for superficial applications. EN 152:2011 Determination of the protective effectiveness of a preservative treatment against blue stain in wood in service

Type	Key product functionality	Technical Quantitative/qualitative minimum requirement	Test method
	Protection from wood-rotting fungi, bacteria and insects	Users would need to include consumer (DIY), professional and industrial. Treatments would need to be compatible with current processes including types of preservative e.g. waterborne, solvent, oil-based and timber required e.g. Softwood (pine, spruce etc) and occasional hardwoods and type of process e.g. pressure impregnation, spray, paint, flow-coat, brush, dipping (manual and automated), deluging and spray-tunnel. Efficacy requirements would depend upon use class and end-use – these would then determine level of penetration and retention of preservative needed to preserve the treated wood.	EN 350: 2016 durability of wood and wood-based products to fungal decay. EN113-1: 2020 Durability of wood and wood-based products test method against wood destroying basidiomycetes. Part 1: assessment of biocidal efficacy of wood preservatives
	Dimensional stability and other properties	Low heat conductivity Mechanical workability Small bulk density High strength – timber for structural use is graded into strength classes. Modulus of elasticity	Softwood 0.14 W/mK conductivity Hardwood 0.14–0.17 W/mK EN 338: 2016 Structural timber. Strength classes
	Wear resistance	UV protection either integral or via top-coat/paint treatment	
	Corrosion resistance	Be non-corrosive to metals	
	Service life/Use class	Durability of timber needs to meet the end-use service life and use class requirements.	EN 350: 2016 durability of wood and wood-based products to fungal decay.
	Suitability for various types of timber	The alternative must be suitable and efficient for treating different type of timber substrates. This is of importance to ensure optimal treatment to the base material for high quality output and service life. As the members of the Eurowindoor association provide various treatment types for multitude end-applications, a potential alternative must have an identical suitability performance for various products	BS8417: 2024 Preservation of wood code of practice.
Product/customer-specific functionality	Economics	Be cost effective.	

Type	Key product functionality	Technical Quantitative/qualitative minimum requirement	Test method
	Sustainable	Be readily sourced and available. Wood sourced from sustainable forests within the EU.	
	Aesthetics	A variety of surface finishes available from natural wood, through to paint and lacquer finishes.	
	Maintenance	Although regular maintenance is to be expected with wood-based products, the maintenance should not be greater than current (every 2 years).	

Based on the BPR, approximately twenty substances (from a total of 51 active substances, 17 of those withdrawn from approval) with fungicide activity are currently approved for use in wood preservatives (PT8). Among these, only a few substances are suitable in preservatives applied by surface treatment and effective against wood-destroying and blue-stain fungi as necessary for wooden products in Use Class (UC) 3 such as window frames, doors or façade elements (DIN EN 599-1:2014, DIN EN 335: 2013). The clear majority of the corresponding wood protection products are based on IPBC in combination with propiconazole. Data from various jurisdictions indicate that IPBC is registered for industrial use in the European Union (EU) at 10–100 tonnes annually, USA at 20–46 tonnes/year, Canada at 0-1 tonne/year and Japan at 1–1000 tonnes/year between 2017 and 2020 (AICIS, 2022).

6.1.1 Efficacy against sapstain/bluestain, mould, fungi and insects

Effectiveness of IPBC against wood-destroying fungi as required by DIN EN 599-1: 2014 can be generally demonstrated in laboratory tests. However, this requires more than 0.9% w/w IPBC in the product which can be achieved by modifying the loading/retention of the IPBC-based wood preservative to greater than 160 g/m². When treating wood, the proper balance of treatment solution must be monitored to ensure the highest quality while minimizing waste and excess cost due to treatment usage or product rejection. Iodine levels (as IPBC) are monitored in solution prior to treatment, and then in the wood to ensure proper retention. A quick, simple, reliable means of analysis is required throughout the quality control process. XRF is an ideal tool for such analysis.

An important disadvantage with IPBC is its low UV resistance, which must be taken into account in the development of impregnation and coating formulations. Especially non-pigmented and low-pigmented coatings may be damaged by IPBC degradation on the surface, resulting in higher maintenance effort of earlier damage of the wood product.

Like other organic iodine compounds, IPBC may also cause discolouration at white or light-coloured coatings, especially at high rates of application and with insufficiently optimised formulation compositions. When used as a film-preservative in paints, coating and other construction materials, IPBC continuously leaches to the top layer of the treated surfaces over time to provide long-term protection from microbial degradation. During rainfall events (for those applications UC2 and greater), IPBC is washed off treated building surfaces to become a component of building run-off (Bollmann *et al.*, 2014) (Burkhardt *et al.*, 2012). It should be noted that there are no corresponding products with IPBC as sole active ingredients on the EU market.

6.1.2 Hardness and tensile strength of resulting IPBC-treated timber

For wood treated with preservatives it may be assumed that any loss of strength or stiffness due to the preservative treatment will be small and may be disregarded. BS EN 15228 Structural timber preservative treated against biological attack lists preservative types that are considered not to affect strength or stiffness of treated wood.

