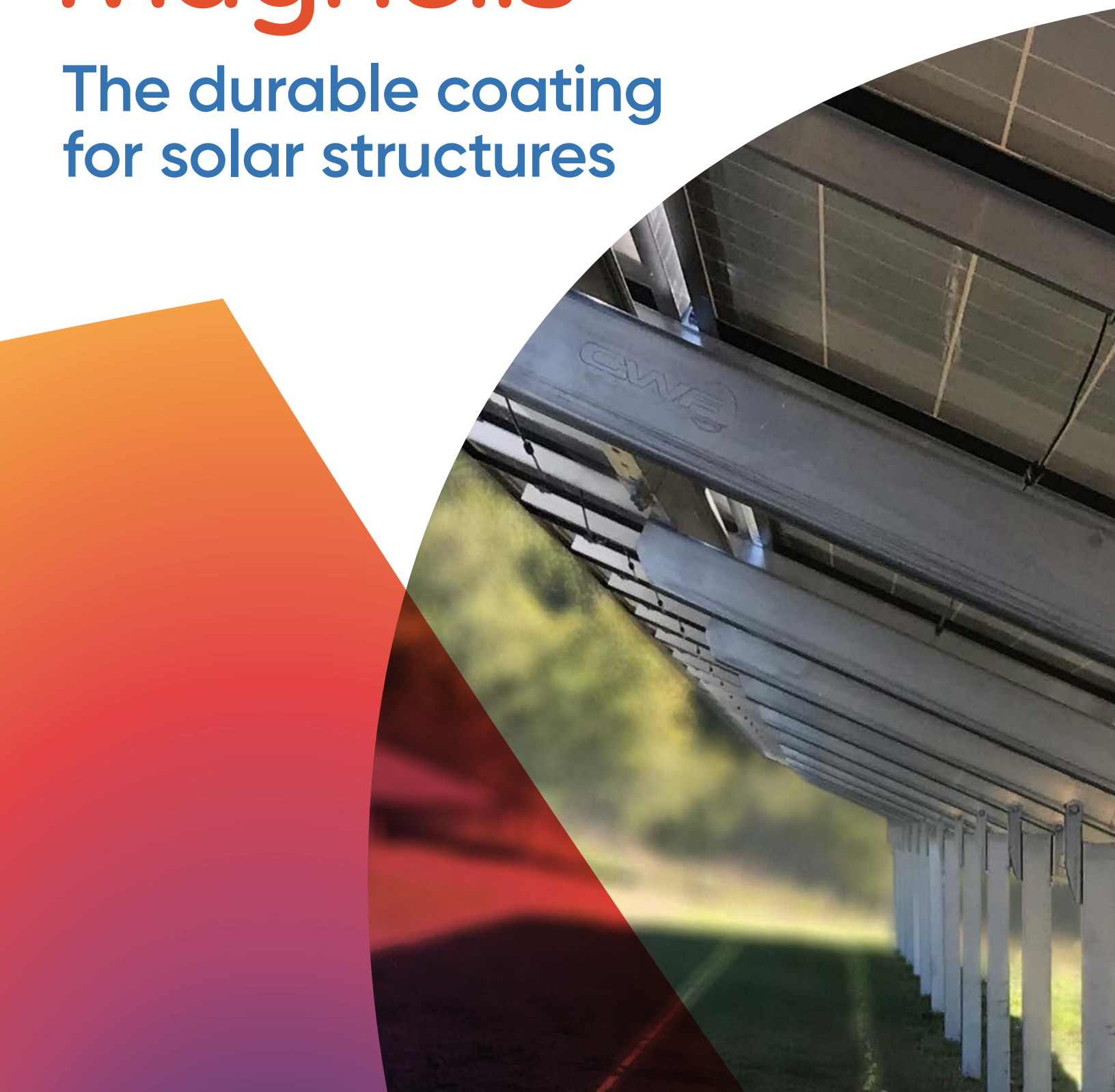


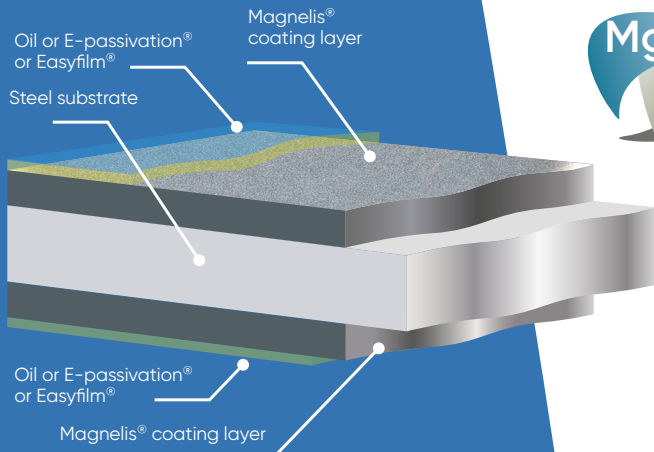


ArcelorMittal

Magnelis[®]

