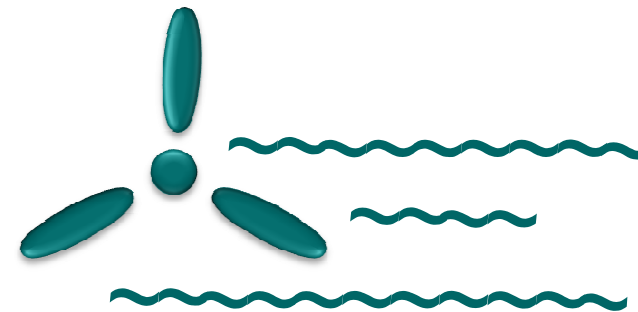


Assessment of Corrosion in Offshore Environment. Study in Windfloat Prototype:

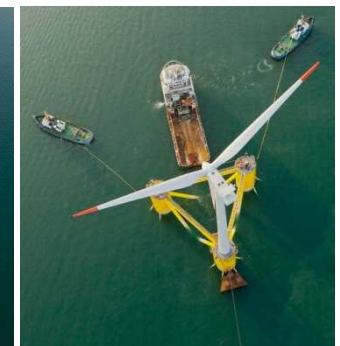
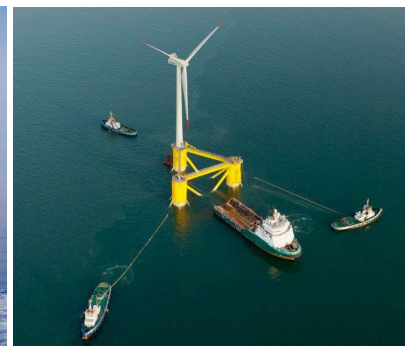
WIND_ENERMAR Project

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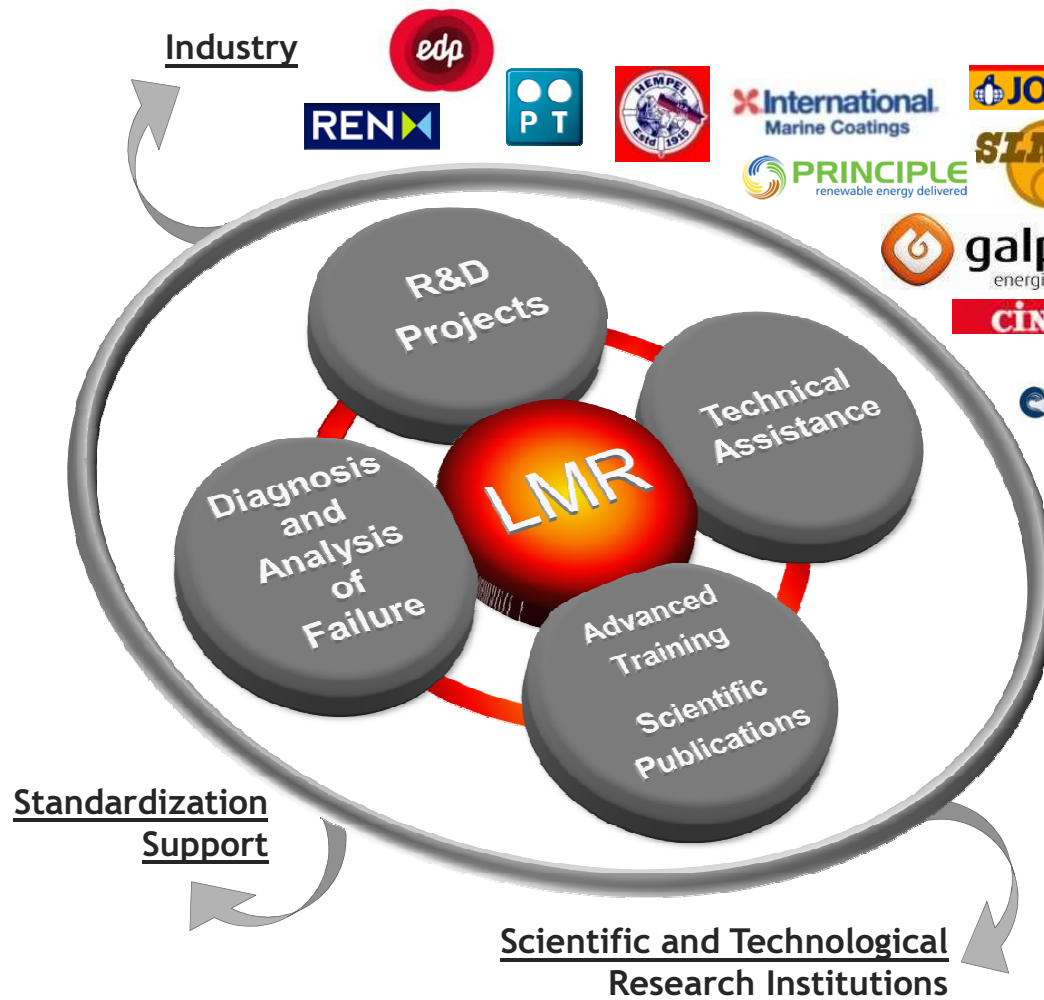