6.1.3 Corrosion resistance

It is important that metal fittings and fixings should not be attached to wood prior to treatment with copper-based preservatives unless the preservative manufacturer confirms this is acceptable.

6.1.4 Service life and use class

The predominant service life and use class requirements of IPBC-treated timber by Eurowindoor representatives is for freshly sawn timber, UC2, UC3.1 (coated) and UC3.2 (uncoated). These correlate with 15 and 30 year service life requirements respectively, with any non-chemical alternative needing to meet these specifications.

6.1.5 Suitability for various species/types of timber

As far as is practicable, wood for which different treatment schedules are appropriate (for example more than one species or end-use) should not be treated in the same charge, unless the most intense schedule required can be applied without detriment to those components only requiring lesser schedules.
The wood should be stacked to ensure that preservative solution shall have access to all faces of the wood and to facilitate natural drainage. Bindings should be sufficiently loose to permit this.

6.1.5.1 Surface characteristics

The surface of the wood shall be free from anything that interferes with preservative penetration e.g. mud, dirt, dust and bark, decorative coatings, paint, stain, polish and any other surface finishes.

7 Efforts made to identify alternatives

7.1 Research and development

The following sections detail the efforts undertaken by members of the Eurowindoor association to gather insights on potentially implementable non-chemical alternatives to IPBC-treated timber.

7.2 Consultation with providers of alternatives

The applicants are largely downstream treaters/users of timber rather than manufacturers of active substances/alternative materials so discussions with suppliers is the main source of information concerning alternatives. These discussions also tend to have a focus on chemical alternatives that may be available to IPBC as opposed to non-chemical, the treatment and manufacturing process used by the association members also making large contribution to these queries. In addition, close dialogue with interest groups at both National and European level, as well as contract research organisations has been utilised by the members to try and identify possible alternatives to IPBC.

Of further consideration is the breadth of current use of IPBC in timber treatment; from treatment of freshly sawn timber to prevent sapstain or mould, through to treatment in combination with other active substances to preserve timber in service, and lastly use of IPBC in paints, lacquers and fillers. This has made it difficult for members to identify one non-chemical alternative to IPBC that could not only align with current practices, but also meet requirements for end-use, economical considerations and sourcing.

7.3 Identification of possible non-chemical alternatives : Long-list of alternatives

The applicants are members of relevant industry associations e.g. European Window and Doors manufacturers group and regularly participate in seminars and workshops to learn more about the potentially implementable non-chemical alternatives to IPBC. Participation in events, collaboration with technology suppliers as well as comprehensive and regular professional literature review contributed largely to gathering the knowledge regarding possibilities for alternatives.

Additionally, it's worth mentioning that the members of Eurowindoor have experienced notable disruptions due to the recent reclassification and altered usage guidelines for Propiconazole in wood preservatives. Consequently, they have directed considerable investment, effort, and resources towards discovering alternative active substances and formulations for wood preservation. This search is quite extensive, often beginning with a five-year minimum and excluding the time required to achieve industry-recognized standards and accreditations, like the EN252 tests, which typically last between 8 to 10 years or longer.

Non-chemical alternatives for the potential replacement of IPBC-based wood preservatives have been evaluated by members of the Eurowindoor association using their expertise, as well as publicly available information. The non-chemical alternatives that can be considered in place of IPBC are outlined below (Table 10) with information pertaining to the manufacture/treatment process, efficacy, service life, and end-uses. Each alternative has been assessed based on these factors and the motive for rejection detailed.

Table 10. Review of short-listed and rejected non-chemical alternatives to IPBC-treated wood

Category	Number	Alternative	Method
Short-listed alternative	1	Organowood	Pressure treatment
	2	Accoya	Acetylation
	3	Thermowood	High temperatures & steam
Rejected alternatives	4	Thermoset resins	Reactive monomers transformed into 3-D polymer matrix and cured.
	5	uPVC	Molten PVC through a moulding machine
	6	Vinyl monomer	Direct chlorination/oxychlorination in a high-temperature reactor.
	7	Concrete	Batching, mixing, transporting, placing, compacting, and curing.
	8	Aluminium clad timber composite	Timber frame overlaid with powder-coated aluminium

Category	Number	Alternative	Method
	9	Glass	Natural raw materials melted in furnace, moulded, and annealed.
	10	Fibre-reinforced plastic/polymer	Bonding fibre and polymer together via compression, moulding, autoclave, filament winding etc.
	11	Fibre-reinforced concrete	Batching, mixing of individual fibres into concrete, transporting, placing, compacting, and curing.
	12	Wood-plastic composite	Two-step process: combination of wood and thermoplastic (HDPE, LDPE, PVC) via compounding. Then extrusion, injection moulding, or pressing.
	13	Steel	Melting iron ore in furnace in the presence of oxygen and coke.
	14	Bamboo	Harvesting, cut into strips and stacked with the grain at right angles. Then impregnated with a low VOC resin, pressed, and cured.
	15	Mycelium-based composites	Mycelium reach full confluence of the substrate, heated to remove moisture, and kill the fungi.
	16	Hardwood species of timber	Hardwood is harvested from deciduous trees that take a long time to grow e.g. approx. 60-100 years. Include beech, oak, mahogany.

