


CORROSION DEPARTMENT INCL. FRENCH CORROSION INSTITUTE & MECM

Research in Progress 2024

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Content

Introduction

The Corrosion Department at RISE (Research Institutes of Sweden) includes more than 100 researchers, engineers and technicians in Sweden and France. We collaborate extensively with industry and the scientific community to help providing solutions to various corrosion issues, both through long-term research projects and shorter consultancy assignments. Our mission is to help our partners and customers to solve their corrosion issues and minimize damage related to corrosion in a sustainable way.

We are located at two sites in Sweden: Kista, close to Stockholm on the east coast, and Borås close to the west coast. The French Corrosion Institute (IC) which is a subsidiary of RISE AB, has offices and laboratories in Brest (French Brittany), St-Etienne and Lyon.

With corrosion being a science that often needs to be studied in real conditions, we also have several atmospheric weathering sites (Bohus Malmön, Brest, Gällivare), natural seawater facilities (Brest and Kristineberg), soil exposure sites (France and Sweden) and mobile testing on trucks (Sweden). Our team in Lyon offers also technical support on site on chemical industries (online monitoring, corrosion assessment, support in material selection). In addition, we have cooperation with numerous sites worldwide for performing different atmospheric, marine and soil exposures.

More than 150 industrial companies all over the world are members of our institute through our different Member Research Consortia, MRC, in which we bring together actors with common interests in specific corrosion areas. We offer a platform for collaboration as well as cost effective R&D. All the MRC research projects are initiated in collaboration with our member companies. Collaboration in any of our MRC's means increased possibilities, expanded networks and access to the most recent knowledge and know-how in corrosion. All our 13 MRC's in corrosion are open to new members.

Our Research in Progress brochure is published yearly, presenting around 100 on-going projects, giving you an extensive overview of our R&D work. All the projects shown here are financed by industry through cost-shared programs, membership through collective programs, European programs, or National and regional agencies. You will also find information about our different MRC's, as well as a list of our publications for 2023.

We hope you will find this Research in Progress brochure interesting and inspiring. Should you find any project of particular interest, please contact the project leader for more information.

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Our membership companies are governed by two different non-profit Associations, one established in Sweden (IKI) and the other in France (ARCOR).

For more information on the membership associations, please contact:

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Being member of our associations implies joining one of the following Member Research Consortia (MRC).

MRC AUTOMOTIVE CORROSION

Alvance Aluminium Duffel BV	Nippon Steel Corporation
Aperam	Nissan Motor Manufacturing (UK) Ltd
ArcelorMittal	NOF Metal Coatings
Auson	Novelis Switzerland SA.
Baoshan Iron & Steel CO., Ltd	Outokumpu Stainless AB
Chemetall GmbH	Porsche
Constellium	POSCO
Daimler Truck AG	PPG
Dörken Coatings	Provexa
Ford Motor Company	Q-LAB
General Motors LLC	Renault
Gestamp HardTech AB	Scania CV AB
Gränges Sweden AB	Schlötter
Honda Motor Co., Ltd.	Speira
Hydro Extruded Solutions	SSAB
Hyundai Motor Company	Stellantis
Hyundai Steel	Toyota Motor Corporation
Jaguar Land Rover	UACJ Corporation
JFE Steel Corporation	Valeo
Mercedes-Benz AG	voestalpine Stahl
Metalsa S.A.P.I. de C.V	Volvo Car Corporation
Nemak	Volvo Technology AB
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MRC AEROSPACE INDUSTRY

Airbus	Henkel Technologies
Airbus Helicopter	Liebherr
AkzoNobel Car Refinishes	PPG Industries Ltd
Boeing Company	Safran
Constellium	SOCOMORE
DGA	UACJ Corporation
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MRC SURFACE TECHNOLOGY

ArcelorMittal Global R&D (AC&CS)	SSAB EMEA AB
BASF Coatings GmbH	ProCoat Tecnologías S.L.U.
Becker Industrial Coatings Ltd.	TopAnalytica
Hydro Extruded Solutions	Volvo Car Corporation
Scania CV AB	voestalpine Stahl GmbH
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MRC COIL COATED STEEL MATERIALS

AkzoNobel Hilden GmbH	SNCZ
ArcelorMittal Global R&D (AC&CS)	SSAB EMEA AB
Becker Industrial Coatings Ltd.	TataSteel NL
Bluescope Steel	Ternium Siderar
Chemetall GmbH	The Sherwin Williams Company
Henkel Technologies	VM Building Solutions
Hyundai Steel	voestalpine Stahl GmbH
PPG France Business	
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MRC CORROSION AND CATHODIC PROTECTION IN SOILS

ArcelorMittal R&D Gent (OCAS)	Nippon Steel
ArcelorMittal R&D Esch/Alzette	Nordion Energi AB
BAC Corrosion Control	Storengy
BS Coatings	Tata Steel NL
GRTgaz	Terega
JFE Steel Corporation	TotalEnergies One Tech
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MRC BRASS ALLOYS

ESBE AB	ISIFLO A/S
FM Mattson Mora Group AB	LK Systems AB
IMI Hydronic Engineering AB	Nordic Brass Gusum AB
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MRC CORROSION IN PULP AND PAPER INDUSTRY

Billerud Skog & Industri AB, Gävle	Stora Enso AB/ Skoghall Mill
Billerud Sweden AB, Skärblacka Bruk	Södra Skogsägarna ek. för. (Södra Cell Mönsterås)
Billerud Sweden AB, Karlsborgsverken	Södra Skogsägarna ek. förening (Södra Cell Värö)
Outokumpu Stainless AB	Valmet AB
SCA Obbola AB	
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MRC CORROSION PROTECTION

Carboline Norge A/S	SSAB EMEA AB
DACAR AB	Stockholm Stad, Trafikkontoret
Hempel A/S	Tikkurila Sverige AB
Hilti Aktiengesellschaft	Trafikverket
Hitachi Energy Sweden AB Components	Zinc Info Norden AB
NKT HV Cables AB	Zingametall BV
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MRC PAINT AND LINING FOR STEEL

AB Volvo Penta	Nof Metal Coatings
AkzoNobel	Orano TN
DGA	Peintures Maestria
EDF	TotalEnergies One Tech
Naval Group	Vallourec
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MRC MARINE CORROSION

AB Volvo Penta	National Oilwell Varco
Alleima	Outokumpu Stainless AB
Aker Solutions	Saipem
Aperam	TechnipFMC Umbilicals
DGA	Thales DMS
EDF	TotalEnergies One Tech
EQUINOR	Vallourec
Grundfos Holding	Veolia Environnement
Industeel, ArcelorMittal	voestalpine Böhler Edelstahl
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MRC STORAGE AND TRANSPORTATION OF HYDROGEN

Alleima	OCAS / ArcelorMittal R&D Gent
Airbus Operation SAS	SHELL
Akzo Nobel UK	Storengy
Aperam	Subsea7 France
Ascometal	Tata Steel NL
Baker Hughes	Technip Energies
DGA	Technip FMC Subsea France
EDF	Tenaris
GE Power Conversion	Terega
Geostock	TotalEnergies One Tech
GRTgaz	Trapil
Industeel, ArcelorMittal	UGITECH
NV Bekaert	Vallourec
National Oilwell Varco	voestalpine Böhler Edelstahl
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MRC BIOREFINERY

Alleima EMEA AB	Outokumpu Stainless AB
Aperam	TotalEnergies One Tech
IFPEN	Valmet AB
Industeel, ArcelorMittal	Valmet Technologies Oy
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MRC CCUS AND H_2S

Alleima	Shell
Aperam	Saipem
ArcelorMittal / OCAS	Technip Energies
Flexi France (Technip FMC)	TotalEnergies One Tech
National Oilwell Varco	Vallourec
Outokumpu Stainless AB	voestalpine Böhler Edelstahl
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Project Title: **Development of a robust and reliable accelerated corrosion test in the aerospace industry II**	Acronym: **CorrTestAero II**
Research area: **Transport, Aerospace**	Project period: **01/01/2023 – 01/01/2025**
Research leader: **Fabienne Peltier** fabienne.peltier@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Aerospace Industry**
	Keywords: Aerospace, corrosion test, aluminium

It is often considered that aluminium alloys exhibit good resistance to atmospheric corrosion due to the presence of a fine oxide passivating layer. Nevertheless, these alloys are not immune to corrosion which can take the form of localised corrosion like pitting or intergranular corrosion (such as exfoliation corrosion). Thus, the assessment of corrosion behaviour under atmospheric conditions is a major topic for many applications including the aerospace industry. In this context new alloys have been developed in the last decades as alternative to AA 2024. Moreover, in the last decades, new environmental regulations have led to major changes for aluminium corrosion protection. So, by limiting or prohibiting some chemicals (CrVI), the European regulation REACH (Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals) has induced major changes in some finish processes of aluminium alloys (chromate conversion, chromic acid anodizing, chromate sealing).