The durable coating
for solar structures

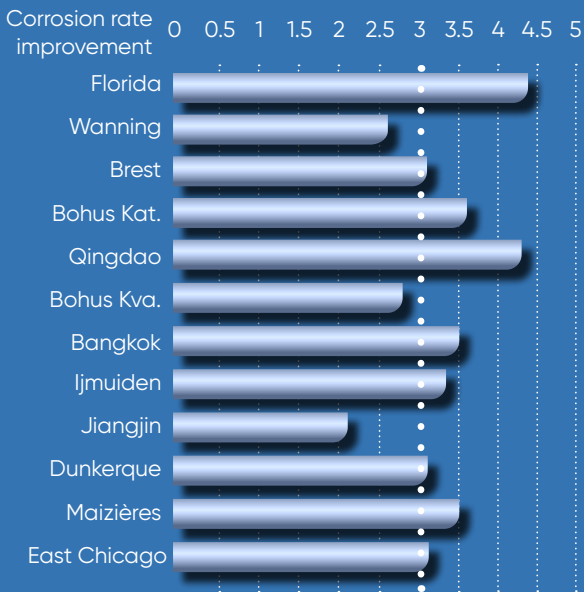




Magnelis® is an exceptional metallic coating containing 3% magnesium, 3.5% aluminum and zinc. This unique composition provides unparalleled surface and cut-edge protection against corrosion.

Magnelis® increases the protection against corrosion for mounting structures of Photovoltaic (PV) solar farms (rooftop and ground-mounted). Magnelis® is used in some of the largest PV plants in the world and has a track record of more than a decade. Magnelis® is included in the new version of ASTM A1046-22 and classified as a Type 2 coating.

Improvement factor between Magnelis® and regular galvanized steel in field testing



Average improvement: ~ 3 times better than regular galvanized steel

Expected lifetime to first maintenance

(First spots of red rust requiring a first local maintenance)

Corrosion category ISO 9223	Galvanized G90 (20 microns per side)	Magnelis® ZM40/ZMM120 (10 microns per side)
C2	18 y to > 50 y	25 y to > 50 y
C3	6 y to 18 y	8 y to 25 y
C4	3 y to 6 y	4 y to 8 y
C5	Not Appropriate	Not Appropriate

These durations are indicative and non-binding. For information, European standard EN508-1:2021 for self-supporting products of steel sheets imposes minimum coating thickness of ZMM180 (for ZM coatings) and G115 (for galvanized steel) for bare metallic coated steel, without paint, used for outdoor applications.

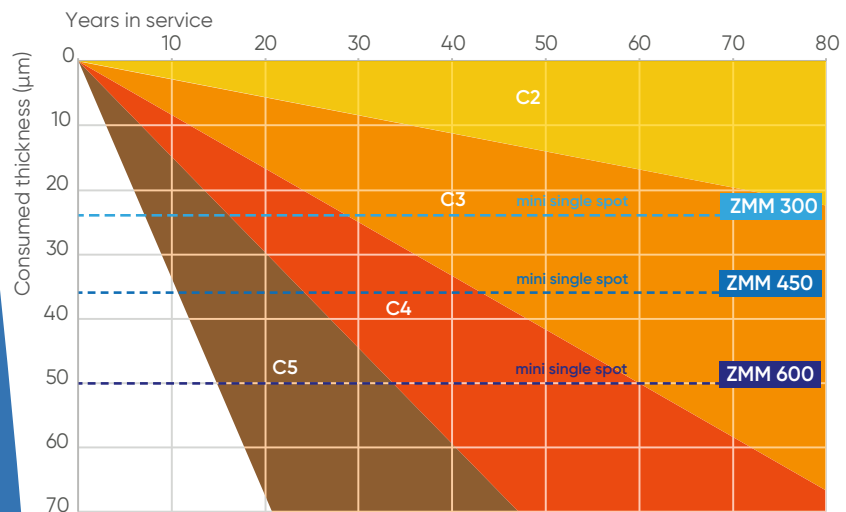
Outstanding corrosion performance

Magnelis® has been tested in a variety of environments worldwide. Test results show that Magnelis® exhibits an average corrosion rates 3 times less than regular galvanized steel. This leads to an increase of expected lifetimes with a factor 3. Based on this performance, it is possible to evaluate the "lifetime to first maintenance" for Magnelis® products.

