

vgbe/BAW-Standard

# Corrosion Protection for Offshore Wind Structures

Part 1: General

VGBE-S-021-01-2023-05-EN

4<sup>th</sup> Edition 2023

(formerly VGB-S-021-01-2018-04-EN)



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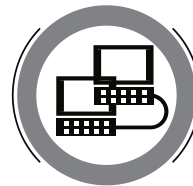
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# vgbe/BAW-Standard

## Corrosion Protection for Offshore Wind Structures

### Part 1: General

4<sup>th</sup> edition, 2023

VGBE-S-021-01-2023-05-EN

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## Foreword

The growing number of wind turbines in Europe and around the world presents operators with new challenges. In order to reduce installation and operating costs and increase operational safety, a coordinated and joint analysis of operational experience is essential. In addition to the exchange of information and experience, the main objective of the participating companies is to promote standardization (best practice). To this end, VGB PowerTech e.V. (vgbe energy e.V. since April 2022) and the German Federal Waterways Engineering and Research Institute (BAW; Bundesanstalt für Wasserbau) decided in 2013 to jointly develop a VGB/BAW standard for the corrosion protection of offshore structures (e.g. offshore structures). The first part of the initial edition was published in 2016. Parts 2 to 4 followed by 2018. With the publication of this edition, parts 1 to 3 are available in a revised version.

The aim of this standard is to take account of the high capital expenditure required for offshore structures by using appropriate corrosion protection systems. Coating systems, for example, should protect the steel structures of offshore facilities from corrosion damage for at least 25 years during their service life without the need for costly repairs. Robust systems are therefore required which, with calculable capital expenditure (CAPEX), keep operational expenditure (OPEX) at a predictable and low level in the long term. In addition, repairs at sea have a significantly higher cost factor compared to onshore repairs.

In order to ensure effective corrosion protection of steel structures, owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials need to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. It is vital that such information is as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

*If anything is unclear, the German version is the reference version.*

The VGBE/VGB-S-021 series of standards from vgbe/VGB/BAW on “Corrosion protection for offshore wind structures” consists of the following parts (as of the publication date of this document):

- Part 1, “General” (VGBE-S-021-01-2023-05-EN), 2023
- Part 2, “Requirements for corrosion protection systems” (VGBE-S-021-02-2023-05-EN), 2023
- Part 3, “Application of coating systems” (VGBE-S-021-03-2023-05-EN), 2023
- Part 4, “Cathodic corrosion protection” (VGB-S-021-04-2018-07-EN), 2018

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Suggestions for amendments can be sent to the following email addresses of vgbe energy [vgbe.standard@vgbe.energy](mailto:vgbe.standard@vgbe.energy) or BAW [info@baw.de](mailto:info@baw.de). The subject line should contain the brief designation of the document in question so that the content can be clearly assigned.

The standard has been revised and comments made by the members of the

- Federal Association for Corrosion Protection (BVK),
- Association of the German Paint and Printing Ink Industry (VDL),
- Operators of offshore wind turbines and offshore-stations

and others.

Essen, March 2023

Karlsruhe, March 2023

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## Part 1 – General

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## 1 General

Unprotected steel corrodes in the atmosphere, in water and in wet soil, possibly giving rise to damage. To avoid such corrosion damage, steel structures are protected so that they can withstand corrosion stresses during their service life.

Offshore structures are exposed to strong corrosive influences over a long period, while the conditions for maintenance and repair are poor. Along with corrosion protection systems that must meet the highest demands, the idea of a corrosion protection strategy must be taken into consideration. This means, among other things, that the specific stresses in the various areas of offshore structures, and also the combination of several methods of protection, e.g. coatings, cathodic protection and corrosion allowances must also be taken into consideration.

This standard is concerned with offshore structures made of steel. In its various parts it takes account of all essential factors having significance for appropriate corrosion protection.