Hence, from the above, there is a need to qualify new materials and surface finishes for different applications in the aerospace industry (including both exterior and interior applications and maintenance aspects). One major difficulty in this task is the lack of robust and reliable corrosion test(s) in this field. Today salt spray (e.g. ISO 9227) is widely used and it is not representative to service conditions and thus not adapted to new developments (alloys and surface finishes). Another problem is that long term corrosion data under atmospheric conditions for these new alloys are, for the moment, rather limited. Some data on outdoor corrosion of new alloys surface finishes are available but they are restricted to exposure performed at 45° angle in a very few numbers of sites (which normally not favours intergranular corrosion).

In the first project “CorrTestAero” devoted to the development of new accelerated corrosion tests, materials with known behavior were selected to be critical on results obtained with the new tests and to determine if the developed test is representative of service conditions. The data have also been correlated to data from field exposures in a marine atmosphere (36 months) to design testing conditions that show the best correlation to the field data.

Based on the results from the matrix of experiment and experience, accelerated tests were selected to be validated in a second phase with different materials with less known behavior.

Project aims:

- To obtain the long-term behaviour of painted materials after 5 years of exposure.
- To implement or validate a test (designed in the first project) which correlates with field exposures on painted materials.
- To study the repeatability and the reproducibility of the test for a standardization of the test in aerospace industry.

Project Title: **Investigation of the corrosion performance of indoor REACH materials**	Acronym: **PerfPaintAlu**
Research area: **Transport, Aerospace**	Project period: **31/12/2022 – 31/12/2025**
Research leader: **Fabienne Peltier** fabienne.peltier@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Aerospace, REACH materials

Aluminum alloys are relatively low cost, light weight alloys and can be heat treated and loaded to relatively high levels of stress. However, as they are not immune to corrosion, it is important to assess their corrosion behavior under atmospheric conditions. To limit the corrosion of aluminum alloys, paints are generally applied on the materials. The corrosion protection in aerospace consisted mainly in CrVI-paint (primer, topcoat ...) However, new environmental regulations have led to major changes for aluminum corrosion protection. By limiting or prohibiting some chemicals as for instance CrVI, the European regulation REACH (Regulation on Registration Evaluation, Authorization and Restriction of Chemicals) has induced major changes in some finish processes of aluminum alloys (chromate conversion, chromic acid anodizing, chromate sealing).

Various projects have been carried out by the French Corrosion Institute on the corrosion performance of new surface finishes (CrVI free) but they were mainly used for exterior applications.

Consequently, there is a lack of knowledges on protection performance of indoor coatings applications since the conditions (e.g., condensation...), the type of corrosion or the modes of failures (galvanic corrosion, crevice corrosion...) encountered inside the plane cannot be compared to those observed at the exterior of the aircraft (rinsing conditions...).

Hence, from this background, there is a need to investigate the performance and the mechanisms of protection of new REACH systems for indoor applications in the aerospace industry.

Project aims:

- To define a testing protocol for indoor Cr free coatings.
- To assess the long-term durability and corrosion performance of indoor REACH systems.
- To understand the mechanisms of protection of selected systems.

Project Title: **Solutions for Corrosion Optimized and Prediction with Efficient Network of Environment Sensors**	Acronym: **Scorpenes**
Research area: **Transport, Aerospace**	Project period: **01/01/2023 – 31/12/2026**
Research leader: **Nathalie LeBozec & Johan Becker** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Public Funding (EDA)**
	Keywords: Aeronautic, condition-based maintenance, sensors

Degradations due to corrosion are a major concern in aeronautic and related issues can appear along the service life of aircraft and helicopters. Although materials and protective coatings are carefully selected to prevent onset of corrosion, exposure to harsh environments, e.g. to marine conditions or decontamination agents may still conduct to corrosion of structural parts. Evidence of corrosion is usually assessed during scheduled maintenance operations which are not considering in-service conditions (exposure to salt contaminants, high relative humidity levels, temperature variations ...) of helicopters and aircraft. This type of maintenance may be therefore inadequate being too extensive or insufficient. Developing solutions enabling to trigger maintenance operations is therefore of great interest and would significantly reduce costs and increase the availability of aircraft and helicopters.

The main objective of the project is therefore to build a condition-based maintenance solution related to corrosion management on aircraft and helicopters and to improve the corrosion testing reliability. This will be achieved through developments and tests of environmental sensors, corrosion monitoring techniques and assessments on specimens aiming to reproduce real helicopters/aircraft assemblies. The design of an accelerated corrosion test to better reproduce in-service conditions will be also investigated.

Project aims:

- To understand, model and simulate the aging of sensors in variety of environmental conditions representative of flight conditions.
- To identify, understand and simulate representative level of corrosion of structures to implement adequate maintenance solutions.

Project Title: **Modelling of hydrogen activity from atmospheric corrosion in ultra-high strength steels for light structure application**	Acronym: **AtHyCor**
Research area: **Transport, Automotive**	Project period: **01/07/2021 – 30/06/2024**
Research leader: **Flavien Vucko** flavien.vucko@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **European funding (RFCS)**
	Keywords: High strength steel, hydrogen, atmospheric corrosion, modelling

Steel in automotive industry excels as a material of choice thanks to the development of high-performance grades displaying excellent mechanical properties. However, the steel industry still faces major challenge that is to prove that their newest steel solutions will sustain the service conditions of a vehicle, particularly those related to hydrogen assisted cracking under atmospheric corrosion conditions. Indeed, ultra-high strength steels are known to be sensitive to hydrogen embrittlement and nowadays, from early steps, the fabrication processes are adapted to control the risks of delayed fracture for instance. Even the microstructures of advanced steels are tailored to decrease the sensitivity of the steels to hydrogen. However, atmospheric corrosion can be an additional source of hydrogen during service life, which was probably not so dangerous for low grades, but become absolutely critical for high strength steels with ultimate tensile strength above 1000 MPa. And this problem needs to be solved to make steel more competitive and to rise reliability.

Extensive work has been performed by the scientific community on the corrosion properties of zinc, zinc-alloy or aluminium-silicon coatings under atmospheric corrosion conditions with several progresses. However, there are still many gaps and for example new sets of relevant experimental data are missing in the case of high strength hot formed steels coated with Zn-based or Al-Si metallic coatings that can show very different corrosion behaviours at cut edges or in pit-like defects. This project answers this need by developing a sound strategy to obtain new local corrosion data sets that will provide novel insights on corrosion mechanisms at these particular locations.

Furthermore, and very importantly, the links between corrosion and hydrogen production remain unclear in the literature especially under atmospheric corrosion conditions. Therefore, an extensive work will be performed at both local and global scales to reveal the most influencing parameters on hydrogen production and entry into coated high strength steels exposed to various corrosive conditions.

All the experimental data sets will be tailored to feed 3 models: 1) Modelling of atmospheric corrosion mechanisms, 2) Modelling of hydrogen production from corrosion, 3) Modelling of hydrogen distribution in strain/stress fields. All these models will be developed in the software COMSOL Multiphysics® to allow their combination in unified model simulating both surface (corrosion activity and hydrogen production) and bulk (hydrogen distribution) phenomena in a sequential manner. The models will be validated by additional experimental data and outdoor exposures in services conditions.

Project aims:

The main scientific objective of this project is to develop a simulation tool that can model hydrogen entry and distribution into coated ultra-high strength steel (UHSS) exposed to atmospheric corrosion conditions. The industrial aim of this project is thus to provide steel makers and car manufacturers with new data related to environmentally assisted fracture risks of ultra-high strength steels and with a simulation tool that could anticipate such risks.