7.4 Assessment of rejected alternatives

In this section, the technical limitations and unmet requirements of all alternative candidates presented in section 7.3 are detailed in the following table 11. Their assessment has been performed based upon extensive research and literature review in comparison with the requirements provided by the members of the Eurowindoor association. Please note that only excluding e.g. 'knock-out' criteria are reported in Table 11.

Table 11. Overview of technical limitations of long-list of non-chemical alternatives

Alternative	Limitations met
Thermoset resins	Manufacture process completely different High production costs Elevated temperatures needed for processing Once shaped, cannot be re-shaped Cosmetically does not meet consumer requirements Cannot be used for all end-uses Low melting point, conduct heat Poor resistance to organic/polar solvents Can possess elastic properties Low tensile strength Non-biodegradable

Alternative	Limitations met
uPVC	Shorter service life Manufacture process completely different Lightweight – can be prone to sagging/sashing Exposure to too much heat can rupture uPVC window frames Cosmetically does not meet customer requirements in terms of range of colours Can discolour and become yellow Non-biodegradable Difficult repair process Less environmentally friendly manufacture. According to WWF in 2005, the overall environmental burden for uPVC was significantly higher than timber. Not sustainably sourced/naturally renewable Once discoloured and brittle, will need complete replacement (normally 15-20 years) Timber frames can last up to 70 years PVC is a major user of fossil fuels
Vinyl monomer	Manufacture process completely different High-production costs Difficult repair process Cosmetically does not meet customer requirements Non-biodegradable Service life requirements not met Cannot be used for all end-uses
Concrete	Manufacture process completely different Cosmetically does not meet customer requirements Construction using concrete in place of IPBC-treated wood is much more labour intensive Less cost-effective Relatively brittle, with low tensile strength Long curing time Cracks Non-biodegradable Cannot be used for all end-uses
Aluminium clad timber composite	High up-front costs to consumer Higher production costs Manufacture process completely different Fades over time. Cannot be repainted. Cannot be used for all end-uses required Layers can separate under stress Some composites are not fire resistant Disposal and recycling can be challenging
Glass	Higher production costs Manufacture process completely different Cannot be used for all end-uses required Disposal and recycling can be challenging Fragile Less cost-effective Relatively brittle, with low tensile strength Cracks

Alternative	**Limitations met**
Fibre-reinforced plastic/polymer	High up-front costs to consumer Higher production costs Manufacture process completely different Ages with time. Cannot offer the same service life. Cannot be used for all end uses needed. Low shear strength and elasticity Long-term temperature resistance is poor Cosmetically does not meet customer requirements – cannot be painted
Wood-plastic composite	Different manufacture process Still requires treatment with wood preservative to prevent decay. Cannot be used for all end uses High up-front costs to consumer Heat sensitive Different final texture and aesthetics to wood. Cannot be painted. Cosmetically does not meet customer requirements. Cannot be painted Recycling difficult UV-degrade The presence of fungal decay and discoloration of wood-plastic composite decking in service has been known for decades (Morris, 1998) with composites comprised of 50% or more of wood particles becoming degraded by brown and white rot fungic(Laks, 2002).
Steel	Different manufacture process Cannot be used for all end uses e.g. is a poor choice for complex roof designs compared with wood In contact with air/water for long periods, will corrode Susceptible to buckling Higher initial costs/less availability Aesthetics Fire-proofing costs Cosmetically does not meet customer requirements – cannot be painted
Bamboo	Different manufacture process High up-front costs to consumer Cannot be used for all end uses Aesthetics Can be more difficult to work with compared with other types of wood Very hard and dense making it a challenge to cut and shape Poor durability/service life without additional treatment Potentially invasive species Can emit VOCs due to the adhesives used in its manufacture Sensitive to moisture and humidity which can lead to warping, swelling or shrinkage.

Alternative	Limitations met
Mycelium-based composites	Different manufacture process – at small scale Low mechanical properties Different manufacture process High water absorption/poor weathering Poor service life Lack of standardised development methods Limited end uses compared with IPBC-treated timber Susceptible to mould growth
Hardwood species of timber	Timber requires conditioning before use. Sourcing/availability is limited due to deciduous nature and age of wood species. Hardwood timber is more difficult to treat (due to greater presence of heartwood). Economically more expensive than softwoods. Less susceptible to sapstain/blue stain than coniferous wood. Less sustainable than softwoods such as Pine etc.

8 Short-list of alternatives

The alternatives that were identified as the most promising for replacing IPBC-treated timber were:

1. Organowood
2. Accoya
3. Thermowood

These are all defined as 'modified wood technologies' and a detailed assessment of all three alternatives is provided in this section.