LNEG/LMR - Materials and Coatings Laboratory



Who we are

The Materials and Coatings Laboratory (LMR) is a specialized Centre in the area of Corrosion and Anticorrosive Protection of materials .



Its main competences include the following:

- Detection, study and prevention of corrosion;
- Definition of materials including surface treatments, metallic and organic coatings;
- Characterization of environments in natural ageing studies;
- Evaluation of anticorrosive protection of structures and/or equipment;
- Physical, chemical and mechanical characterization of materials;
- Diagnosis and analysis of failure in coated structures and/or equipment

OCEAN RENEWABLE ENERGY



The European energy situation and policy imply a greater dependence on the seas, oceans and harbours which indicates an increase in synergies between the energy and maritime policies. Not only because the forecasts for energy maritime transport in European waters (oil tankers, gas tankers, pipelines and submarine power cables) point out to a significant growth within the next years, but also due to the fact that the European maritime areas are a relevant resource of energy.

Different energy conversion technologies ...

Distinct level of technical, economic or industrial maturity ...

But one point in common...

High corrosiveness of marine environment

More work is needed to fully understand the effects of physical, chemical and biological factors present in marine environment and to devise materials and coatings that provide cost-effective protection.

CORROSION CHALLENGES in OFFSHORE WIND ENERGY

For offshore wind energy towers in contact with open sea water, different types of corrosion occurs for distinct exposure zones:

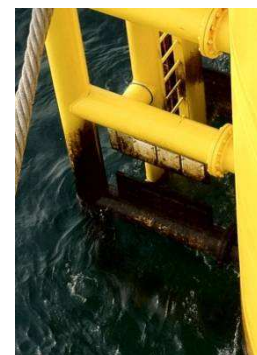
- Atmospheric
- Submerged
- Splash
- Soil

Marine corrosion is also dependent on geographical location and its environmental parameters (water chemistry, physical and biological factors ...)

- Factor as:**
- Long-term exposure to humidity with high salinity
 - Intensive influence of UV light
 - Wave and current actions
 - Biofouling ...

Lead to high corrosion risks:

- Severe corrosion splash zone
- Accelerated low water corrosion (ALWC)
- Uniform corrosion
- Local corrosion
- Microbiologically influenced corrosion (MIC)
- Erosion corrosion
- Fatigue corrosion



CORROSION PROTECTION in OFFSHORE WIND ENERGY

Partnership with offshore sector to enhance understanding and technological development on corrosion and anticorrosive protection for offshore wind structures.



Offshore wind energy sector has focused on the importance of **reducing the costs of installation, operation and maintenance**, which are **significantly higher in the marine environment**, less accessible and significantly more aggressive than the onshore environment.