Project Title:	Acronym:
Environmental Induced Cracking Susceptibility in Aluminium Alloys for sustainable Electrification of Heavy-Duty Vehicles	**EICAl**

Research area: **Transport, Automotive**	Project period: **01/04/2022 – 01/05/2025**
Research leader: **Stefan Norgren** stefan.norgren@ri.se +46 102 284 884	Source of funding: **Public funding (Swedish Energy Agency)**
	Keywords: Aluminium alloys, Al-Si, Al-Mg-Si, VDA atmospheric corrosion, fatigue, SSRT, 4-point bend strain, mobile truck exposure, localized corrosion, microstructure, SEM, SKPFM

This project investigates the sensitivity to environmentally induced cracking of recycled aluminium when combining stress and corrosion that may lead to a reduced technical lifespan. Cast aluminium alloys (Al-Si type) investigated contains higher recycled content. Also included are forged (Al-Mg-Si type) alloys used for truck wheel rims. Corrosion and fatigue studies are carried out both in the lab and for the mobile road condition to be compared the outcome to understand their relations.

Lab tests simulate the corrosive situation adding stresses (strain and fatigue) to mimic field road situation but also mechanistically understand the effect of chlorides, pH, and temperatures. Results from such static stress and/or dynamic loads (fatigue) test situations of corrosion exposed aluminium samples will be evaluated.

Laboratory atmospheric corrosion test for automotive parts using VDA233-102 test standard will produce corroded samples. For the forged (Al-Mg-Si type) we modified this test applying a special corrosive mud for better acceleration effect corresponding closer to road conditions. These sequentially tested samples with corroded defects are run through a resonant fatigue test machine to understand reduction compared to nominal samples. Stress cracked surfaces will be studied by SEM.

Furthermore, a combined in situ corrosion fatigue test using low frequency fatigue set-ups inside a corrosion lab chamber while running the VDA test will be studied. In this way we can compare results to the sequential fatigue test data to understand if these two approaches differentiate or not.

A deeper understanding of corrosion mechanisms related to microstructure using SKPFM electrochemical technique will support us in understanding how microstructure-corrosion-stress related effects to aluminium alloys in the project are related. Results in the above lab tests will finally be compared to both free- and strained aluminium samples exposed to the road environment when fit to truck trailers for a period of two years.

Project aims:

- Understand the effect of road conditions on aluminium corrosion and how this impacts fatigue life, both for primary and recycled alloys used for heavy transport vehicles.
- Develop a more rapid methodology to test the stress-load perspective of road conditions.
- Determine whether recycled alloys are more susceptible to corrosion and applied stresses.
- Describe and evaluate the corrosion mechanisms of these alloys in greater detail looking at microstructures and impact of chlorides, pH and temperature.

Project Title:	Acronym:
Adhesive bonding of aluminium in the Automotive industry, part III	**MRC-AC25**

Research area: **Transport, Automotive**	Project period: **01/01/2021 – 31/12/2025**
Research leader: **Carolina Schneiker** carolina.schneiker@ri.se +46 10 228 48 61	Source of funding: **MRC Automotive corrosion**
	Keywords: Adhesive, Lap-shear test, Mobile exposure, Accelerated corrosion testing

Adhesive bonding is a frequently used joining method for aluminium alloys and is typically used for structural and hang on parts on the car body. Pre-treatment of the aluminium is carried out at the aluminium supplier and is the state of the surface that will be bonded with adhesives at the OEMs. Ongoing research, within MRC Automotive corrosion, has compared the influence of the pre-treatment on the corrosion resistance of different aluminium alloys joined with adhesive. Other aspects that are relevant when comparing the performance of pre-treatment for adhesive bonding are the type of adhesive, aluminium alloy and sample geometry. The accelerated corrosion tests commonly used are time consuming, which make it valuable to find a reliable test with shorter exposure periods.

This project will investigate the possibility to use lap-shear samples with a static load during exposure to a standardized accelerated corrosion test as well as for exposure on a running trailer in a road-environment.

Project aims:

- Continue to find a reliable test method for testing systems of pre-treatment, adhesive and type of aluminium alloy.
- Investigate the relevance of using a constant-load cell for lap-shear samples during accelerated corrosion testing and mobile exposure.

TRANSPORT

Project Title:	Acronym:
Development of an accelerated corrosion test that better mimic field conditions	**MRC-21**

Research area:	Project period:
Transport, Automotive	**01/01/2024 – 31/12/2024**
Research leader: **Bo Rendahl** bo.rendahl@ri.se +46 (0)10 228 4858	**Source of funding:** **MRC Automotive corrosion**
	Keywords: Accelerated corrosion testing, Mobile on-vehicle exposure

The studies performed on the corrosivity in road environment have shown that approximately 90 % of the corrosion takes place during the winter period when there is frequent use of de-icing salt on the roads but also rather low temperatures.

When looking into the OEM's different accelerated corrosion tests, all of them increase the corrosivity of the test with high temperatures. The corrosion mechanism taken place at these higher temperatures will probably not be the same as what will be found in the field. An accelerated test at lower "winter" temperatures might thus better mimic the corrosion observed in the field.

The activities within the project are to perform a series of cyclic corrosion tests with selected automotive materials together with atmospheric corrosion sensors at lower temperatures. The new tests at lower temperatures will have a considerably lower acceleration factor compared with the OEM's cyclic test used today and therefore the exposure period will become much longer.

Project aims:

From the obtained results and together with existing field data try to develop an accelerated corrosion test that better mimics the corrosion observed in the field.

TRANSPORT

Project Title:	Acronym:
Warm Press-Formed Zinc-Coated Third Generation Advanced High Strength Steels with High Crash and Corrosion Resistance and Minimized Microcracking	**WarP-AHSS**

Research area:	Project period:
Transport, Automotive	**01/10/2023 – 31/03/2027**
Research leader: **Dominique Thierry** dominique.thierry@ri.se +33 67 680 6676	**Source of funding:** **European funding (RFCS)**
	Keywords: Medium manganese steel, Automotive corrosion, LME, hot stampling

Steel sheets at automakers are formed in different ways (e.g. cold forming, hot forming, roll forming etc.) for use in car bodies. Hot stamping (or hot forming or hot pressing or press hardening) is one of the forming methods for automotive components which is growing rapidly in Europe. The major process steps for producing sheet steels at the steelmaker and their processing at the automaker using the hot forming process. Hot stamping allows manufacturing of complex parts with minimal spring back, which is not possible by cold stamping process, while simultaneously achieving ultrahigh strength levels in service.

"Medium manganese steels" (MMnS) are candidate materials for the 3rd generation advanced high strength steels. These steels typically contain 3-12 wt.% Mn, along with low C in a ferritic and/or martensitic matrix. The broad possibility of changing the heat treatment of these steels can lead to a wide spectrum of final mechanical properties (Rm ~ 800-1500 MPa and A ~ 10-45%) that can be achieved. Interestingly, the relatively high amount of Mn additions in MMnS decreases the ferrite-to-austenite transformation temperature (Ae3) in these steels. Although MMnS are usually intended for cold stamping applications, their low Ae3 can allow lower reheating and hot stamping temperatures if used for hot stamping leading to a "warm stamping" process. This possibility can ensure that during the warm stamping of Zn-coated sheet steel no Zn-rich liquid phase is in contact with the steel substrate minimizing the risk of LME and associated coating degradation.

Project aims:

- To develop "warm pressed" medium Mn steel products that will use significantly lower processing temperatures enabling the use of Zn-coated sheet steels for warm stamping parts.
- To avoid the occurrence of LME and other coating and surface degradations during warm stamping.

The consortium is formed with the following partners: Tata Steel (Coordinator), Steel Institute (IEHK) of RWTH, RISE, CSIC-CENIM and Volkswagen.

TRANSPORT

Project Title: **Comparison of different automotive accelerated corrosion standards**	Acronym: **MRC-AC29**
Research area: **Transport, Automotive**	Project period: **01/05/2023 – 31/12/2025**
Research leader: **Carolina Schneiker** carolina.schneiker@ri.se +46 10 228 48 61	Source of funding: **MRC Automotive corrosion**
	Keywords: Accelerated corrosion testing, bimetallic corrosion

Most of the OEM's have their own accelerated corrosion test with their own knowledge about the correlation to the field data. Important parameters for the corrosivity of the test are among others, salt concentration, droplet size, frequency of spraying, and temperature and relative humidity e.g. wet and dry phases.

The MRC Automotive corrosion projects often use the German standard VDA 233-102 (DIN 55635) but its correlation to other standards is not always well known.

Six different standardised accelerated corrosion tests have been chosen to be a part of the project. The test matrix includes samples such as:

- Cosmetic panels of CRS, GI60, ZM60 and AA6016 with both thin-film and phosphate pretreatment.
- Creviced samples in GI60, ZM60, PHS (AlSi) and bimetallic samples with the combinations GI60-AA6016 and GI60-PHS(AlSi)
- Reference panels of CRS and Zn
- Zn-flake and Zn-Ni coated fasteners in combination with cast aluminium.

