



# Welcome

WIND ASSURING CONFIDENCE  
THROUGH COMPETENCE

## Studies of heavy corrosion protection coatings

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## Short profile of Fraunhofer IWES Northwest

**Head of the institute:**

Prof. Dr. Andreas Reuter

**Research spectrum:**

Wind energy from material development to grid integration

**Overall budget 2012:**

around 11 million €

**Staff:**

130 employees

**Previous investments in the establishment of the institute:**

50 million €

Forschungsverbund  
Windenergie



Strategic association with **ForWind** and the German Aerospace Center (**DLR**)



**Fraunhofer**  
IWES



## Research spectrum:

Wind turbine as the sum of dynamically interacting subsystems



# Goal of the presentation

- Short overview on familiar and new products on the market
- Advantages and disadvantages of the visualization software used to compare various coating systems
  - Results of the research project „BESTkorr“
- View of MIC (microbial induced corrosion)
  - Risks of ICCP (impressed current cathodic protection) and interaction with microorganisms

# Agenda

- **Short market overview on familiar and new products**
- Visualization software to compare various coating systems
- MIC<sup>1</sup> and ICCP<sup>2</sup> Risk

<sup>1</sup>MIC – Microbial Induced Corrosion

<sup>2</sup>ICCP – Impressed Current Cathodic Protection

# Familiar and new products on the market

## Familiar products that are frequently in use

- < Epoxy resins
- < Polyurethane
- < ICCP / Sacrificial anodes

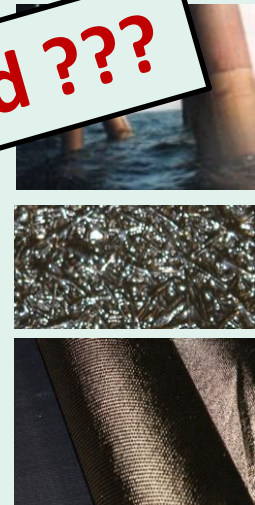
Standard

## New products or seldom used materials

- < Thermoplastic products like polypropylene, polyethylene
- < Coverings with Copper/Nickel alloys
- < Adhesive foil based systems
- < Composites in spray application
- < Composites combined with polymers
- < Textile composite materials

**How do they perform in Offshore-Wind ???**

Trends



# A simple visualization of coating properties to support commercial decisions is needed

## ✧ Problem

- ✧ Many different protection systems on the market
- ✧ Different advantages and disadvantages
- ✧ Nobody knows about all characteristics of these systems
- ✧ Only corrosion experts have a certain overview

- ✧ → **Businessmen make their decisions, in most cases, only considering the price of the product for the first application**

e.g.

**System 1**

20 \$ / m<sup>2</sup>

vs.

**System 2**

30 \$ / m<sup>2</sup>



# Research project **BESTKorr**

Partner: 5  
(2 scientific, 3 industrial)  
Budget: 380.000 \$  
Duration: 21 Months

**Project aim:** Visualization of coating properties to support commercial decisions

- ✧ Experimentation
  - ✧ application tests
  - ✧ laboratory tests
  - ✧ field tests
- ✧ Selected familiar and new corrosion protection systems of different brands

- ✧ Polyurethane
- ✧ 3-Layer epoxide resin
- ✧ 2-Layer epoxide resin
- ✧ 1-Layer epoxide resin
- ✧ Sacrificial anode

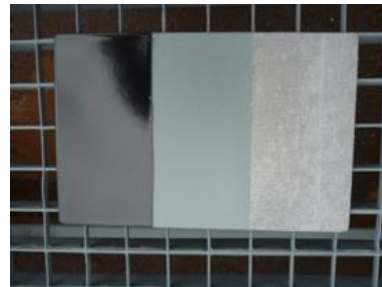
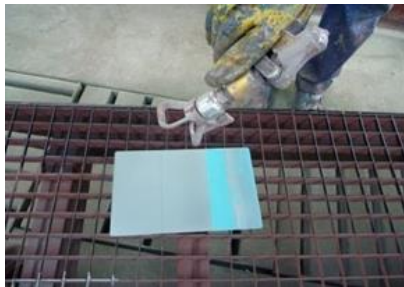
**Familiar**

- ✧ Coating with a foil
- ✧ Coating with a textile
- ✧ 1-Layer epoxide resin

**New**



# Application tests



# ISO 20340 – Results

## Corrosion progress on the artificial damage

Material	Zinc base coat	Small	Medium	Big	Corrosion creep [mm]
Polyurethane	Yes	x			0,2
1-Layer epoxide resin	No	x			1,5
1-Layer epoxide resin	Yes		x		0
Coating with a textile	Yes		x		0,4
Coating with a foil	Yes			x	0,7