8.1 Modified wood technologies

Some of the limitations of wood, including its dimensional change in changing moisture levels, and susceptibility to insect attack or decay, have traditionally been addressed through good design, chemical treatments (such as IPBC) and strategic choice of wood species for the intended applications. However modified wood technologies offer an alternative approach, although tend to also be created via proprietary processes with limited end-uses in comparison with IPBC-treated timber.

Wood modification has been defined by (Hill, 2006) as a process that 'involves the action of a chemical, biological or physical agent upon the material, resulting in a desired property enhancement during the service life of the modified wood'. As a result, this is frequently considered to be a separate technology to established wood preservative treatments using biocides (Spear *et al.*, 2021).

8.1.1 Alternative 1: Organowood AB

Organowood uses proprietary technology that mimics the natural fossilization process. The wood is modified by the pressure treatment and attachment of protective silicon compounds (via silicon dioxide) to the wood fibres. This is via a water-based formulation containing alkali metal silicate that has a shelf-life of one month at 15–35 °C. During the process, the timber mineralises and becomes significantly harder and denser than normal timber thus making adherence of traditional paints and lacquers difficult to bind to the wood fibres.

During use, Organowood timber fades to an uneven silver-grey colour and 'fibre furring' with time, with this discolouration largely affected by end-use such as direction it is placed, and weather exposure. To try and prevent uneven discolouration and furring of the timber surface, Organowood recommend two-yearly maintenance with a water repellent treatment that prevents the absorption of water in the sapwood.

8.1.1.1 Comparison with IPBC treated alternative – efficacy, service life, applications/end-uses

Organowood is timber coated in silicon via pressure impregnation that prolongs service life to 10 years (for pressure treated timber). This base coat is colourless but does confer the wood a light grey silver patina (‘Organowood’, 2024). The silicon penetration is most effective with absorbent types of wood, such as pine and spruce with the process mimicking that of traditional pressure impregnation treatment of timber and is claimed to improve flame-retardant properties as well as resistance to wood rot, fungus, mould and insect attack. Following pressure treatment, timber is cured at elevated temperatures ranging from 40 to 150°C in order to insolubilize the alkali metal silicate.

However, a major problem when using alkali metal silicates as a wood preservative has been their water solubility. In particular, sodium silicate (commonly known as water glass), is highly soluble in water. When subjected to outdoor conditions such as rain, or being placed in water, the sodium silicate is dissolved and leaches out from the treated wood – a factor that is currently evaluated under the biocidal products regulation (BPR, (EU) 528/2012) for conventional biocides such as IPBC, but not necessarily closely evaluated for modified timber such as Organowood (Hellberg, 2016). However, an industrially feasible, completely environmentally friendly method to use sodium silicate as a wood preservative is still lacking. There is still a need for an industrial method using a wood preservative comprising sodium silicate which gives the wooden material good resistance to water and also a method wherein the wood preservative does not leach out from the treated wood (Hellberg, 2016).

Regarding the constraints of the Organowood process for treating different timber types and applications, it is currently advised exclusively for decking and cladding purposes, and only when using Swedish pine. This is in contrast to the many types of timber species, softwood/hardwood, penetration classes, service life and end-uses outlined as required with IPBC-treated timber by the Eurowindoor representatives. Modified wood is produced throughout Europe and other parts of the world. However, in wood modification technologies, the process of transforming from the laboratory phase to production level has been started from the last decades, it is still growing slowly. Higher prices in both special equipment for wood modification process and final wood products, the lack of experience of using the material, consumer perceptions about new materials can be the possible reasons (Khademibami and Bobadilha, 2022).

However, even though the properties of sodium silicate as a wood preservative have been known for a long time, a wider acceptance by the industry has not been achieved. A major cause is the high cost involved in multi-step applications. In large scale industrial applications such as vacuum-pressure impregnation of wood, the cost of the process must be kept at a minimum. The two-step process described above is therefore a difficult and uneconomic way as the wood need to dry in between the two steps which is costly. In addition, Organowood is produced only in Sweden, so would need to be imported into other EU countries.

8.2 Alternative 2: Accoya

Accoya wood is chemically modified (acetylated) New Zealand radiata pine trees. These are sourced and taken to Accoya’s production facilities in the Netherlands where they undergo the acetylation process. During the acetylation process with acetic anhydride in the presence of either alkaline or acidic catalysts, the free hydrophilic hydroxyl groups present in the wood cell walls are esterified into more hydrophobic acetly groups, reducing bioavailability and enabling accetylated timber to exhibit a high-resistance against wood-destroying fungi. In addition, acetylation improves resistance to white rot fungi, termites and weathering (Elder, 2001). A summary in diagram form can be found below in Figure 4.

However, the long-distance transportation involved in its production, along with the chemical treatment process, can contribute to a higher carbon footprint compared to locally sourced and treated timber options.