Project aims:
The aim with the project is to include materials and sample designs of interest to bench mark the OEMs test methods.

TRANSPORT

Project Title: **Galvanic coupling of die cast Aluminum and coated steel fastener**	Acronym: **MRC-AC32**
Research area: **Transport, Automotive**	Project period: **01/01/2024 – 31/12/2024**
Research leader: **Bo Rendahl** bo.rendahl@ri.se +46 (0)10 228 4858	Source of funding: **MRC Automotive corrosion**
	Keywords: Mega casting, die cast aluminum, Zn flake fasteners, galvanic corrosion, mobile exposure, accelerated corrosion test

The transition towards e-mobility and the need to lower the weight of vehicles has entailed higher use of lightweight materials. The amount of aluminum in vehicles is increasing due to the combined properties of low weight, high strength, and good corrosion resistance. The environmental impact of new production of aluminum is huge and it will be necessary to use more and more recirculated materials. Recycled or secondary die cast aluminum can contain higher amount of impurities e.g. Cu and Fe resulting in the risk of lowering the corrosion resistance of the material. The risk of galvanic corrosion when assembling coated steel fasteners towards die cast aluminum in accelerated corrosion tests and in the severe road environment will be studied.

Project aims:
Learn more about contact corrosion behavior of representative aluminum alloys coupled with coated fasteners e.g. Zn flake, ZnNi, ZnFe, ZnSn, Stainless steel (or EPDM sealings) to be able to provide recommendations for corrosion avoidance and material choice.

Primary and secondary die cast aluminum combined with different types of coated steel fasteners will be exposed to different types of accelerated corrosion tests as well as during mobile on-vehicle exposures.

A methodology to measure the galvanic current between the fasteners and the aluminum during the different phases in the accelerated corrosion tests will be established. The result from the galvanic measurements will be compared with the findings of corrosion attack on fasteners and on the aluminum material.

In a second phase the methodology will be used for measuring the galvanic corrosion in a field exposure.

TRANSPORT

Project Title: **Field survey**		Acronym: **MRC-AC30**
Research area: **Transport, Automotive**	Project period: **01/04/2023 – 31/12/2025**	
Research leader: **Carolina Schneiker** carolina.schneiker@ri.se +46 10 228 48 61	Source of funding: **MRC Automotive corrosion**	
	Keywords: Real-life performance	

RISE has performed several surveys of the corrosion resistance of the car body. Parts of the car body have been collected from dismantling plants from collision damaged vehicles. The last survey was reported 2014 and included inspection of more than 1900 crevice surfaces of year models 2006 to 2009. A follow up project but in a minor extent is run within the MRC Automotive corrosion.

The project has two focus areas whereas the first one is focusing on thin-film technology as a replacement to phosphating. Thin-film technology have been used by some OEMs for more than 10 years, it is thereby possible to get access to vehicles that have been in service for a long period of time.

The second focus is to investigate the effect of design, adhesives and sealers by collecting hem-flanges and spot-welded joints from chosen car models. The parts will be opened, documented and, if interesting, evaluated with respect to corrosion.

Project aims:

- Investigate the performance of vehicles pre-treated with thin-film technology after 5 to 10 years in service in one of the most corrosive road networks in the world.
- Evaluate and compare the corrosion resistance of the car body of some recent models and to evaluate the effects of design as well as adhesives and sealers.

TRANSPORT

Project Title: **Influence of the composition of recycled cast aluminum alloys on their corrosion and fatigue corrosion performance**		Acronym: **ReCalCor**
Research area: **Transport, Automotive**	Project period: **01/05/2023 – 31/12/2026**	
Research leader: **Flavien Vucko & Bo Rendahl** flavien.vucko@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**	
	Keywords: Cast Aluminum, recycling, fatigue	

In the automotive industry, the transition towards global e-mobility to fulfill current and future CO^2 emission regulations is quite challenging. Extensive research and developments are done to improve the efficiency of electric engines and to reduce the weight of batteries. However, the decrease of the weight of the vehicle itself is of key importance for its energy efficiency and carbon footprint. In addition to this, the use of recycled materials, in particular aluminum alloys, can even further improve the environmental impact the vehicle manufacturing.

To lighten future vehicles, multi-material concepts are necessary, and aluminum alloys are of high interest due to their versatile properties combining lightweight, high strength and good corrosion properties. Die-cast aluminum alloys is a material of choice for complex geometries. The current trends towards mega-casting will make it even more important. Indeed such technique allow to improve profitability by reducing assembly time, length of the assembly line, but need further developments in terms of component design to optimize their weight. Mega-casting also helps to increase the material utilization as well as the use of secondary aluminum.

For the integrity of the cast components, both pitting and intergranular corrosion are particularly risky in case of high or cyclic loads as both could act as crack initiation sites. Combination of mechanical stress and corrosive environments could also lead to environmental assisted cracking or fatigue-corrosion mechanisms that would even further reduce the lifetime of the component.

As a conclusion, the corrosion behavior of secondary cast aluminum and its impact on mechanical and fatigue behavior must be investigated to anticipate the risk of failure under service conditions.

Project aims:

- Investigate the influence of Cu and Fe content on the corrosion properties of various commercially available cast alloys.
- Investigate the properties of model cast alloys to mimic successive recycling operations.
- Quantify the impact of corrosion on the mechanical properties and fatigue/fatigue-corrosion performance of the cast alloys.
- Gives recommendation in terms of material selection and design of cast parts made of secondary alloys.

SURFACE PROTECTION

Project Title:	Acronym:
MRC-ST-202301 Pre-treatment systems for automotive and coil coating applications	**Thin Film**

Research area:	Project period:
Surface protection, Automotive	**01/01/2023 – 31/12/2024**

Research leader:
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Source of funding:
MRC Surface Technology

Keywords:
Thin film, conversion coating, surface characterization

Conversion coatings are used for increased adhesion and corrosion protection of organic coatings on metals. The traditionally used phosphate and chromate conversion coating are replaced by more sustainable thin film pre-treatments. These thin films are however less established and the influence of properties such as substrate composition and microstructure, bath properties and the result of the cleaning steps done before the pre-treatment.

Understanding the influence of these parameters is therefore key in obtaining a successful pre-treatment.

This project focuses on the bath properties in both the cleaning and pre-treatment steps. Factors such as temperature, time, pH, additives and/or contaminants may be considered. Both in situ (AESEC) and ex situ (SKPFM, FT-IRRAS, XPS, XRF and Tof-Sims) techniques will be used to characterize the surfaces during and after surface treatment with different bath parameters.

Project aims:
The aim of this project is to investigate the effect of bath parameters on thin film pre-treatments for an increased understanding of the deposition process.

SURFACE PROTECTION

Project Title:	Acronym:
Recycled aluminium alloy coatings with chemically tailored electro-chemical potential for safe protection of steel structures	**ALCOAT**

Research area:	Project period:
Surface protection, Automotive	**01/09/2023 – 28/02/2028**

Research leader:
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Source of funding:
European funding (RFCS)

Keywords:
Metallic coatings, high strength steel, galvanic protection, Aluminium, Hydrogen embrittlement

Although currently indispensable in steel corrosion protection, zinc coatings have several drawbacks, including lower corrosion resistance in marine environments, the risk of hydrogen embrittlement when applied to high strength steels, and a relatively low recycling rate. The only economically viable alternative metallic coating material, aluminium, is cheaper, lighter, widely available, and more corrosion resistant. However, it is unable to provide sufficient protection to steel in defects, leading to red rust formation, and thus it is used only marginally.

Project aims:
To solve these shortcomings, this project will develop two new families of aluminium alloy coatings for protection of wind towers, ships, and other structures exposed to sea water and atmosphere, and steel sheet products for automotive, building, and home appliance industries. The coating composition and microstructure will be designed using advanced computational and molecular modelling. A novel, ground-breaking chemically-tailored potential difference concept will be developed and applied to precisely tailor the potential difference between the coatings and steel substrate in relevant environments. Application of this revolutionary concept will ensure that the corrosion potential of the coatings is more negative than that of steel guaranteeing thus sacrificial protection of steel in defects and protection against red rust formation, and still more noble than that of zinc, which is in a range where the risk of hydrogen embrittlement exists.

The new coatings will be more sustainable than zinc coatings due to lower corrosion rate, lighter due to lower specific mass of aluminium, ensure savings of primary raw materials due to use of iron-contaminated aluminium scrap, and improve the safety of steel constructions due to no risk of hydrogen embrittlement.