1-Layer-EP



Foil



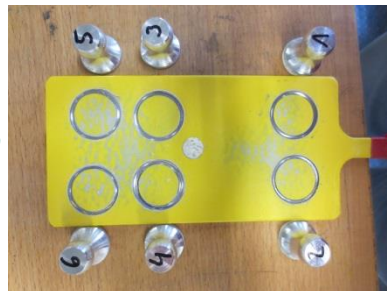
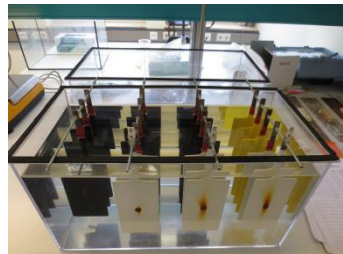
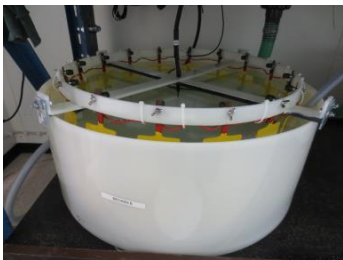
1-Layer-EP



Polyurethane

# DIN EN ISO 15711 – Results

## Loss of adhesion strength



over 25 Weeks

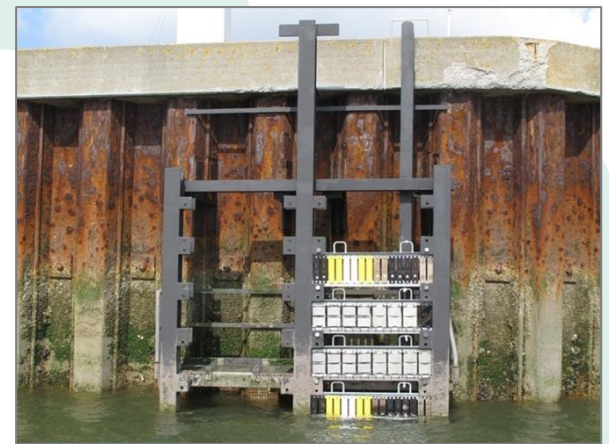
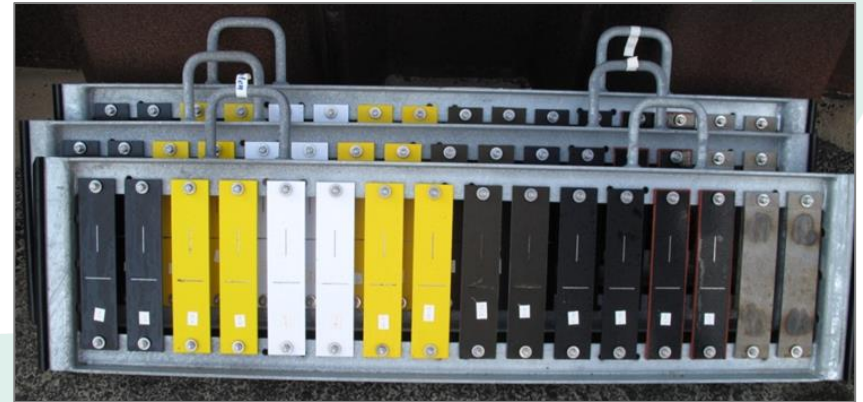
Material	Zinc base coat	Pull-off Strength <i>before</i> Test [MPa]	Pull-off Strength <i>after</i> Test [MPa]	Percentage of loss of adhesion strength
Polyurethan	Yes	6,55	6,14	- 6,3 %
1-Layer epoxide resin	No	2,73	2,39	- 12,4 %
1-Layer epoxide resin	Yes	7,61	5,12	- 33,0 %
Coating with textile	Yes	4,48	4,64	+ 3,6 %
Coating with a foil	Yes	0,92	1,09	(+18,5 %)

Longer test duration required !!