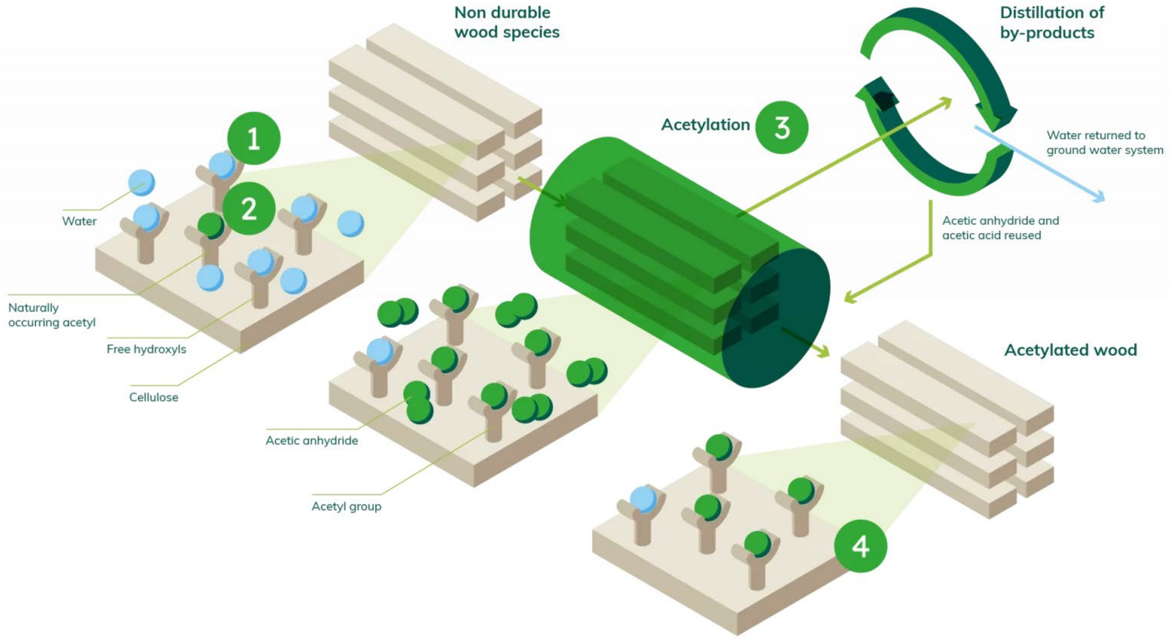


Figure 4: Diagrammatical overview of the process for acetylating timber. Extract from: ('What is Accoya wood made from?', 2024).

Wooden window frames are known for their low-maintenance properties however wood and Accoya window frames should still be regularly inspected for damage or imperfections and regularly cleaned with water and a cloth or stiff brush. If any paint is flaking or peeling, it should be removed with sandpaper, primed and repainted to maintain its appearance. One of the best known and most widely studied properties of acetylated wood is its dimensional stability. Wood properties like dimensional stability (swelling/shrinkage) and equilibrium moisture content are improved ('Protection of the bio-based material', 2017).

Mechanical properties are generally similar to those of the untreated wood, except for documented decreases in shear parallel to the grain and an increase in the work to proportional limit. In addition, acetylated wood posseses thermoplastic properties that are of utilty in the manufacture of molded products (Elder, 2001). Because Accoya wood goes through the acetylation process, this can slightly alter its natural appearance. Many homeowners prefer the appearance of traditional wood windows, however both wood and Accoya can be coated with suitable paints and stains to achieve the desired look ('Accoya vs. traditional windows', 2-24).

8.2.1 Comparison with IPBC treated alternative – efficacy, service life, applications/end-uses

The acetylation process of Accoya alters the wood's cellular structure, converting hydrophilic hydroxyl groups into hydrophobic acetyl groups, which significantly reduces its moisture absorbency, a key factor in decay. Consequently, Accoya boasts enhanced durability and resistance against fungal decay, termites, and weathering, lasting up to 50 years above ground and 25 years in-ground or freshwater contact. Wood is sourced from certified New Zealand forests including Forest Stewardship Council (FSC) and Programme for the endorsement of forest certification (PEFC) accredited sources.

Nonetheless, industrial-scale acetlyation processing currently relies solely on timber from one source/location can give rise to complications related to the supply chain and have adverse impacts on carbon emissions, availability of acetylated timber, and thus the cost and obtainability for the consumer/Eurowindoor members. Further, compared with IPBC, Accoya is not resistant to surface growths such as sapstain/bluestain, and mould – with this a key benefit provided by IPBC-treated timber to Eurowindoor members.

Depending on the acetylation process, it is possible that small quantities of the acetic acid used remain in the wood, which might influence fittings and fasteners negatively. It is consequently important to use non-corrosive material for fixtures and fittings e.g. stainless steel when using acetylated wood ('Protection of the bio-based material', 2017). This again is comparable to treatment and use of IPBC-treated wood in end-use application and thus, is not a benefit of using Accoya.