The consortium comprises the following partners partners: University of Chemistry and Technology Prague (Coordinator), RISE, V_zkumn_ a zku_ební ústav Plze_, Tata Steel Nederland Technology B.V., Catalan Institute of Nanoscience and Nanotechnology, RMIT Europe, RMIT University, Pyrogenesis SA.

Project Title: **Elyfog - Testing and development of long-term reliable electrical contacts**	Acronym: **Elyfog**
Research area: **Surface protection, Automotive**	Project period: **15/09/2023 – 15/09/2026**
Research leader: **Karin Beaussant Törne** karin.b.torne@ri.se +46 10 228 48 81	Source of funding: **Public funding (Vinnova)**
	Keywords: Electric vehicles, contact resistance, aging

In electric powertrains, fast charging and discharging of batteries and high voltages, current, and power levels and other stresses make the characteristics of the electrical contacts critical for the basic functions of the vehicles as well as for lighting, window lifts, infotainment, etc. In other words, a faulty or inferior contacts will cause unnecessary energy losses, non-functioning or at worst inoperative vehicles. It is therefore critical for EV OEMs to ensure they are using highly reliable electrical connection concepts, designed to withstand the higher voltages and temperatures sustained in these environments. Depending on the mounting location of the electrical connection also environmental exposure and corrosion resistance needs to be considered as well.

The project will analyse how different materials, surface treatment, concept, and assembly affect performance and long-term properties. Properties to evaluate are primarily: mechanical joint strength and electrical contact resistance (structural and functional characteristics) in correlation to the chosen configuration (geometry, surface properties, materials, fasteners, assembly parameters). Changes of the parameters during exposure to mechanical, electrical and environmental loads will also be evaluated.

Project aims:

- Development of a test rig allowing for simultaneous application of two or more stresses and online measurement of electrical contact resistance over the runtime of the experiment.
- Evaluation of at least 3 established material combinations and surface treatment for electrical contacts and development of at least 3 optimized combinations for a comparative study.
- Instructions and guidelines for testing, material selection and assembly to improve connection lifetime and guidelines for re-using connection parts and the use of recycled materials in electrical connections.

Project Title: **Respirometry technique for corrosion studies**	Acronym: **RESPIRO**
Research area: **Surface protection, Automotive**	Project period: **16/11/2023 – 30/12/2024**
Research leader: **Dominique Thierry & Smita Gangaprasad Rao** dominique.thierry@ri.se +33 67 680 6676	Source of funding: **Public funding (Hugo Carlssons stiftelse)**
	Keywords: Oxygen reduction, hydrogen evolution, corrosion monitoring

The mobility/transportation sector has high targets in reducing the CO^2 emissions from vehicles. To achieve this, reducing the weight of the vehicles is required. Utilization of steels with strength over 1500 MPa known as ultra-high strength steels (UHSS) are potential candidates for such applications. However, UHSS are susceptible to hydrogen embrittlement (HE). Hydrogen embrittlement is a metal's loss of ductility and reduction of load bearing capability due to the absorption of hydrogen atoms or molecules by the metal. The result of hydrogen embrittlement is that components crack and fracture at stresses less than the yield strength of the metal.

During corrosion the oxidation of the metal releases electrons which must be consumed to ensure electrical neutrality. This is why one or more reactions of reduction of oxidizing chemical species present in the aqueous phase necessarily happen simultaneously at the interface. The most common cathodic reactions are the reductions of dissolved oxygen and H 3O + and water. Hydrogen can thus be produced during the corrosion reaction both in aqueous and atmospheric environments. Hydrogen can then enter and diffuse through steel even at room temperature. This can occur during various manufacturing and assembly operations or operational use (e.g. during the corrosion process).

Recently a new technique, so called "respirometry" that allows to quantify in-situ the rate of O2 reduction reaction (ORR) and H^2 evolution reaction (HER) has been developed and applied to corrosion science. The technique can be used to monitor the amount of hydrogen produced and consumed oxygen during exposure to aqueous/atmospheric conditions.

Project aims:

- To build a respirometry equipment at RISE in Stockholm.
- To use the equipment to quantify HER/ORR for HSS under different atmospheric conditions.

SURFACE PROTECTION

Project Title:	Acronym:
MRC-ST 202302 Influence of microstructure of ZnAlMg alloys on adhesion of organic coating	**ZnAlMg coat**

Research area:	Project period:
Surface protection, Coil coating	**01/01/2023 – 31/12/2024**
Research leader: **Karin Beaussant Törne** karin.b.torne@ri.se +46 10 228 48 81	**Source of funding:** **MRC Surface Technology**
	Keywords: Thin film, conversion coating, surface characterization

Zinc coated steel has been used for a long time in automotive and construction industries due the galvanic protection of the steel offered by the zinc coating. In recent decades ZnAlMg alloys has been introduced as an alternative to the zinc coating due to their superior corrosion resistance. However, both zinc and Zn alloys are coated with organic coating for further corrosion resistance and aesthetic reasons.

ZnAlMg alloys has a complex microstructure where microstructure is separated into Zn rich (cathodic) and Al/Mg rich (anodic) areas. This phase separation may affect the adhesion of organic coatings. Both by the risk of galvanic corrosion, and by introducing inhomogeneities in the conversion coating typically applied prior to the organic coating.

In this project heat treatment is used to obtain samples with the same composition but different microstructures. ZnAlMg and ZnAl alloys are pre-treated and/or coated with an automotive and a coil coat system. Surface analysis (SKPFM, FT-IRRAS, XPS, XRF and Tof-Sims) and adhesion tests is performed prior to and after exposure.

Project aims:

The aim of this project is to investigate the effect of microstructure on pre-treatment and adhesion of organic coatings on ZnAlMg and ZnAl alloys.

SURFACE PROTECTION

Project Title:	Acronym:
Novel approaches for investigating local corrosion and mechanical degradation of multiphasic alloys	**LoCoMecha**

Research area:	Project period:
Surface protection, Medical inplants	**01/01/2023 – 31/12/2026**
Research leader: **Michel Prestat & Flavien Vucko** michel.prestat@institut-corrosion.fr +33 2 98 05 15 52	**Source of funding:** **Public funding (ANR)**
	Keywords: Titanium implants, stress corrosion cracking, additive manufacturing, materials modelling

Titanium and its alloys are among the most widely used non-biodegradable materials for implants in the human body. The corrosion resistance of titanium is mainly attributed to the presence of a thin passive layer on its surface that degrades in the presence of oxidizing species, such as oxygen peroxide (H_2O_2), leading to the device degradation and release of its constituents in the surrounding tissues. H_2O_2 is produced by the immune system during inflammatory episodes and is also utilized by surgeons for tissue disinfection during operation. A recent study of the French Corrosion Institute revealed that Ti6Al4V, a popular _+_ alloy, exhibits a phase-specific degradation in H_2O_2-containing solution with a thick oxide layer growing on the _ phase and a dissolution of the _ phase, leading to the formation of undesired cracks.

By combining experimental and modelling approaches, the LoCoMecha project ambition is to gain insights into the processes at play in the degradation of Ti6Al4V without and with external mechanical load (stress corrosion cracking).

This project is carried out in collaboration with the Laboratoire de Réactivité de Surface (Université Paris Sorbonne, France), the Institute of Computational Physics (Zurich University of Applied Sciences, Switzerland), the Thermomechanical Metallurgy Lab (Swiss Federal Institute of Technology Lausanne, Switzerland).

Project aims:

- Understanding the phase-specific mechanisms of Ti6Al4V corrosion in H_2O_2-containing physiological electrolyte by using global and local electrochemical methods.
- Assessing the impact of β phase cracks on the mechanical properties of the alloy.
- Modelling and predicting stress corrosion cracking and fatigue corrosion by using virtual materials testing.
- Investigating the effect of the various microstructures prepared by additive manufacturing on the Ti6Al4V corrosion behavior.

Project Title: **Crevice Corrosion Mitigation Technology**	Acronym: **CCMT**
Research area: **Building and Infrastructue, Coil coating**	Project period: **01/06/2022 – 01/12/2024**
Research leader: **Björn Tidbeck** Bjorn.tidbeck@ri.se +4672 734 08 17	Source of funding: **MRC Corrosion Protection**
	Keywords: Life extension of painted steel, Maintenance strategy

The stretch goal of this project is to extend the life of existing steel structures and reduce future maintenance needs for new steel structures. Bridges with an expected lifespan of 120 years, generally needs to be repainted or repair-painted at least three times during their lifespan. During such maintenance work, the entire steel surface of the bridge is often treated as per the current due diligence praxis. However, we know from experience that crevice corrosion in bolted connections, riveted web constructions, bridge bearings and stay cables often constitute weak points with increased risk of corrosion.