# Field tests on Sylt

Fixing the frames with the coupons in the field test rig for 12 Months

- Splash zone
- Tidal zone
- Submerged zone





# Marine growth in the submerged zone on Sylt



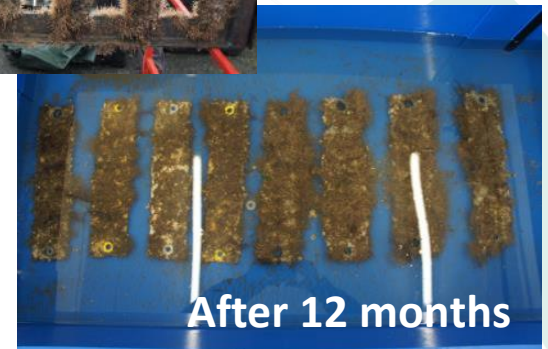
After 2 months



After 5 months



After 8 months

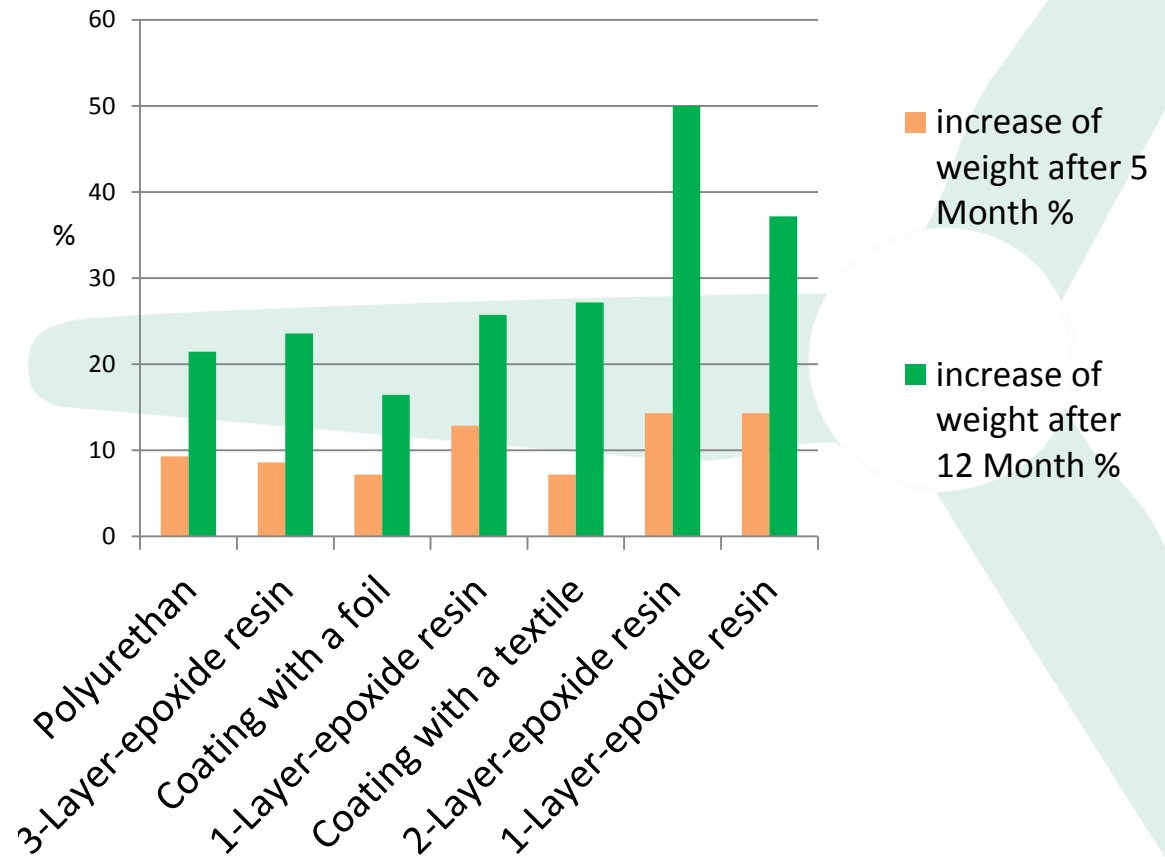


After 12 months

# Results after field test

## Mass of marine growth

Change of the weight of the coupons in the submerged zone related to the initial weight



# Agenda

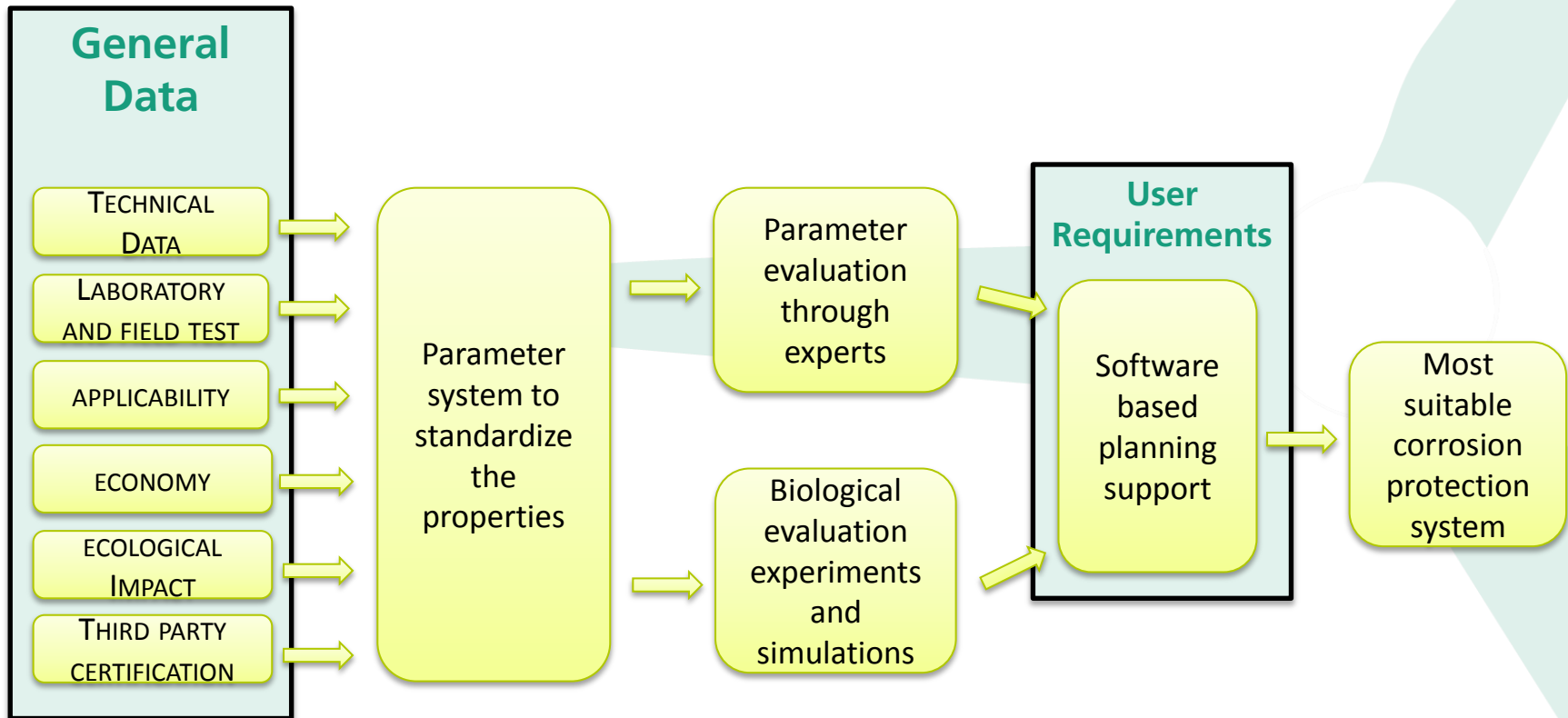
- Short market overview on familiar and new products
- **Visualization software to compare various coating systems**
- MIC<sup>1</sup> and ICCP<sup>2</sup> Risk