Prevention and corrosion control play a key role in the feasibility of energy exploitation in marine environment

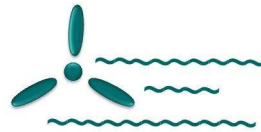
Study of corrosion mechanisms, together with the correlation between tests on sea and laboratory tests allow, not only to mitigate damage caused by corrosion phenomenon and to increase the longevity of renewable marine energy systems but **simultaneously to reduce the costs associated with capital investment and maintenance procedures and repairs.**

With the first offshore floating wind turbine demonstration project being carried out in Portugal, **WindFloat Project**, a unique opportunity to assess metal corrosion and anticorrosive protection systems efficiency in offshore environment was created.

This kind of assessment has never been performed in Portugal.

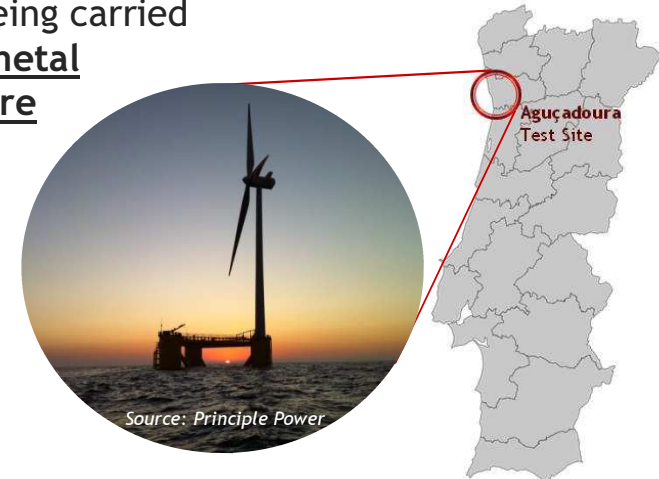
In these context, LMR carried out the

Wind_Enermar project



"Prevention and corrosion protection for offshore energy. Experimental study on WindFloat prototype"

which involved the exposure of steel samples with and without application of different paint systems, selected according to the different sections of the WindFloat platform: atmospheric, splash and immersed zone.



Source: Principle Power

Project Schedule (2011 – 2014)

Phase 1: Samples preparation and exposure in WindFloat prototype.

Phase 2: Laboratory study using tests methods acc. with standards and specifications for offshore sector.
Characterization of materials.

Phase 3: Evaluation and dissemination of results.

The project experimental design proposed was based on the ISO 9226 standard for the evaluation of atmospheric corrosivity and on current standards, ISO 12944, ISO 20340 and NORSOK M 501, for corrosion protection study of offshore structures.

PHASE 1 - Samples Preparation and Exposure on WindFloat Prototype

Substrate material: AH36 Structural steel

Surface Preparation:

Abrasive blasting to Sa 3 acc. ISO 8501-1 - Steel with metallization + organic coatings.

Abrasive blasting to Sa 2^{1/2} acc. ISO 8501-1 - Steel + organic coatings.

Polished with 120 grit abrasive paper acc. ISO 9226 and ISO 9223 - Steel samples without organic coatings.

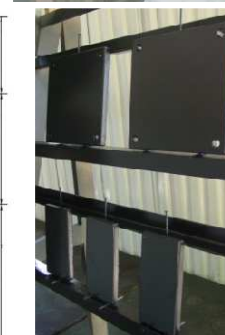
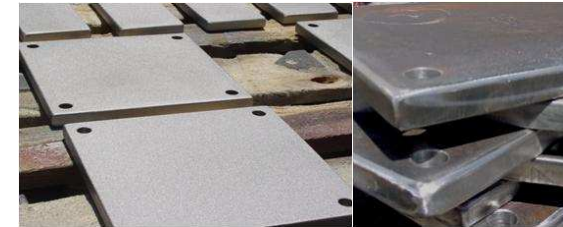
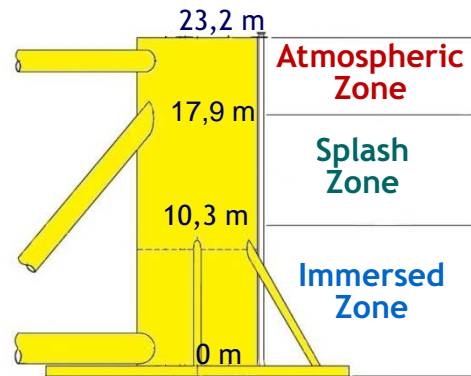
Coating Application:

Nine painting systems were applied following the guidelines described in the paint's technical data sheets, three systems for each zone: atmospheric, splash and immersed zone. These coatings were applied under real conditions work.