## 2 Scope

The VGBE/VGB-S-021 standard with all its parts regulates the requirements for areas with corrosion protection of the following components of the primary structure of offshore wind turbines and offshore stations which are exposed to water and atmosphere (see Figure 1 and Figure 2). The primary structure includes all load-bearing structural elements that are in the main flow of forces and are essential for stability.

This standard does not regulate requirements for coatings that are only intended for protection during transportation (temporary corrosion protection) and/or the commissioning phase (e.g. line coating for weld seams) but not for the entire service life.

*Note:*

*The application of this vgbe/BAW standard can also be agreed between the parties for structures outside the normal area of application, e.g. for towers and topsides.*

### 2.1 Offshore wind turbines

The scope of offshore wind turbines (figure 1) includes the substructure and the locally fixed structures (foundation elements such as piles or suction buckets) in the atmospheric area, underwater area and in the top 2 m of the seabed. Installation tolerances and scour must be taken into account.

In the upper area of the seabed, increased microbial induced corrosion (MIC) is to be expected, therefore the risk of MIC must also be assessed individually below the 2 m limit in accordance with ISO 24656.



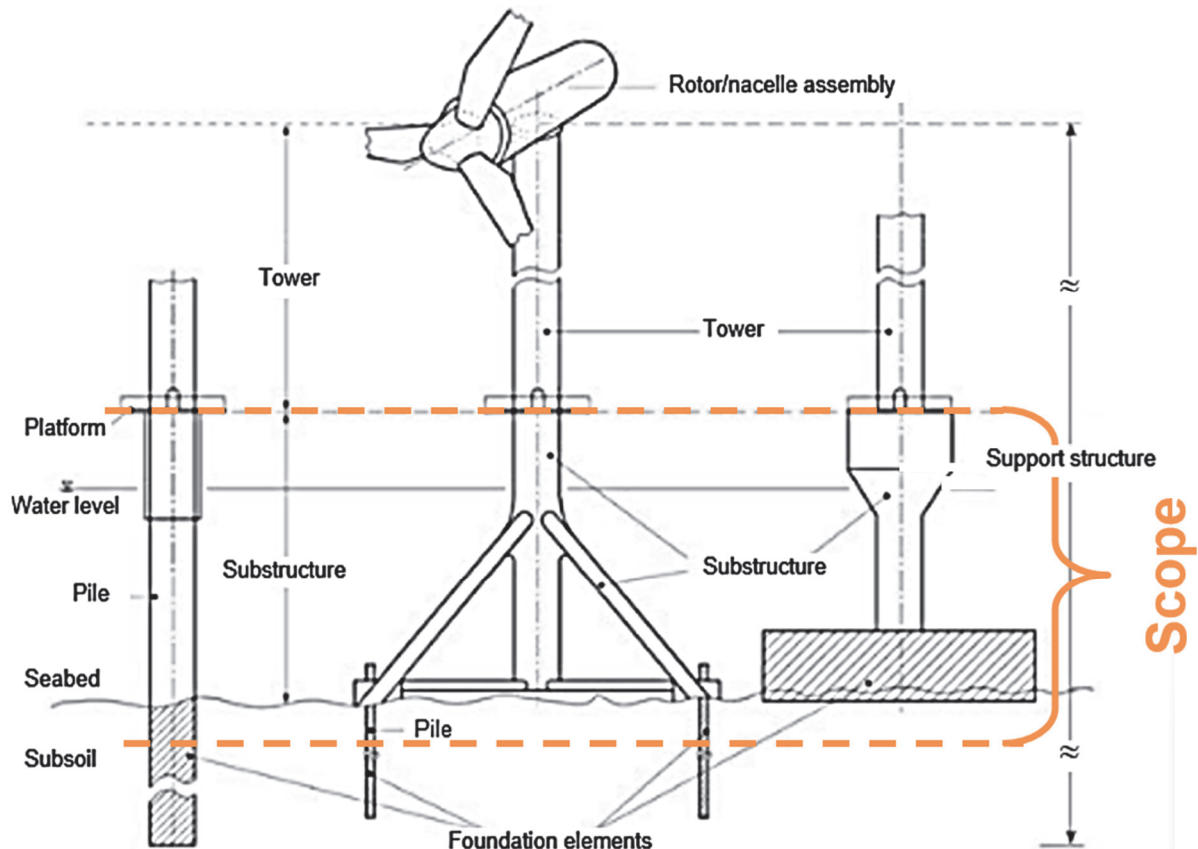


Fig. 1: Schematic diagram – examples of support structures for offshore wind turbines to illustrate the scope of application of this standard.  
Source: BSH standard design