<sup>1</sup>MIC – Microbial Induced Corrosion

<sup>2</sup>ICCP – Impressed Current Cathodic Protection



# Evaluation tool to support user requirements



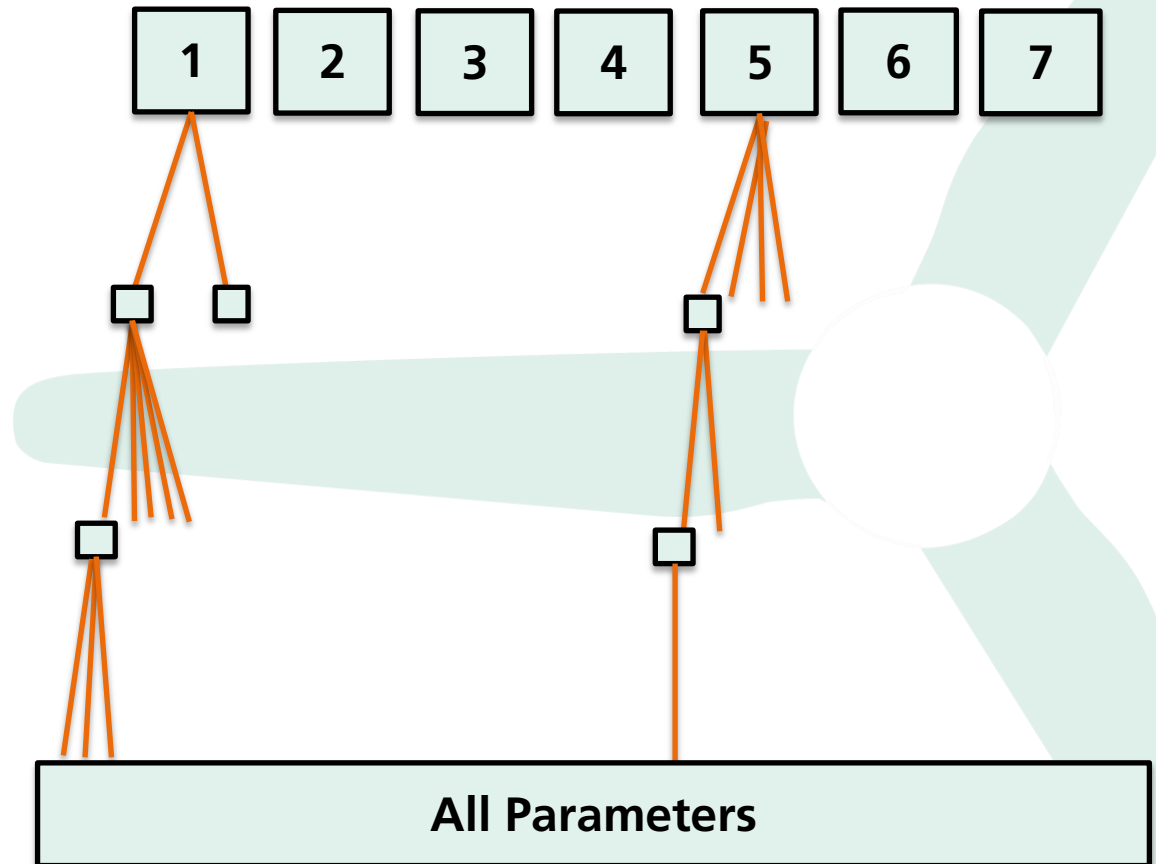
# Tree structure

7 Aspects

Level 1

Level 2

Level 3



# Analysis

Graphical diagram and analysis of two different systems

In 3 Levels

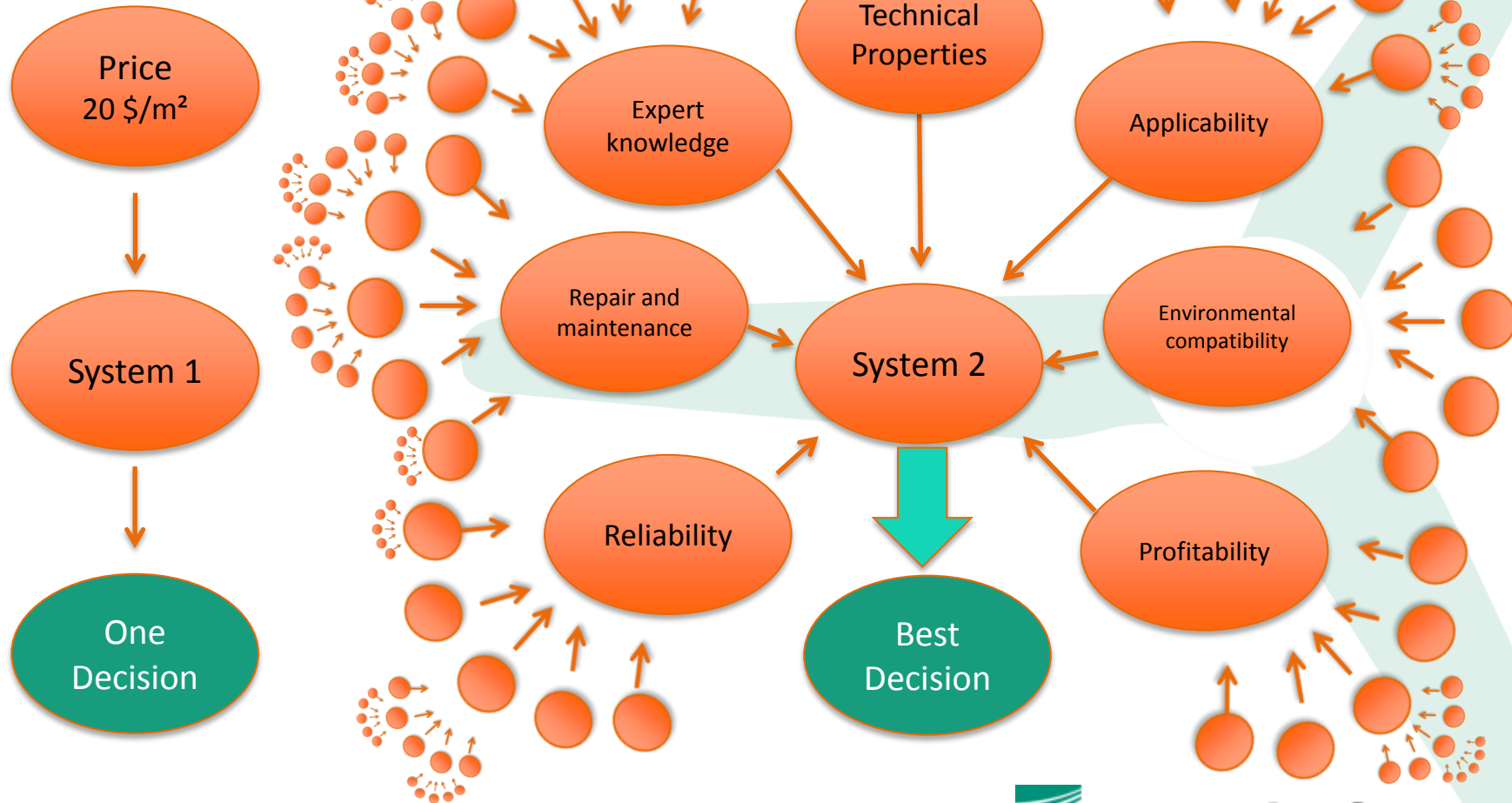
Aspects

Level 1

Level 2



# Decisions



# Agenda

- Short market overview on familiar and new products
- Visualization software to compare various coating systems
- **MIC<sup>1</sup> and ICCP<sup>2</sup> Risk**

<sup>1</sup>MIC – Microbial Induced Corrosion

<sup>2</sup>ICCP – Impressed Current Cathodic Protection

# MIC – Microbiological Induced Corrosion

**Where to find?**

**How it looks like...**

Known issues among others at:

- Watergates
- Harbor facility
- Pipelines
- Oil tank,
- Industrial water systems
- High-alloy steel
- .....