The initiative to this project is to investigate if the bulk of such maintenance work can be reduced by focusing on the above-mentioned problem areas. The methodology of this study is to perform a state of the art focusing on prevention of crevice corrosion on low alloyed steels, including weathering steels, treatment of ongoing crevice corrosion on existing steel and proactive maintenance on structures susceptible to crevice corrosion.

The study explains theoretical treatment options and surveys alternative treatment options that have been employed by asset owners outside the Swedish market. The study also includes a collection of case studies where alternative treatment protocols have been tested and can be evaluated after exposure on infrastructural assets in field after up to 30 years in service.

The planned continuation of this project includes corrosion testing of promising alternative corrosion protection strategies. And proof of concept studies of new ideas for proactive maintenance that this study has resulted in.

Figure 1. To the left: cross sectional beam with pack rust and ongoing crevice corrosion.
To the right: edge beam with shot out rivet heads.

Project aims:

- Evaluate technology to extend technical life of existing structures with crevice.
- Reduce future maintenance need for both new builds and existing steel structures.
- Perform corrosion testing and follow up case studies with crevice corrosion.

Project Title: **Data base on the corrosion performance of coil coated steel materials**	Acronym: **CoilDataBase**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2017 – 31/12/2024**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Coil Coated Steel Materials**
	Keywords: Database, coil coated steel, field test, laboratory tests

A large number of research projects on the degradation of coil coated steel products have been conducted at the French corrosion institute. However, a direct comparison of results within these different programs is difficult as different products have been selected (e.g. pretreatment, primer, top coat etc.). Hence, it is rather difficult to build a database from the results of these projects. In order to overcome this issue, it has been decided to select 10 to 12 systems that will be used as references in future projects for the next 5-10 years. This will allow us to build a database on these different reference materials and to model the results for instance with respect to environmental parameters.

Project aims:

The aim of the project is to build a database on reference coil coated materials and in the future to use this database to predict the corrosion behavior of coil coated steel materials. This includes field exposures as well as exposure in various corrosion testing or weathering tests. Electrochemical Impedance Spectroscopy (EIS) measurements with focus on water uptake and stability, Delamination studies using for instance Cathodic delamination test and/or Kelvin probe will also be conducted.

Project Title: **Influence of distance from the sea on degradation of coil-coated materials**	Acronym: **SeaDis**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2017 – 31/12/2025**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Coil Coated Steel Materials**
	Keywords: Coil coated steel, chloride deposition

Airborne salinity plays a relatively significant role in the degradation of metallic infrastructures. Empirical relationships have been found between chloride deposition onto surfaces and corrosion rates [1]. The deposition of marine aerosols is the primary source of chlorides which concentration and deposition rates tend to decrease rapidly when increasing the distance to the seashore. Aerosols concentration and corrosion rates depend on the nature of the aerosol sources being very high close to surf and moderate near calmer waters of bays and estuaries. Other factors influencing the aerosol concentration are the intensity and direction of prevailing wind, the topography of the land.

If the effect of chloride deposition is rather well documented on the corrosion of bare metals such as pure zinc, no systematic study on the influence of the distance to the sea on the degradation of coil coated steel materials has been carried out, especially when it concerns Zn-Mg-Al metallic coating as well as new chrome-free technologies commercially available. From an on-going project at Institut de la Corrosion where the outdoor performance of some coil-coated steel materials (prepared in laboratory) was assessed at various distances from the seashore, it was shown that the edge creep increased with decreasing distance to the sea and increasing chloride deposition.

Project aims:

The goal of the project is thus to assess the degradation of a large number of commercially available coil coated materials as a function of chloride deposition and distance from the seashore. In addition, the performance of identical coil coating systems applied on various metallic coatings will also be studied.

Project Title: **Outdoor Corrosion Performance of Prepainted Galvanised Steel – A long term field exposure**	Acronym: **WORLDCOIL 3**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/04/2023 – 31/03/2026**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Prepainted steel, outdoor exposure, marine atmosphere, distance to the sea

Long term outdoor exposures have to be conducted to fully evaluate the corrosion performance of prepainted materials upon corrosivity classes since thin organic protective layer must withstand very harsh conditions in various outdoor applications. This is particularly true with the evolution of coating technology for example those with a reduced environmental impact, such as coatings with reactive biorenewable diluents, but also any changes in the process of coil-coating as well as in the coating formulation.

Two large field exposure programmes of prepainted galvanised steel materials have been conducted at the French Corrosion Institute (FCI) since 2007. The first project that was performed over 8 years e.g. between 2007 and 2015 included 7 sites worldwide with marine temperate, marine industrial, marine tropical and acid rain sites. Conventional prepainted galvanised steel Zn-0.2Al, Zn-5Al and Zn-55Al materials were selected, most of them including chromated pre-treatments and primers. With the development of new zinc-alloy coated steel and the transition from chromate-based systems to fully chrome-free solutions, a second outdoor exposure programme including a new set of commercially available coil coated materials was started in 2015 for a total duration of 6 years. Most of the systems were fully chrome-free and included Zn-Al-Mg coatings in addition to conventional Zn-0.2Al and Zn-55Al substrate. Valuable data were obtained from these exposure programmes. In particular, the second project highlighted the need to take into consideration the quality of the backcoat that was highly degraded in some sites influencing thus the corrosion of the front side. It was also concluded that a larger number of prepainted systems (based on Zn-0.2Al which is commonly produced by the Coil-Coater) should be carefully selected and tested in outdoor sites, allowing a larger statistical analysis of the data. Moreover, the distance to the seashore in a similar geographical location without change in elevation shall also be considered to assess how the chloride load affects the degradation of the materials (e.g., all sites being at the seawater level).

Project aims:

- To test the long-term durability and corrosion performance of prepainted galvanised steel materials in various atmospheric sites in marine environment.
- To study the influence of the distance to the seashore.
- To better understand the role of different climatic parameters and corrosiveness in the degradation of coil coated material and to a provide a full statistical analysis.

BUILDING AND INFRASTRUCTURE

Project Title: **Testing the durability of repair solutions for prepainted steels**	Acronym: **RepairCoat**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2020 – 31/12/2024**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Coil Coated Steel Materials**
	Keywords: Coil-coated steel, Repair solution, outdoor exposure, accelerated tests, mechanisms

Prepainted steel materials are widely used in the construction of building industry. During service life, their durability is affected by weathering conditions in particular when exposed to marine and/or industrial environments. This may result in noticeable underpaint corrosion at defects in the paint such as cut-edges or scribes, for examples. These degradations will obviously propagate with ageing time at a rate that will depend upon the system e.g. metallic coating, surface treatment and organic paint, and the corrosiveness of the environment. Repair solutions are available at paint suppliers for treating such damages and thus improving the life durability of the materials. However, the efficiency of such solutions is not well-known. Thus, there is a need to test them under different conditions including laboratory test and field exposure, as well as to better understand their mechanisms of protection.

Project aims:

- To test the durability of repair solutions on various prepainted steel materials in laboratory test and field exposure.
- To compare the efficiency of the repair solution upon the metallic coating.
- To compare the efficiency of the repair solution upon the chemical nature of the organic coating.
- To better understand the mechanism of protection of the repair solutions.