Lifetime to first maintenance is defined as the minimum duration until the coating deteriorates to a point requiring the first local maintenance to avoid enlargement of the corroded area. Deterioration occurs due to the local consumption of the coating. First local maintenance is required when the first spots of red rust appear.

The expected lifetimes are calculated based on single spot minimum coating thicknesses (as per EN 10346 and ASTM A1046 standards), and based on corrosion rates as per the German Technical Approval for Magnelis® delivered by DiBt (Z-30.11-51).

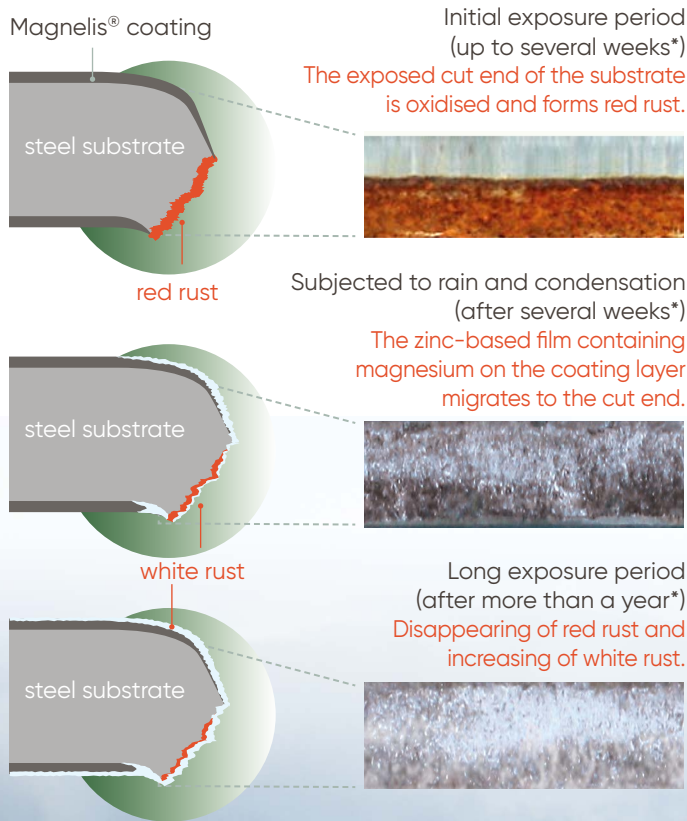
Expected lifetime to first service of Magnelis®



Edge protection with self-healing effect

When exposed to an environment, Magnelis® forms a very dense zinc-based protective film, unlike galvanized steel, whose film is very porous.

This unique dense film is formed on edges, welds, perforations and scratches and provides overall protection to the produced parts.



* The speed of the self-healing depends on the environment and coating thickness.

High durability, even in soils

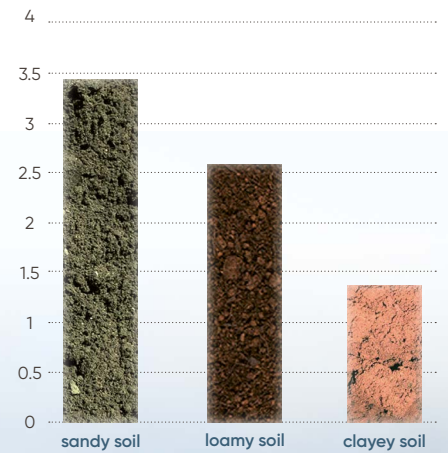
Magnelis® durability was extensively tested in contact with different types of soils to acquire deep proprietary knowledge. These tests confirm that Magnelis® outperforms galvanized steel for durability in soils.



Field outdoor testing at ArcelorMittal Global R&D center (OCAS Belgium)

Illustrative result from soil corrosion testing by ArcelorMittal Global R&D:

Corrosion rate improvement with Magnelis® versus post-galvanized steel in various soils



Source: ArcelorMittal Global R&D

This improved performance is confirmed by a third-party assessment. The French Corrosion Institute, a subsidiary of RISE Research Institutes of Sweden AB, is among the largest laboratories in the world in the field of materials and corrosion performance. After many soil tests with Magnelis®, this lab concluded that *“Corrosion resistance of Magnelis® in soils was improved by an average factor of 3.8 compared to continuous hot dip zinc coating”.*

These results suggest that for the durability needs of solar structures, Magnelis® ZMM620 or above are recommended for posts driven into soils or embedded in concrete.