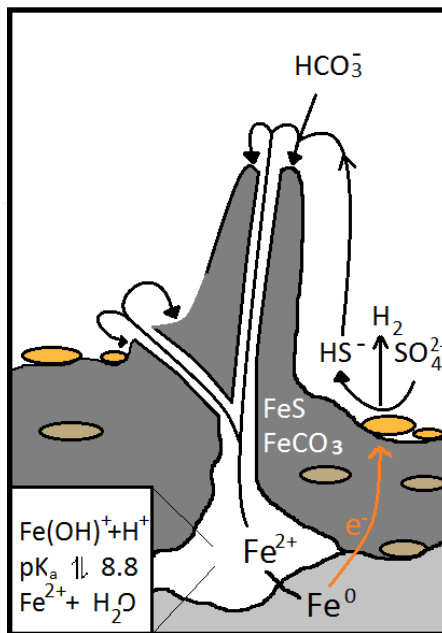
# MIC – High-alloy steel



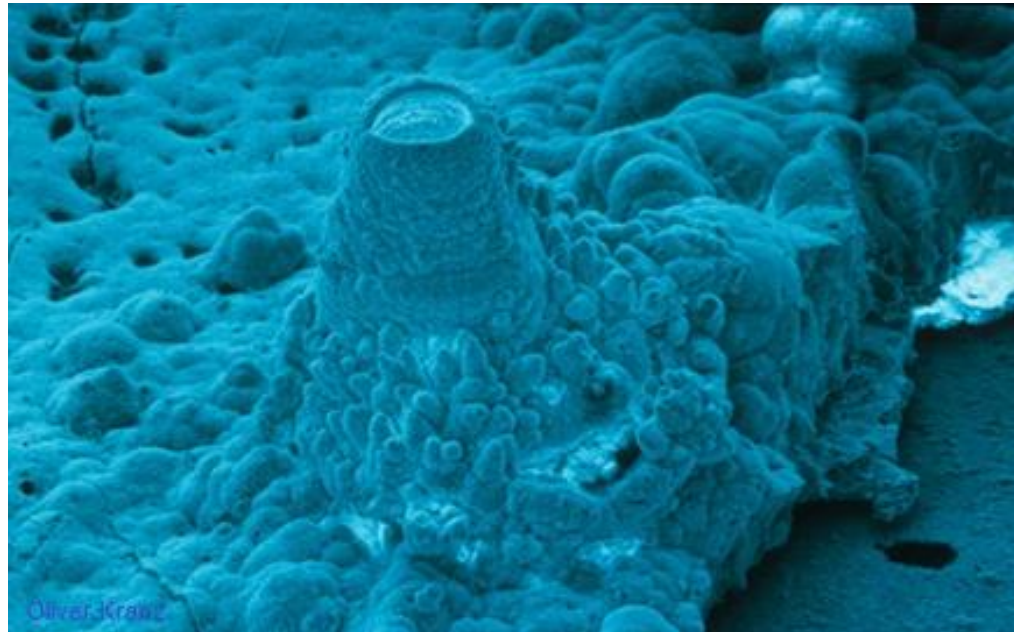


# Microbiological iron corrosion under electroconductive crust

Stoichiometry



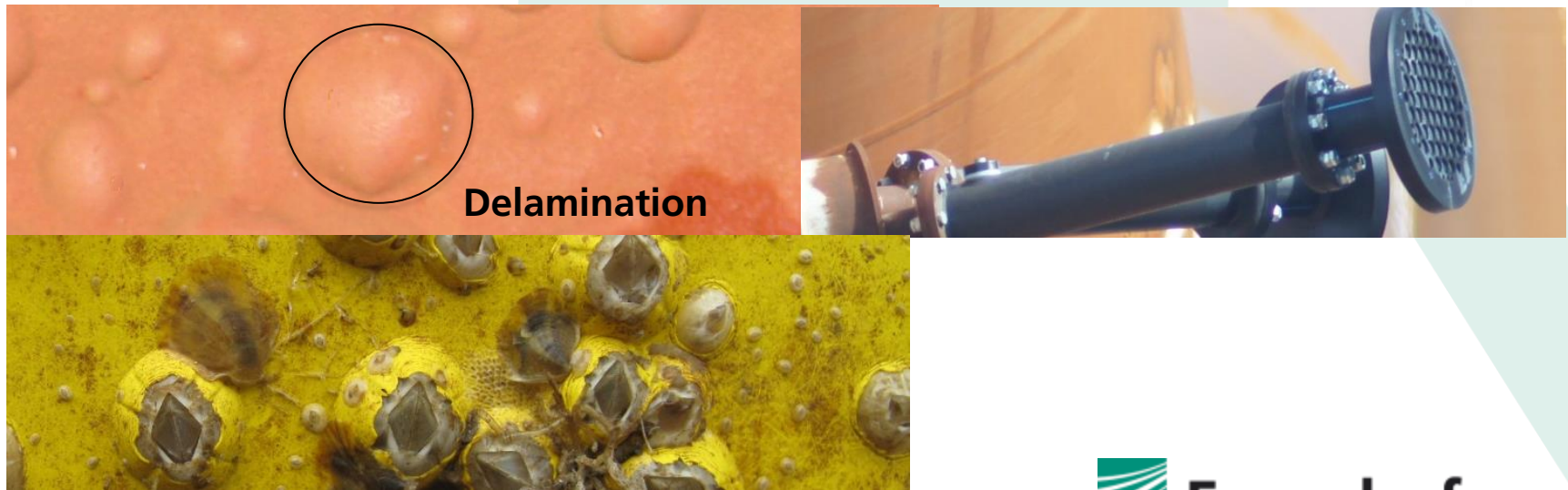
Grown semiconductive chimney