On the other hand, wood treated with IPBC (3-iodo-2-propynyl butylcarbamate) relies on a biocidal chemical to protect against fungal decay and insects. IPBC-treated wood has been a popular preservative choice for a long time due to its effectiveness in protecting against a wide range of wood pests and fungi. It is often applied to various species of timber and used for a myriad of applications, both indoor and outdoor.

Directly comparing Accoya wood and IPBC-treated wood:
Accoya is specifically made from New Zeland radiata pine, while IPBC can be applied to a variety of wood species. In addition, Accoya undergoes a chemical modification through acetylation, whereas IPBC treatment involves the application of a biocidal preservative. These involve contrasting treatment methodologies, with Accoya chemical modification limiting in its breadth of treatment types in comparison with IPBC. The acetylation process used in the manufacture of Accoya, modifies the free hydroxyl groups into acetyl groups reducing the ability of the material to absorb water by 80% - improving the stability of the timber and enabling Accoya to be used in UC2 and UC3 situations.

Both materials are designed to extend the life of wood, with Accoya providing up to 50 years of durability, potentially outlasting IPBC-treated wood depending on the application and exposure conditions. In addition to good durability and dimensional stability without loss of strength, the acetylated wood shows significant resistance to moisture and fungi due to the hydrophobic treatment. It has the same end-of-life scenarios as untreated wood and can be burned for energy recovery without producing extra hazards (Hill, 2006).

While Accoya wood offers resistance to wood-destroying fungi and some weathering due to its chemical modification process, IPBC-treated wood presents a more cost-effective solution and is efficacious against sapstain, bluestain and mould – a key requirement for both the Eurowindoor association and consumers. IPBC, provides robust protection against fungi and insect infestation at a lower initial investment. Furthermore, the ubiquity and established nature of IPBC treatment mean that it can be applied to a broader range of wood species (both soft and hardwoods) and used for various applications, potentially offering better overall value for consumers and contractors alike.

Accoya is generally used for high-end applications where longevity and reduced maintenance are paramount, including outdoor decking and cladding. IPBC-treated wood is versatile in application (and used in a far broader scope of end-uses than Accoya) but is also subject to regulations and restrictions.
In summary, while both Accoya and IPBC-treated wood aim to extend the lifespan of timber products and improve resistance to environmental stresses, they differ significantly in their manufacturing process, environmental impact in terms of sustainable sourcing and carbon emissions, economics and potential

applications. While both materials promise extended timber life and resilience against natural elements, it is their prospective applications, initial costs, and ecological considerations that differentiate them.

8.3 Alternative 3: Thermowood

Thermowood, also known as thermally modified timber, is a type of enhanced wood manufactured by treating lumber with heat and steam, typically in the range of 180 to 230°C. This heat treatment fundamentally alters the chemical and physical properties of the wood, increasing its dimensional stability, decay resistance, and insulation characteristics. The process doesn't involve any chemical preservatives, making thermowood an attractive option for consumers.

The thermal modification process reduces the wood's hygroscopic properties, significantly diminishing its ability to absorb moisture. This leads to a lower equilibrium moisture content, which means the wood is less likely to warp, swell, or shrink when exposed to changes in temperature and humidity. Thermowood also becomes more resistant to rot, fungi, and insects, extending its service life and reducing maintenance requirements. However, Thermowood is not more resistant to sapstain/bluestain or surface mould a key requirement for end-uses, consumers and Eurowindoor members.

Aesthetically, Thermowood features a rich, darkened colour throughout its entirety, which is a natural outcome of the thermal process. It retains its natural wood grain, offering an authentic look with increased durability. The process also improves the material's insulating properties, contributing to better energy efficiency in applications such as cladding, decking, and outdoor furniture.

As an environmentally friendly option, Thermowood is free from volatile organic compounds (VOCs) and other chemicals commonly used in conventional wood treatments. At the end of its life cycle, Thermowood can be recycled or used as a biofuel, much like untreated wood.

Due to the thermal treatment, Thermowood is less likely to react with metal fasteners and fittings, reducing corrosion risks and increasing the longevity of the construct. Despite its enhanced properties, Thermowood maintains a comparatively lightweight profile and can be processed using standard woodworking tools and equipment.

Thermowood's modifications produce a material that stands up well to outdoor elements, making it highly suitable for applications where traditional wood might not perform as effectively without the requirement of chemical treatments.

8.3.1 Comparison with IPBC treated alternative – efficacy, service life, applications/end-uses

Thermowood and IPBC-treated timber both enhance the durability and longevity of wood. However, while Thermowood is subjected to high temperatures to improve its resistance to decay, IPBC-treated timber receives a biocidal treatment that offers robust protection against a wider spectrum of wood-degrading organisms.