## 2.2 Offshore converter stations

The scope of offshore stations (Figure 2) includes the locally fixed structures in the seabed (foundation elements such as piles or suction buckets) limited to the area of expected microbial induced corrosion (MIC), which is expected in the top 2 m of the seabed in accordance with ISO 24656 and must be extended to include installation tolerances and any scour.

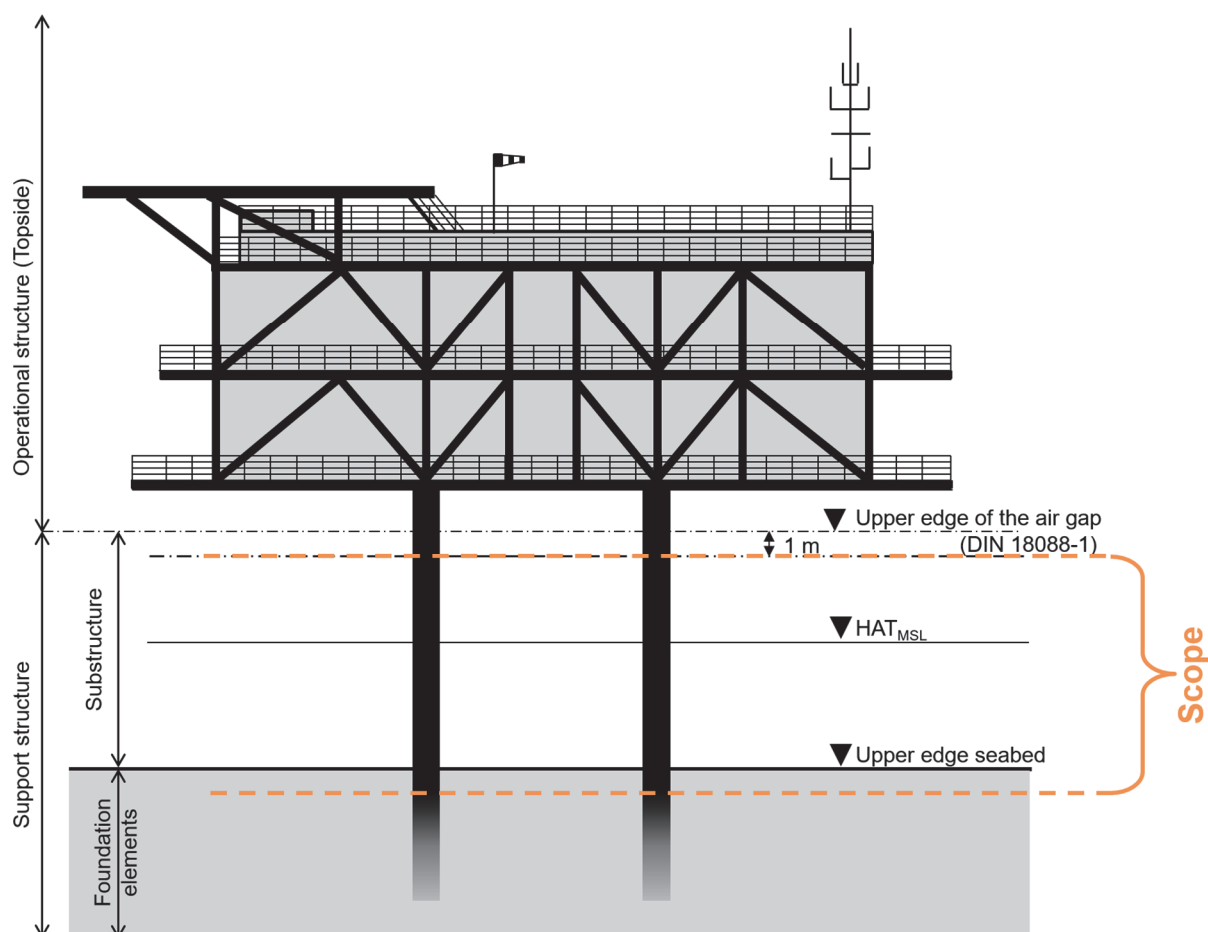
The scope of offshore stations also includes the structure up to the upper edge of the air gap (to DIN 18088-1), based on the mean sea level (MSL), reduced by one meter.