Reported pitting corrosion speed by Roland Baier from the BAW (Federal Waterways Engineering and Resource Institute) found at the Eder-dam in Germany about **20 mm/year**

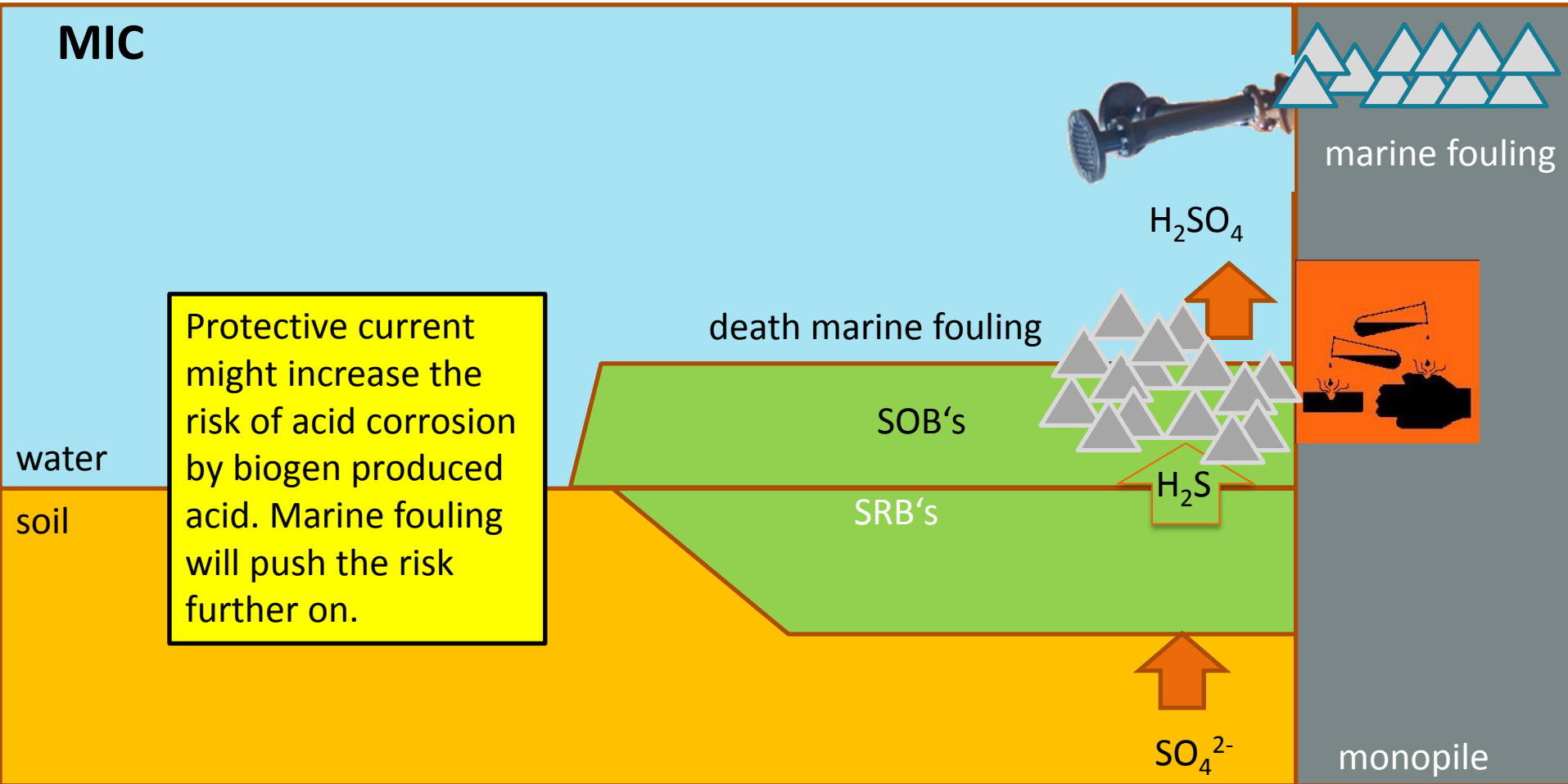
# Damages through protective current (ICCP) and/or marine fouling