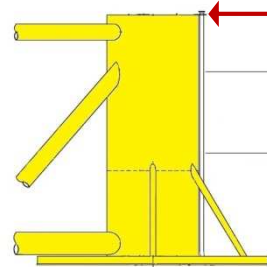
The coatings thickness were evaluated according to NP EN ISO 2808

In the case of atmospheric zone, samples with and without scribed organic coatings were exposed. The scribes were made at LNEG/LMR with 1mm milling cutter down to the steel substrate.

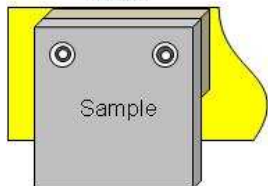
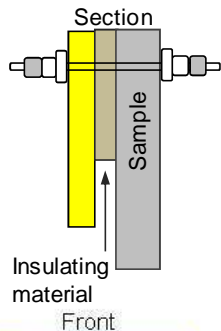
Since October 2011 steel samples with and without paint systems are exposed on different sections of the windfloat platform deployed of at Aguçadoura test site, North sea of Portugal.



ATMOSPHERIC ZONE



8 Steel samples all with (250x250x17)mm
12 Steel samples with and without scribed organic coatings



Exposed Coating Systems

distribution and thickness	chemical composition
----------------------------	----------------------

320 μm	Top coat	60 μm
	Intermediate coat	100 μm
	Intermediate coat	100 μm
	Primer	60 μm
Steel		

TC: Polyurethane with aliphatic isocyanate (contains zinc phosphate)
 IC: Epoxy-polyamide
 P: Zinc rich epoxy

System AZ1

260 μm	Top coat	100 μm
	Intermediate coat	100 μm
	Primer	60 μm
Steel		

TC: Polysiloxane with high-solids
 IC: Epoxy with synthetic mineral fibres and aluminium pigments
 P: Zinc rich epoxy

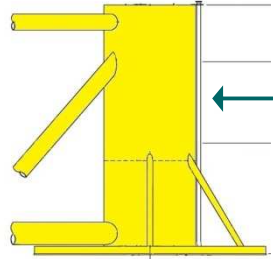
System AZ2

310 μm	Top coat	60 μm
	Primer	second layer 150 μm first layer 100 μm
	Metallization	80-100 μm
Steel		

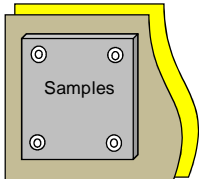
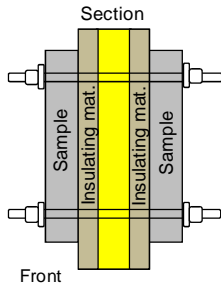
TC: Aliphatic acrylic polyurethane
 P: Epoxy
 Zinc metallization

System AZ3

SPLASH ZONE



12 Steel samples (250x250x17) mm
and (150x150x17)mm
24 Steel samples with organic
coatings (250x250x17)mm



Exposed Coating Systems

Distribution and thickness	Chemical composition
----------------------------	----------------------

675 μm	Top coat	75 μm
	Intermediate coat	200 μm
	Intermediate coat	200 μm
	Primer	200 μm
		Steel

TC: Polyurethane with aliphatic isocyanate (contains zinc phosphate)
IC: Epoxy-polyamide / amine
P: Epoxy-polyamide / amine

System SZ2

660 μm	Top coat	60 μm
	Intermediate coat	200 μm
	Intermediate coat	200 μm
	Primer	200 μm
		Steel