$$\text{Scope [m]} = \text{Top of air gap} - 1$$

*Example for calculation of the top of the air gap:*

$$\text{Scope [m]} = HAT_{MSL} + StS_{50} + HC_{50} + \Delta_{Inst} + S + SLR + 0.2 * HS_{50}$$

$HAT_{MSL}$	Highest astronomical tide in relation to mean sea level
$StS_{50}$	Storm surge with a 50 year recurrence period
$HC_{50}$	Wave crest with a 50 year recurrence period
$\Delta_{Inst}$	Possible installation tolerance
$S$	Settlement at the end of the operating phase
$SLR$	Sea level rise during the operating phase
$HS_{50}$	Significant wave height with a 50 year recurrence period



**Fig. 2:** Schematic diagram – Example of an offshore station (HVDC converter) to illustrate the area covered by this standard.

### 3 Service life and durability

The structural steelwork of offshore structures is designed for a service life of at least 25 years. No total refurbishment of the corrosion protection is planned during the service life. The durability of the corrosion protection must therefore also be at least 25 years and therefore falls into the very high (vh) durability as defined in ISO 12944-1. This means that it exceeds the requirements of ISO 12944-9.

### 4 Stress zones

Corrosion protection systems have to withstand a variety of stresses such as exposure to underwater, tidal water, splash water in a marine atmosphere, extreme temperature fluctuations, strong ultraviolet exposure or ongoing mechanical damage and abrasion.

Depending on location and environmental influences, different stress zones are defined for offshore structures. The stress zones are shown using a wind turbine with monopile foundations as an example; see Figure 3 and Table 1.