BUILDING AND INFRASTRUCTURE

Project Title: **Degradation of coil-coated materials under extreme conditions**	Acronym: **CoilXtreme**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2021 – 30/06/2026**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Prepainted materials, weathering degradation, extreme outdoor conditions

The degradation of coil-coated materials in field is a complex process depending on the panel orientation, the atmosphere at a given field site, the coating thickness, the paint chemistry and physical properties (such as type and thickness of the metallic coating, pretreatment, anticorrosive pigment formulated in the primer etc…). Each atmospheric exposure site has a unique blend of environmental stresses. It should also be noticed that each material will answer differently to a given environmental factor. The sites differ in the amount of ultraviolet light (UV), overall temperature, daily temperature cycles affecting the time of wetness, relative humidity, precipitation, deposition rates of atmospheric contaminants such as chloride, SO2, and dust etc. Although the effect of some of these parameters on the corrosion of coil-coated materials is known, there are many unclear aspects. In addition, trustable data on microclimate conditions are missing. Several exposure programs have been conducted at FCI in the last 15 years. Worldcoil I and Worldcoil II were conducted at different sites worldwide. The focus of these projects was on edge creep and creep from scribe rather than on degradation due to weathering. Even if these projects gave important information on the degradation of coil coating materials in different climatic conditions, sites of extreme conditions (related for instance to weathering and/or extreme temperature) were not covered in these studies. In another project conducted at IC, the mechanisms of blistering have been studied and compared to field data. Even though cut-edge creep and blistering are the most common defects when considering coil-coating materials performance, it is also important to take into account the weathering of the paint system. Weathering is a joint action of ultraviolet radiation, heat, oxygen, humidity and chemicals species. These agents can induce physical and chemical changes in the polymer. Indeed, the weathering of the paint can affect the paint properties and thus changes water or electrolyte transport through the organic coating and consequently the tendency to blistering. It should also be noticed that the different weathering parameters can also induced stresses in the top coat and thereby largely influence the transport properties of for instance water.

Project aims:

- To expose and test different coil coated materials in different weathering sites (with high UV, humidity and pollution).
- To perform different laboratory test commonly used to evaluate the performance to weathering of coil coated materials.
- To compare the results of the laboratory test and field tests.
- To better understand the role of different climatic parameters in the degradation of coil coated material with the final aim to design more appropriate testing conditions for simulation of weathering conditions.

BUILDING AND INFRASTRUCTURE

Project Title: **Corrosion performance of new emerging and energy saving curing technologies for coil coating**	Acronym: **EnSaveCoat**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2023 – 31/12/2025**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Coil Coated Steel Materials**
	Keywords: Curing technology, Energy saving, Radiation curing, UV, E-Beam

Due to the actual situation on the energy sector linked to the war in Ukraine, there is a request from the EU and national authorities to save energy. This is crucial with respect to the rising cost of gas and electricity. Energy is highly consumed in surface treatment processes used in coil coating in a variety of ways such as process solution heating and cooling, paint curing, drying of the part.. etc. It is believed that the new request in term of energy saving will lead to new products or/and new processes that would need to be characterized and tested regarding their corrosion properties for instance.

In the field of coil coating industry, several ways of saving energy can be identified by using: Radiation curing techniques (for instance UV, E-beam..), Induction and IR or NIR curing techniques, Low PMT paints.

In this project, several energy saving technologies will be identified and used to cure the coatings applied on galvanised steel substrate. The materials will be characterized in both laboratory conditions and outdoor exposure to assess their performance versus conventionally thermal cured systems.

Project aims:

- To identify energy saving curing technologies of interest.
- To characterize the corrosion performance of energy-saving-cured systems in laboratory tests.
- To assess the long-term performance of energy-saving-cured systems in field exposure.
- To compare the corrosion performance of energy-saving-cured systems to thermal-cured prepainted steel.

BUILDING AND INFRASTRUCTURE

Project Title: **Optimization of Accelerated Corrosion Test for Coil Coated Materials**	Acronym: **CoilTest 2**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2017 – 30/06/2024**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Coil-coated steel, Accelerated tests, marine atmosphere

Coil coated products are generally tested under both accelerated and natural weathering conditions with respect to their corrosion properties at cut edges, their delamination at scribes, and with respect to their corrosion properties at open surfaces and at formed areas. Field tests are normally the most reliable but they are costly and time consuming. The accelerated corrosion test that is used as a standard in the building industry is the neutral salt spray test (ISO 9227, ASTM B-117). Although this test has been used for decades to evaluate the corrosion performance of coil-coated products, it is well known that it fails in providing the type of degradation observed on coil-coated products at natural weathering sites and consequently is not useful to predict the durability of the products. In the last decades, several attempts have been done in order to develop more reliable accelerated corrosion tests for the building industry. These included for examples projects conducted within RFCS funding (2007) or more recently through ECCA programs or at the French Corrosion Institute (FCI).

ECCA has thus developed a cyclic corrosion test for coil coated aluminum products while FCI has proposed a cyclic corrosion test (Test 1A) of 2000 h for coil coated steel materials involving HDG, Galfan and Zn55%Al metallic coatings. From the round robin test conducted by ECCA, the test 1A was found to be too long and its reproducibility was not fully demonstrated.

ECCA: European Coil Coated Association

Project aims:

The aims are to optimize cyclic corrosion testing for coil coated steel products in view of shortening the test duration to 1000 hours on the basis of so-called Test 1A (or other cyclic corrosion tests).

BUILDING AND INFRASTRUCTURE

Project Title: **Assessing the Corrosion Properties of Metallic Materials on Model Buildings with various architectural features in marine atmosphere**	Acronym: **ModelBuilding**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2018 – 31/12/2024**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Coil-coated steel, marine atmosphere, model building

A number of test methods have been developed to ensure that prepainted materials for building applications fits to the desired purpose such as EN 13523-19 and EN 13523-21 when considering the corrosion resistance at weathering sites. A minimum of 2 years exposure of standardized prepainted steel panels is required for assessing the corrosion resistance at outdoor sites of corrosion category ranging from low RC2 (rural) to high RC5 (marine, industrial) according to EN 10169.

Because real buildings offer a variety of architectural features (low angle roof, unwashed walls..), a project aiming to compare the mode and degree of degradations of prepainted steel on a model building with standardized ECCA panels exposed at 90° and 5° (EN 13523-19) was conducted at Institut de la Corrosion between 2012 and 2016. The model building was designed to include various architectural features such as roofs of various angles (5, 60°), washed and unwashed walls. Close to the seacoast, extremely high metal loss was measured on zinc exposed in unwashed locations of the model building with value up to 7 µm/year. Such metal loss has never been measured on standard exposure rack at 90°. It was also shown that the degree of damages observed on a model building could not be fully simulated by standardized panels especially in coastal regions: RC5M certificates would have been attributed to some products on the basis of standardized panels while unacceptable behavior was noted on the model building, especially in unwashed locations. Such results obviously put some questions on the reliability of small ECCA designs of panels to simulate such building conditions. It is thus of importance to test the materials in configurations that better mimic real building situations in order to be safe on the long-term durability of the product.

Project aims:

- To study the corrosion performance of newly commercial materials for building applications (prepainted steel in particular) on a model building with various construction features.

BUILDING AND INFRASTRUCTURE

Project Title: **Corrosion in agriculture environments**	Acronym: **FARM**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2018 – 31/03/2026**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Ammonia, coil coating

There are many potential causes of corrosion in animal buildings. Animals exhale large quantities of moisture into the air and create high relative humidity in the building if the moisture is not properly vented. High humidity increases the potential for condensation. In addition ammonia may be found in large quantities in animal buildings. Ammonia is released from manure and urine, especially during storage and decomposition. Levels could exceed 50 ppm with lowered winter ventilation rates and reach 100 to 200 ppm in poorly ventilated buildings. Additional corrosive agents are acids, and salts (from silage and feed residues, cleaning agents, fertilizers, and preservatives), mechanical destruction and bacteria causing microbially induced corrosion.

Project aims:

- To study the material performance of metallic coating in both liquid and atmospheric environments in a selected animal farming.
- To evaluate new coil coating materials with respect to these environments.

BUILDING AND INFRASTRUCTURE

Project Title: **Holistic method for evaluation and testing of coatings**	Acronym: **Coat test**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/01/2020 – 01/01/2025**
Research leader: **Alexander Wärnheim** alexander.warnheim@ri.se +46 73 079 29 38	Source of funding: **Public funding** Keywords: FTIR, spectroscopy, AFM, coatings, analysis methods, nanotechnology

The project, which is a PhD financed by SSF, aims to use advanced characterization methods such as micro- and nanoscale resolution infrared spectroscopy, nanomechanical analysis, and other high resolution analysis techniques to provide better understanding of the degradation of organic coatings. This knowledge will be used to better understand the effect of local properties on the robustness of a coating regarding exposures to UV-light, humidity and other damaging species. This is an enabling technology that will help with, among other things, the current push towards bio-renewable formulations. In addition, the project also uses the previously mentioned advanced analysis techniques to compare long-term outdoor weathering to artificial accelerated weathering methods that are widely used in industry.

Project aims:

- Transfer of already established spatially resolved analysis techniques used in different applications, and if necessary, development of new methodology to allow for e.g.
  - A deeper understanding of the chemical effects of coating degradation.
  - More accurate comparisons between outdoor and accelerated weathering methods.
- Expanded understanding of how nanoscale properties in biobased and synthetic organic coatings can be used to determine their durability and lifetime.