Institut de la Corrosion
French Corrosion Institute

Bruxelles, France, December 17th 2021

Global statement of the relative corrosion performance of Magnelis® in soils

Since 2006, the Institut de la Corrosion has performed comparative corrosion studies in soils of zinc-based coatings for ArcelorMittal. The materials studied were mainly continuous hot dip zinc coating and continuous zinc-aluminum magnesium coating (Magnelis®), both produced according to EN 12464. Most of these studies have been carried out under collaborative joint industrial programs including material suppliers and end-users.

The exposures consisted in field exposure, laboratory exposure using natural soils and synthetic soils. The range of parameters investigated, and exposure time are detailed in Table 1.

Table 1: Soil parameter ranges in the corrosion studies including Magnelis® based on EN12464-2

Parameter	Range
Exposure time	6 months to 3 years
Texture	clay, silt and sand mixtures
pH	4 to 9
Resistivity	5 to 900 Ω.m
Chlorides	-10 to 2200 ppm
Sulfates	0 to 107 ppm
Sulfides	0 to 82 ppm

The obtained results show that the average corrosion resistance of the Magnelis® in soils was improved by an average factor of 3.8, compared to continuous hot dip zinc coating. This factor has been calculated based on mass loss according to the ISO 8467 standard.

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Institut de la Corrosion SAS au capital de 500 000 €. Filiale de RISE
Agée par le Ministère de l'Environnement Supérieur et de la Recherche au titre de Crédit Impôt Recherche

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Additional advantages

Easy substitution of galvanized by Magnelis®:

- Same roll-forming tools or dies can be used with Magnelis® and regular galvanized products, saving on setup time and cost.
- Magnelis® has a lower friction coefficient and induces less powdering. Its harder surface compared with galvanized steel increases surface protection against scratches during forming and handling operations.

Benefits for part manufacturing include:

- Reduction of zinc pickup on forming tools (such as profiling rolls). Magnelis® is a harder coating than pure zinc galvanized coatings and exhibits less friction. This leads to less sensitivity to scratches and less powdering.
- Reduction of cleaning frequency and overall maintenance.

Benefits for welding:

- Thinner Magnelis® coating means that welding consumes less energy and generates less fumes and splashes in comparison to regular galvanized products. It leads to increased welding speed & productivity.
- A more efficient welding process reduces the amount of consumables used (energy, reactive gas, filler wire, ...).

Benefits for the environment:

Magnelis® is 100 percent and infinitely recyclable, and does not contain any harmful elements. Replacing galvanized steel with Magnelis® reduces the environmental footprint of manufactured products by:

- using fewer raw materials and natural resources at the galvanizing stage.
- reducing zinc run-off during the product's life.
- increasing the lifetime of the finished product.

Combination with HyPer high strength steels

Magnelis® can also be combined with higher strength steels, resulting in immediate weight, cost and CO₂ footprint reductions. These HyPer grades are a cost-effective solution for structural parts such as posts and tubes.

Coating designation	ASTM A1046M	ZMM90	ZMM120	ZMM180	ZMM300	ZMM450	ZMM600
	ASTM A1046	ZM30	ZM40	ZM60	ZM100	ZM140	ZM210
Coating mass (total both sides)	g/m ²	90	120	180	300	450	600
	oz/ft ²	0.30	0.40	0.60	1.00	1.40	2.00
Coating thickness	µm/per side	7	10	14	24	36	50
	mils/side	0.28	0.38	0.55	0.94	1.41	1.95
Surface treatment	E-Passivation® (CrVI-free), Easyfilm® (acrylic), Oiled						
Thickness	0.016 to 0.236 inches (0.40 to 6.00 mm)						
Width	Up to 66 inches (1680 mm)						
Steel grades*	CS Type A, B and C Grades 50 up to 100 (including high-elongation grades)						

* Contact us for the detailed feasibility, other coating weights on request.

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ArcelorMittal

Magnelis® vs. aluminum: reduces the environmental impact and improves efficiency



Steel module frames can reduce CO₂ emissions by 86%, from 217 to 29 tonnes CO₂e per MW solar capacity installed*. In addition, steel frames are cost efficient and able to support higher loads compared to traditional aluminum module frames.

* Boundless Environmental Impact Report May 2022

In conclusion

Magnelis® is proven to extend the lifetime of solar structures. Applications of Magnelis® will maximize return on investment of Photovoltaic plants by delaying and/or reducing maintenance costs. Key advantages in solar structures include:

- guaranteed durability up to 25 years, including in contact with soils or embedded in concrete.
- improved abrasion resistance.
- wide range both in thickness and steel grade.
- cost advantage in comparison to post galvanizing.
- reduced environmental impact.

Credits

Photos cover: CWF

inside: ArcelorMittal Global R&D, CWF, Profil du Futur, Hanwha Q CELLS

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