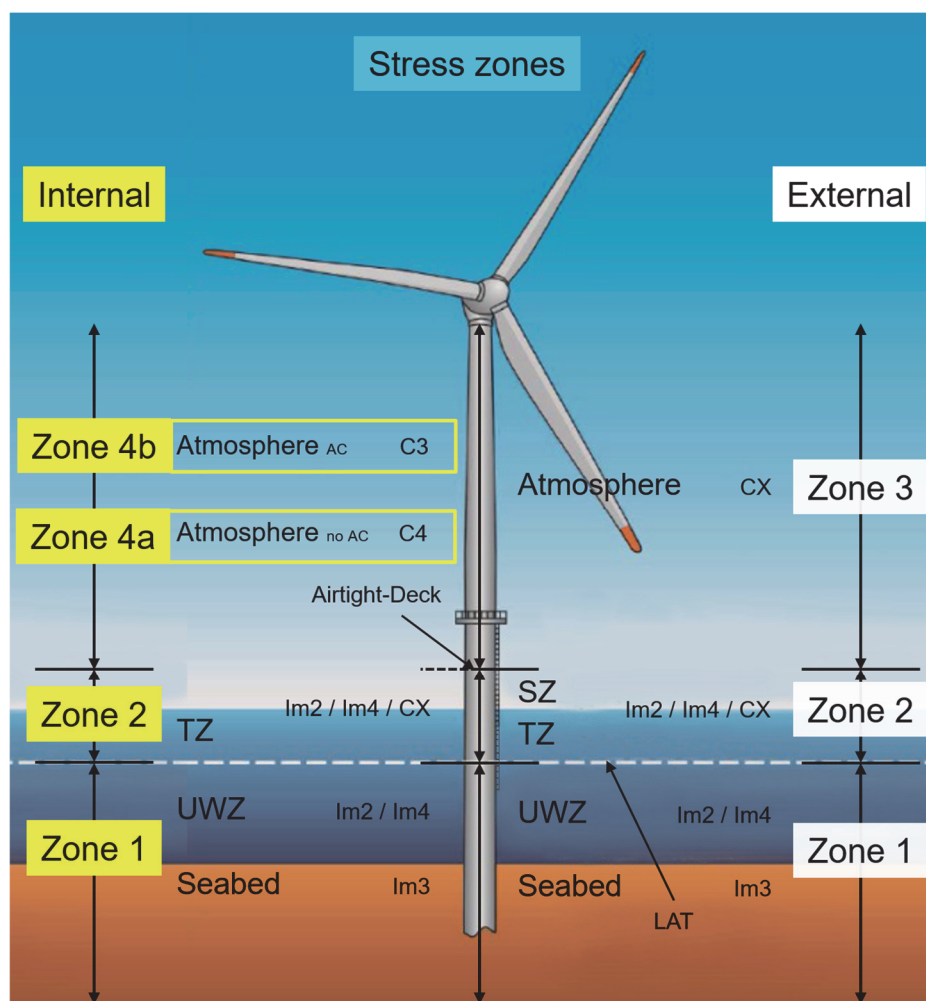


Fig. 3: Schematic diagram of the stress zones on an offshore structure;  
Im4 = Im2 with CCP; LAT = Lowest Astronomical Tide

The height of the splash zone can be calculated in a manner similar to that presented in IEC 61400-3-1.

The coating system for zone 2 can be applied to zones 3 and 4a/b in whole or in part in order to achieve an optimized design from a manufacturing point of view. This also applies to zone 3 coating systems that may be used in zones 4a/b.

Zone 4b is air-conditioned (AC) and has a permanent relative humidity of less than 60 %. In addition, suitable measures for transportation and installation time must be ensured for this zone.

Table 1: Stress zones and corrosive stress areas

Zone	Corrosive stress areas	Adapted from the corrosivity categories set out in ISO 9223 und ISO 12944-2
4b	Atmosphere, internal (air-conditioned)	C3
4a	Atmosphere, internal (not air-conditioned)	C4
3	Atmosphere, external	CX
2	External – Splash zone (SZ) – Tidal zone (TZ)	Im2 / Im4 / CX Im2 / Im4 / CX
	Internal – Atmosphere below the airtight deck – Tidal zone (TZ) *	CX Im2 / Im4 / CX
1	Underwater zone (UWZ), external and internal	Im2 / Im4
	Soil, external and internal	Im3

Im4 = Im2 with cathodic protection

\* The existence of a tidal zone is dependent on the design of the foundation structure.

## 5 Corrosion protection plan

A plan for the corrosion protection of offshore structures, including repair and accessibility plans, is to be compiled. The corrosion protection plan shall take into account both passive and active corrosion protection or a combination of the two.

With regard to the minimum requirements for corrosion protection plans, reference is made to the current issue of “BSH Standard Design – Minimum requirements concerning the constructive design of offshore structures within the exclusive economic zone (EEZ)”.

Over and above that standard, the specific minimum requirements of individual countries and the regulations etc. of the relevant authorities for the locations of the wind turbines, wind farm components and other offshore structures for the use of wind energy must be taken into account for the requirements and design of the corrosion protection.

As part of the plausibility proof at the BSH, a summarizing profile must also be created to ensure that the corrosion protection plan is clear. A project-related profile template is shown in the appendix. This template can be downloaded from [www.baw.de](http://www.baw.de).