Thermal modification subjects wood to heat over 180 °C, fundamentally altering its cell structure and reducing its equilibrium moisture content, which increases its decay resistance. This process also improves the wood's insulation properties and results in a darker aesthetic finish. However, the high heat can weaken the wood's structural integrity, making it less suitable for load-bearing applications e.g. door frames (a key requirement for end-use by the windows and doors association) and the darker colouration of the end-product is aesthetically not preferable to consumers or Eurowindoor members. A summary of the Thermwood treatment process and resulting wood properties can be found in Figure 5.

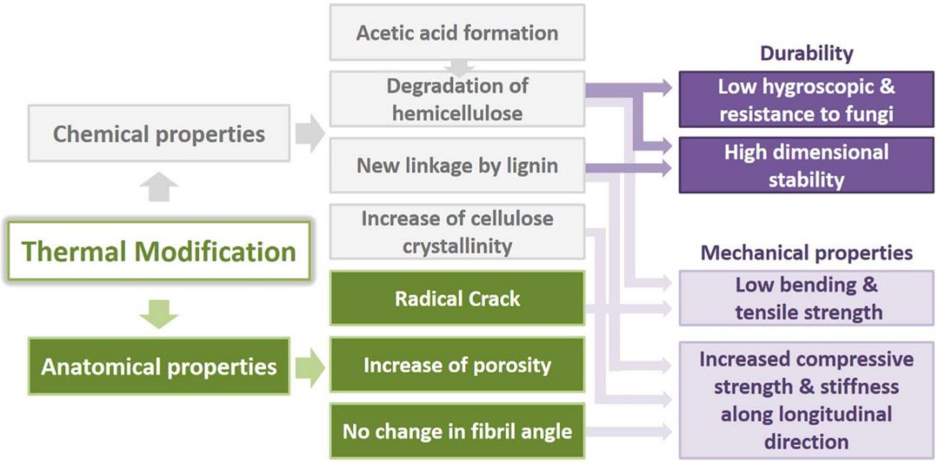


Figure 5: Property changes involved in thermal modification. (Ramage *et al.*, 2017)

In contrast, IPBC treatment infuses wood with a fungicide and insecticide, effectively shielding it from fungal decay and insect damage. This preservative treatment is versatile, as it can be applied to a multitude of wood species and is suitable for a range of structural and decorative purposes. Notably, IPBC-treated wood retains more of the original mechanical properties of the timber, making it a stronger candidate for structural uses. In addition, IPBC prevents the discolouration of timber by sapstain, bluestain and surface moulds – an attribute that Thermowood cannot provide.

IPBC-treated timber stands out for its efficacy in preserving wood without significantly altering its mechanical strength. The treatment is also more adaptable, suitable for various types of wood and applications, from ground contact to interior uses. It's recognized for providing lasting protection with a smaller alteration of the wood's initial properties compared to the intensive thermal modification that Thermowood undergoes.

Due to Thermowoods production process where the wood is heat-treated to improve its durability and water resistance, it has a lower moisture content which can affect paint adhesion. To ensure the best results when painting Thermowood, it is essential to use paints and primers that are specifically formulated for use on heat-treated wood and to follow the paint manufacturer's instructions for surface preparation and application. Regular maintenance will also be necessary to preserve the paint coating over time. This is in contrast to the ready paintability of IPBC-treated timber; where the applications of lacquers, paints, top-coats and flow-coats is not limited to a single manufacture source and is readily available to consumers, professionals and industrial scales.

Moreover, IPBC treatment often requires a less intensive manufacturing process than Thermowood, which demands significant energy consumption due to the high temperatures needed for treatment. The reduced processing complexity renders IPBC-treated wood a more cost-effective option, especially in cases where structural integrity and a broader range of applications are important considerations.

Ultimately, while Thermowood offers benefits like improved stability, IPBC-treated timber presents a compelling alternative, particularly from a structural, economic, and versatility standpoint. Its established protection against biodegradation, cost-effectiveness, and minimal alteration of wood’s natural properties position IPBC-treated wood as a superior choice in various applications.

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9 Conclusion on shortlisted alternatives

To conclude, establishing an alternative technology meeting all the requirements provided by IPBC-based wood treatment (i.e., technological viability, service life, end-use), while being economically viable (i.e., market competitive), is extremely challenging for the applicant.

Comparing the short-listed alternatives Organowood, Accoya andThermowood and IPBC-treated timber involves examining their treatment processes, efficacy against decay and pests, service life, environmental impact, structural properties, application versatility, and maintenance requirements. Below is an overview of how the non-chemical alternatives compare with IPBC-treated:

9.1 Treatment process

Organowood – Mimics natural fossilization, using silicon compounds to mineralize timber, becoming harder and denser.

Accoya – Chemical modification using acetylation, where hydroxyl groups in wood cells are converted to acetyl groups.

Thermowood – Heat treatment with temperatures of 180 to 230°C, improving durability and stability without chemicals.

IPBC-treatment – traditional variety of treatment types ranging from pressure impregnation, through to brushing, dipping, painting and flow-coating. Infers protection against in particular, surface moulds, sapstain, bluestain and fungi.