- The damage in the coating might lead to almost similar conditions like the behavior mentioned (Eder-dam)
- Equal damages and corrosion rates might be possible
- **Optimal conditions for MIC**



# Mechanism of MIC

## MIC



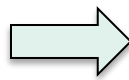
SRB = sulfate reducing bacteria  
SOB = sulfide oxidizing bacteria

# Verify the proteins by a specific enzyme assay (Micronaut Enviro)

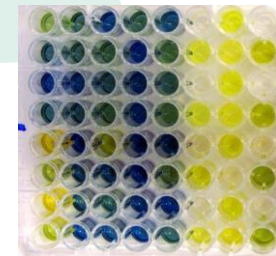
- User-friendly enzyme-assay for rapid detection of MIC
- Developed by **imare GmbH**, a partner institute of Fraunhofer IWES
- Used to initiate appropriate counter-measures



Simple, non-destructive sampling



Easy and fast preprocessing



MIC assay

# Conclusion - Evaluation Tool

- The Evaluation Tool – first decision support system for corrosion protection
- New and innovative products could also be involved in the comparison
- Decisions are no further depending only on the price of the first application

# Conclusion - MIC

- Can occur at different constructions and different iron materials
- ICCP can produce optimal conditions for MIC
- Marine fouling can operate as an activator and/or an accelerator
- Enzyme-assay can help to collect more knowledge about interaction with ICCP and distribution of MIC
  - Development of maintenance strategies for corrosion protection

# Acknowledgements

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Federal State of Hessen

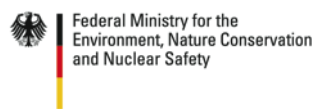
Federal State of Lower Saxony

Federal Republic of Germany

BMU Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

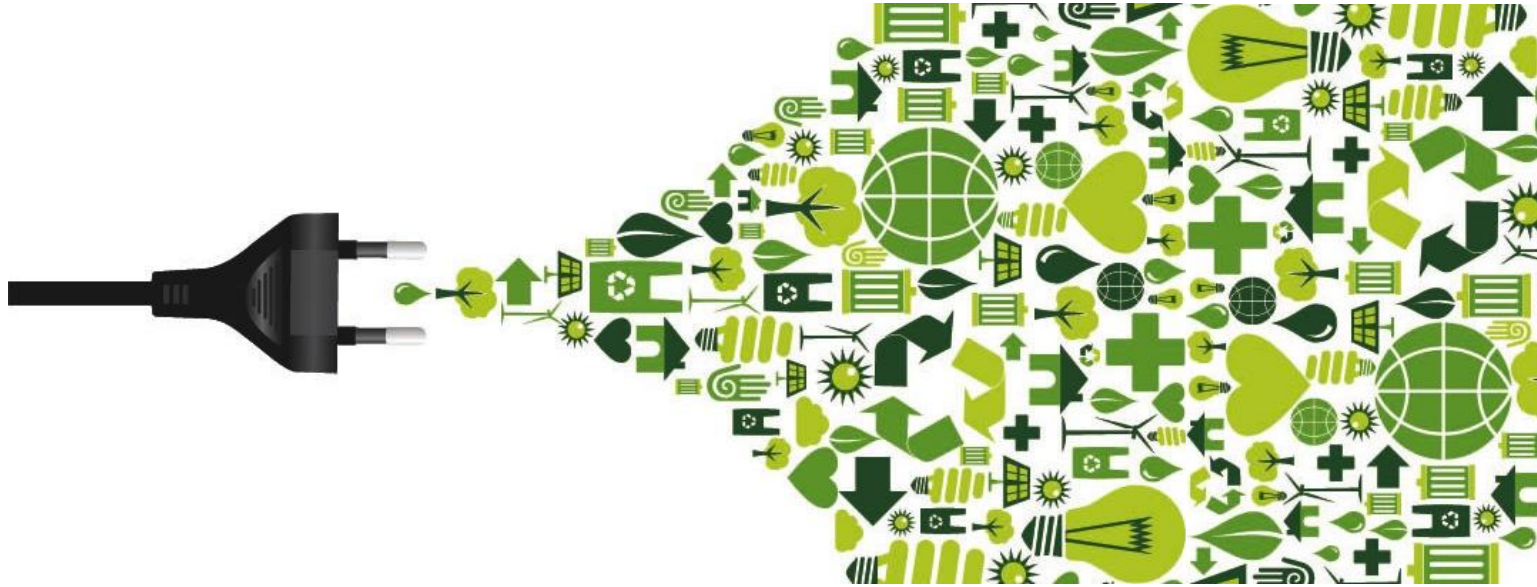
BMBF Federal Ministry of Education and Research

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EUROPÄISCHE UNION:  
Investition in ihre Zukunft  
Europäischer Fonds für  
regionale Entwicklung





# THANK YOU FOR YOUR ATTENTION

Any questions?

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