## 6 Design of steel structures and their surfaces

In order to achieve the required durability of coating systems for offshore structures, ISO 12944-3 and ISO 8501-3 must already be taken into account during planning and design, and allowance made for the possibility of maintenance or refurbishment of the corrosion protection systems.

Components which are subject to corrosive stresses and are no longer accessible for corrosion protection measures after erection must have corrosion protection that is so effective that structural safety is ensured during the service life of the offshore structure. If this cannot be achieved with corrosion protection systems, other steps must be taken (e.g. manufacture of components from corrosion-resistant material, replaceability of components, or stipulation of a corrosion allowance).

## 7 Duplex system – metallisation

Metallisation in combination with an organic coating constitutes a duplex system. Metallisation without a further organic coating is not permitted within the scope of this standard.

Thermal spraying is currently regarded as the only method of producing a metallisation on primary structures.

The thermally sprayed metallic coating is to be applied in accordance with ISO 2063. For thermal spraying, the relevant qualifications, approvals and regulations for the companies carrying out the work, which must present a certificate of suitability in accordance with ISO 2063-2, must be observed:

- ISO 12690 Thermal spray coordination,
- ISO 14918 Qualification testing of thermal sprayers, and
- ISO 14923 Characterization and testing of thermally sprayed coatings.

In addition, the requirements of Part 2 are to be fulfilled.

## 8 Cathodic corrosion protection

Cathodic corrosion protection (CCP) systems provide active protection by means of an appropriately rated protective current and the resulting protective potential in areas in contact with water (zones 1 and 2), thereby reducing the corrosion rate on offshore structures. The VGB/BAW Standard VGB-S-021-04 (Part 4) “Cathodic Corrosion Protection (CCP)” and ISO 24656 provide recommendations and information on the cathodic corrosion protection of offshore wind farm structures.

A distinction is made between the following CP systems:

- Impressed current cathodic protection (ICCP)
- Galvanic protection

Hybrid systems, which consist of a combination of an impressed current cathodic protection and a galvanic protection, are generally used when the offshore structures remain without a power supply for an extended period during the installation phase. In this phase, the galvanic protection initially provides the cathodic protection. Once the power supply has been restored, the galvanic protection can support the impressed current cathodic protection.

The combination of cathodic corrosion protection with corrosion protection by coating systems can lead to reduced power consumption. This changes the design of impressed current systems and galvanic anodes, the possible negative effects of which on the marine environment have not yet been conclusively clarified [Kirchgeorg et al.].

Impressed current cathodic protection is to be equipped with measuring, monitoring and control systems in order to monitor and control the main system parameters centrally. Monitoring systems are recommended for galvanic protection systems, e.g. to detect possible passivation of the anodes at an early stage; alternatively, as a minimum, the functionality of the anodes must be verified at regular intervals using a measurement plan.



## 9 Standards and codes of practice

List of standards and regulations in force at the time of publication of this standard:

### Standards:

DIN 18088-1:2019-01	Structures for wind turbines and platforms – Part 1: Basic principles and actions
EN 1090-2:2018-09	Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures
IEC 61400-3-1:2020-11	Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines
ISO 2063-1:2019-07	Thermal spraying – Zinc, aluminium and their alloys – Part 1: Design considerations and quality requirements for corrosion protection systems
ISO 2063-2:2017-09	Thermal spraying – Zinc, aluminium and their alloys – Part 2: Execution of corrosion protection systems
ISO 8501-3:2006-03	Preparation of steel substrates before application of paints and related products – Visual assessment of surface cleanliness – Part 3: Preparation grades of welds, edges and other areas with surface imperfections
ISO 9223:2012-02	Corrosion of metals and alloys – Corrosivity of atmospheres – Classification, determination and estimation
ISO 12690:2010-12	Metallic and other inorganic coatings – Thermal spray coordination – Tasks and responsibilities
ISO 12944-1:2017-11	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 1: General introduction
ISO 12944-2:2017-11	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 2: Classification of environments
ISO 12944-3:2017-11	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 3: Design considerations
ISO 12944-9:2018-01	Paints and varnishes – Corrosion protection of steel structures by protective paint systems – Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures

ISO 14918:2018-04	Thermal spraying – Qualification testing of thermal sprayers
ISO 14923:2003-07	Thermal spraying – Characterization and testing of thermally sprayed coatings
ISO 24656:2022-09	Cathodic protection of offshore wind structures

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Part 4 “Cathodic corrosion protection (CCP)” (VGB-S-021-04-2018-07-EN), 2018

Codes of practice (in the current version):

BSH Standard Design	Minimum requirements concerning the constructive design of offshore structures within the exclusive economic zone (EEZ)
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## 10 Literature

Kirchgeorg, T. et al.: Emissions from corrosion protection systems of offshore wind farms: Evaluation of the potential impact on the marine environment, Elsevier, Marine Pollution Bulletin 136 (2018) 257–268

## 11 Appendix

A template for the project-related profile (in English) for submission to the BSH can be downloaded from [www.baw.de](http://www.baw.de).  
The following example is provided for illustration purposes.

Name of project: \_\_\_\_\_

BSH approval phase: ☐ First ☐ Second

Construction [number]: ☐ WT [ ] ☐ Offshore Station ☐ Other

Foundation: ☐ Monopile ☐ Jacket ☐ Gravity Base ☐ Other

Site: ☐ North Sea ☐ Baltic Sea

Planned corrosion protection measure(s) at the foundation:

☐ Organic coating ☐ ICCP ☐ Galvanic anodes [total weight: \_\_\_\_\_ kg]  
☐ Thermally sprayed coating ☐ Remote-ICCP ☐ Other

**Column explanation for table:**

- 1) e.g.: Monopile grout zone, Jacket submerged, Pile bottom, Transition piece, Secondary Steel etc.  
 2) Full description of outside and inside corrosion protection measures from tower to tip of pile  
 4) According to zone 1-4 in Fig. 1 (VGBE-S-021-01)  
 5) Galvanic anodes with alloy specification (e.g.: Al-anodes)  
 6) e.g.: 1 x 120 µm TSZ  
 7) e.g.: 1 x 80 µm EP-Zn(R), 2 x 250 µm EP, 1 x 80 µm PUR  
 8) e.g.: grout, stripe coating, corrosion allowance [mm]

Detailed corrosion protection measures: (filled with examples)

1	2	3	4	5	6	7	8	9
Construction element	Outside / inside	Height related to LAT or MSL [m]	Zone 1-4	Cath. corrosion protection	Coating [from substrate to top]		Other	Source (related to column)
				ICCP and/or galvanic anodes	Thermally sprayed layer, number of layers, NDFT, alloying	Organic layer, number of layers, NDFT, binder		
Monopile submerged	Outside	-6.0 to -36.2 m	Zone 1	ICCP	-	3x 200 µm EP	-	DOK-123.pdf (3) ICCP-815.pdf (5) COAT-789.pdf (7)
Monopile floor	Outside	-36.2 to -43.9 m	Zone 1	ICCP	-	-	Stripe coating	DOK-123.pdf (3) ICCP-815.pdf (5) COAT-789.pdf (8)
Monopile grout zone	Outside	+2.5 to +2.0 m	Zone 2	-	-	3x 200 µm EP	Grout, corrosion allowance [1.2 mm]	DOK-123.pdf (3) COAT-789.pdf (7) COAT-789.pdf (8) DES-101.pdf (8)
Transition piece	Outside	+21.2 to -7.0 m	Zone 2	Al-anodes	-	3x 200 µm EP 1x 80 µm PUR	-	DOK-123.pdf (3) GAL-456.pdf (5) COAT-789.pdf (7)
Sec. steel	Outside	n.a	Zone 1-2	-	1x 100 µm TSZ (Zn/Al 15) with 40 µm Sealer or 1x 100 µm HDG	3x 200 µm EP 1x 80 µm PUR	-	GAL-456.pdf (6) COAT-789.pdf (7)

Appendix: Construction draft if available

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