9.2 Efficacy

Organowood Claims to improve flame-retardant properties and resistance to wood rot, fungus, mold, and insect attack.

Accoya – Resistant to fungal decay, termites and to an extent weathering.

Thermowood Increased resistance to rot, fungi, and insects. The heat treatment reduces the wood's moisture content significantly.

IPBC-treatment – Most effective at controlling/preventing anti-sapstain, bluestain and mould from the surface of newly cut timber as well as preventing fungal decay in combination with other preservatives in pressure treatments.

9.3 Service life

Organowood Prolongs life up to 10 years for pressure-treated timber, with the recommendation of two-yearly maintenance.

Accoya – Up to 50 years above ground use, and 25 years in contact with ground or freshwater (UC2 and UC3 respectively).

Thermowood Long-term decay resistance improves lifespan, but less data on exact service life compared to chemically treated woods.

IPBC-treatment Effective for long-term wood preservation; specific lifespan depends on exposure and application, but main use classes required by members of the Eurowindoor association are covered, with substantial data to support.

9.4 Environmental Impact

Organowood Water-based technology with some concerns around leaching but seen as an environmentally friendlier alternative to conventional biocides.

Accoya The process is classed as eco-friendly, with by-products and waste that are more easily managed. However, transportation of singly sourced timber for treatment can contribute to a higher carbon footprint.

Thermowood No chemical preservatives used, resulting in an eco-friendly product with a smaller ecological footprint. However, the energy needed to heat treat the timber can be extensive and expensive.

IPBC-treatment While effective, IPBC is a conventional biocide with some environmental and health concerns leading to regulatory scrutiny. Aside from this, the use of IPBC is an established process with appropriate human and environmental health mitigation measures in place where necessary.

9.5 Applications

Organowood Advised mainly for decking and cladding purposes, specifically with Swedish pine.

Accoya Well-suited for high-end projects, including outdoor decking and cladding, due to its durability and low maintenance. However, Accoya projects tend to be more costly from the outset and limited in its end-uses.

Thermowood Ideal for cladding, decking, and outdoor furniture due to its enhanced durability and natural weather resistance. Otherwise limited applications and end-uses.

IPBC-treatment Versatile, applicable to various wood species and a range of structural and decorative purposes and end-uses.

9.6 Maintenance

Organowood – Requires periodic application of a water repellent treatment to prevent water absorption and discolouration.

Accoya Lower maintenance compared to traditional woods. Can be painted or stained for aesthetic purposes, limited to Accoya produced paints and stains, though not required for protection.

Thermowood May require special paints and coatings formulated for heat-modified wood; the paint may require more frequent maintenance.

IPBC-treatment – Generally requires less maintenance than untreated wood but must be regularly inspected and treated in outdoor uses.

In summary, each non-chemical alternative to IPBC-treated timber offers unique benefits and trade-offs; the optimal choice depends on the specific requirements of the end-use application, environmental impact considerations, desired maintenance levels and budgetary constraints.

In evaluating timber options for long-term durability and versatility, IPBC (3-iodo-2-propynyl butylcarbamate)-treated wood stands out as an exemplary choice, given its wide-ranging protective capabilities against wood-degrading organisms like fungi and insects. Unlike its counterparts—Accoya, Thermowood, and Organowood—IPBC-treated timber integrates a tried-and-true biocidal treatment that effectively shields wood without requiring an extensive modification of its structural properties.

Accoya, while honing an impressive resistance against fungal decay due to its chemical alteration via acetylation, is limited to a single wood source and involves a more energy-intensive manufacturing process. It also tends to be on the higher end of the price spectrum, making it a less economical choice for widespread use.

Thermowood, though valued for its enhanced stability and eco-friendly thermal process, is subject to a drop in structural integrity as a result of the high temperatures involved in its production. The thermal modification may limit its applicability in load-bearing scenarios, a drawback that IPBC-treated wood does not share.

Organowood, which employs a silicon-based preservative mechanism, presents a unique approach to wood protection by mimicking the fossilization process. However, it faces certain challenges, such as a susceptibility to weathering and leaching, which can diminish its efficacy over time, especially in comparison to the robustness of IPBC-treated wood.

IPBC-treated timber nods to cost-effectiveness and adaptability. Its preservation process does not radically change the mechanical properties of the timber, thereby preserving its natural strength for structural applications. It's versatile enough to be applied across various wood species and accommodates an array of uses, ranging from indoor to outdoor settings, making it an all-around suitable and economical option.

Moreover, the reliable protection it offers from biodegradation promotes a longer lifespan with lower maintenance, enhancing its appeal as a prudent investment. The well-established nature of IPBC's application in the timber industry, alongside its cost advantages and minimal alteration of wood's natural characteristics, firmly establishes it as a superior choice in various applications.
In sum, IPBC-treated timber is underscored as the best option among its current alternatives, taking the lead in efficacy, economic viability, and applicability across a spectrum of demands in both residential and commercial contexts.

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