TC: Polysiloxane with high-solids
IC: Epoxy-polyamide / amine
P: Epoxy with synthetic mineral fibres and aluminium pigments

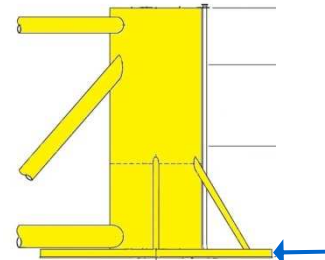
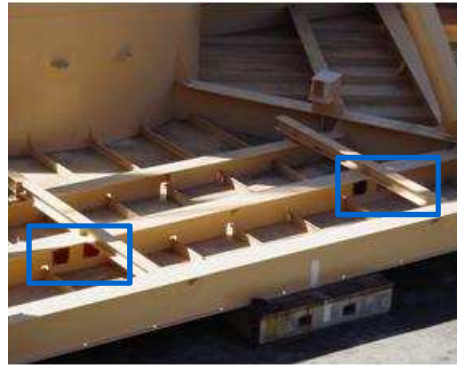
System SZ2

560 μm	Top coat	60 μm
	Intermediate coat	second layer 100 μm first layer 300 μm
	Primer	100 μm
	Metallization	80-100 μm
		Steel

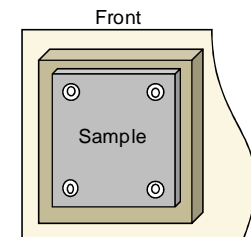
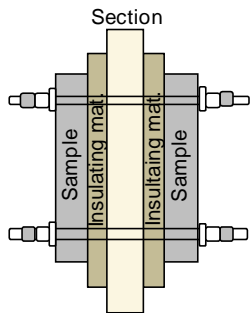
TC: Aliphatic acrylic polyurethane
IC: Epoxy polyamine reinforced with glassflake
P: Epoxy-polyamide
Zinc metallization

System SZ3

IMMERSED ZONE



2 Steel samples
6 Steel samples with organic coatings all with (250 x250x17)mm



Exposed Coating Systems

Distribution and thickness	Chemical composition
----------------------------	----------------------



TC: Epoxy-polyamide/amine
P: Epoxy-polyamide/amine

System IZ1



TC: Silicone
S: Silicone
IC: Epoxy-polyamide/amine
P: Epoxy-polyamide/amine

System IZ2



TC: Epoxy polyamine reinforced with glassflake
P: Epoxy-polyamide/amine

System IZ3

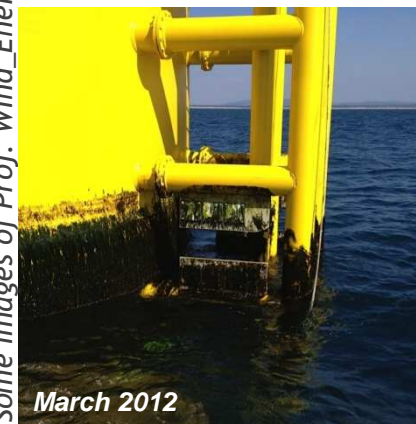
PHASE 2 - 2012 / 2013

Assessment of steel corrosion and anticorrosive behavior of coatings systems before and after field and laboratory tests:

- Colour and change of colour (ISO 7724 - 2)
- Adhesion / pull-off (EN ISO 4624)
- Specular gloss (ISO 2813)
- Corrosion rate of steel (ISO 9226)
- Laboratory ageing test (ISO 20340/NORSOK M- 501)
- SEM / EDE
- XRD

PHASE 3 - Evaluation and dissemination of results

In the end of this project LMR wants to have achieved the optimization and development of corrosion and anticorrosive protection skills for offshore energy exploration, that will allow to increase the competitiveness of the distinct industrial partners directly and indirectly associated to this sector.



Some images of Proj. Wind_Enermar - Splash zone

Acknowledgements:

The authors wish to thank the financial support of
and



for providing WindFloat platform as test site.

THANK YOU VERY MUCH FOR YOUR ATTENTION