BUILDING AND INFRASTRUCTURE

Project Title: **Accelerated Corrosion Test for Coil Coated Aluminum**	Acronym: **ACT-Al**
Research area: **Building and Infrastructure, Coil coating**	Project period: **01/03/2018 – 30/06/2027**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding** Keywords: Coil-coated aluminum, Accelerated tests, marine atmosphere

The development of prepainted metal products for the building and construction market usually requires prolonged exterior exposure studies in order to validate product performance. An accelerated corrosion test that correlates with exterior exposure studies would enable the coil coated industry to shorten their development time for new products and reduce the cost of their research programs.

During the last 10 years, some efforts have been made by the Steel Industry for developing better reliable corrosion test for prepainted steel products in order to replace the conventional neutral salt spray test that is known to fail in reproducing real degradation. A project sponsored to ECCA is on-going at the French Corrosion Institute (FCI) to optimize the testing conditions on the basis of the so-called Test 1A.

Considering coil coated aluminum products, there is also a need to develop accelerated testing conditions that simulate service conditions in better way than the acetic salt spray test (ASST) currently used by the industry. Since 2008, some projects under the frame of ECCA were conducted at SINTEF in particular with the aim to develop an accelerated corrosion test for coil coated aluminum. The resulted test was able to reproduce similar degradations e.g. filiform corrosion from scribes or cut-edges. They were some limitations to the work carried out in this program and it was agreed that further development activity was required.

ECCA: European Coil Coated Association

Project aims:

The aim is to develop an accelerated corrosion test for prepainted aluminum products that correlates with exterior weathering performance. The test must be able to be used in commercially available equipment and would become the standard for the coil coated aluminum industry.

BUILDING AND INFRASTRUCTURE

Project Title: **Development of measurement method to determine the risk of necking on steel piles**	Acronym: **BBTPILE**
Research area: **Building and Infrastructure, Corrosion in concrete**	Project period: **01/09/2023 – 01/03/2026**
Research leader: **Jonas Engblom** jonas.engblom@ri.se +46 72 546 2171	Source of funding: **Industrial funding / Public funding (Swedish Road Administration)**
	Keywords: Corrosion in soil, Infrastructure, Material efficiency, Piling.

Steel pilings are, after concrete pilings, the most used type of piling in Sweden. The most common method of preventing corrosion to ensure the technical lifetime of the piling is through the use of a corrosion allowance, which means an over-dimensioning of the pilings. This over-dimensioning is based on empirical values from exposure studies, from which the corrosion rate has been extrapolated. When high corrosion rates have been recorded, these has been limited to a vertically restricted area, a phenomenon commonly referred to as “necking”. Despite this, the corrosion allowance for the entire piling has been based on the corrosion rate of this small area. In a previous project, a method for assessing the risk of occurrence of necking has been developed and compared with long time exposures with good results. In the planned project, the method will be further developed to improve practical use as well as the scientific value. The ambition is to enable a method that already in the planning stage of a construction project can assess if there is a risk of necking or not. If there is a risk, additional corrosion protection, or increased corrosion allowance, can be applied to the critical part of the piling. Dimensioning the corrosion allowance based on the need contributes not only to safer construction, but also to potential material savings. These material savings are planned to be calculated using LCA in the end stage of the project.

Project aims:

- Validation of a new type of sensor designed to detect small aeration cells (necking).
- Determination of proper field application, such as installation time, time of the year for installation, temperature fluctuations, etc.

BUILDING AND INFRASTRUCTURE

Project Title: **Partial repairs of concrete structures - Methodology to ensure extended service life**	Acronym: **BBTCORR**
Research area: **Building and Infrastructure, Corrosion in concrete**	Project period: **01/06/2023 – 31/03/2026**
Research leader: **Bror Sederholm** bror.sederholm@ri.se +46 73 512 78 44	Source of funding: **Industrial funding / Public funding (Swedish Road Administration)**
	Keywords: Corrosion, concrete structures, chloride environments, repair materials

Both in Sweden and Norway, the Swedish Transport Administration and the National Road Administration have drawn attention to the fact that concrete damage caused by reinforcement corrosion occurs locally. The problem has also come to the fore within the nuclear power industry in, among other things, cooling water ways. This has meant that the question of the choice of suitable repair methods has become relevant to minimize traffic disruptions at the Swedish Transport Administration and operational disruptions within the nuclear power industry. It will be important to avoid traffic and operational disruptions in above all road tunnels and cooling waterways where local repairs are and will be a used repair method for concrete structures. According to the Swedish Transport Administration, local repairs are made to bridge piers, bridge slabs, retaining walls and edge beams and retaining walls. There is uncertainty regarding the choice of repair material and methodology to avoid damage in the transition zone between repaired and original concrete. Previously carried out local repairs on, among other things, Öland’s bridge, have proved to be not permanent.

In the project, it is planned to test the corrosion protection ability of different repair materials using a laboratory method that was previously developed. In connection with the testing, the chloride-binding properties of the repair materials and the resistivity of the repair material are also analyzed. The properties are considered important to achieve a permanent repair.

The chlorides can be transported from the old chloride-contaminated concrete to the boundary layer between repair and old concrete, which can be one of the reasons why new corrosion can start. It is therefore important that the repair is carried out in the right way to prevent the chloride levels from increasing in certain places along the reinforcement.

Project aims:

- The aim of the project is to develop suitable repair materials to avoid corrosion in the existing concrete structure using permanent local repairs.
- The goal of the project is to show which types of repair materials are most suitable to be used to permanently repair localized concrete damage caused by reinforcement corrosion in chloride-containing environments.

Project Title: **Study of 100 mV criteria efficiency in soils**	Acronym: **100mV**
Research area: **Building and Infrastructure, Corrosion in soil**	Project period: **01/12/2022 – 01/12/2024**
Research leader: **Erwan Diler** erwan.diler@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Keywords: Soil, cathodic protection, carbon steel, moisture level, current demand, corrosion sensors

According to the ISO 15589-1 standard, the protection potential Ep corresponds to a potential in where the corrosion rate is less than 10 µm/y. This rate of corrosion is low enough for corrosion to be allowable for the rated life. The Ep values for such materials depends on the temperature and soil resistivity.
In field, if Ep cannot be achieved, a minimum lowering of cathodic potential of 100 mV is another acceptable method to reduce the corrosion rate. However, the ISO 15589-1 standard also mentions that a residual corrosion rate of less than 10 µm/year may not be achievable. This can be assessed with the use of electrical resistance (ER) corrosion sensor.

In soil, the local environment, i.e. initially polarized or not, as well as the moisture level can have a strong impact on the open circuit potential (OCP), oxygen diffusion, resistivity, active surface and depolarization kinetic. This environment can thus affect the efficiency of the 100 mV method, explaining that under certain cases rather high residual corrosion might subsist. The understanding of such mechanisms is crucial to ensure as much as possible the efficiency of such method.

The overall objective is to better understand and quantify the degree of the actual protection when the -100mV is applied, depending on the soil environment, as well such as:

- To assess the efficiency of the 100 mV criteria under unsaturated soil conditions both in terms of uniform and localized corrosion.
- To investigate the relation between the Open Circuit Potential of carbon steel and the moisture level for different soils.
- Assess the electrical resistance method to obtain the residual corrosion under CP at low moisture level in soils (higher risk of localized corrosion).

In this program, the localized corrosion induced by microorganisms (CIM), particularly possible at water saturation level in soil (anoxic condition) is not considered.

Project Title: **Coating ageing of buried structures in environments chemically affected by the cathodic protection – effect of alkaline interface**	Acronym: **COATAGE II**
Research area: **Building and Infrastructure, Corrosion in soil**	Project period: **01/01/2024 – 31/12/2026**
Research leader: **Krystel Pélissier & Erwan Diler** krystel.pelissier@institut-corrosion.fr	Source of funding: **Industrial funding**
	Keywords: FBE, 3LPE, Liquid Epoxy, cathodic protection, EIS, water uptake, Glass Transition temperature

The corrosion of buried structures is usually mastered by the combination of organic coatings and cathodic protection (CP). However, detrimental interaction between these two protections can be observed on site either by the induced cathodic disbondment or by the chemical aging of the coating due to the local environment (induced by the CP).

In soil, under CP, the limited species diffusion and the possibly high current demand can lead to pH as high as 14 at the vicinity of the defect. Such environment also containing oxygen radicals might be particularly severe for organic coatings. In a study performed at IC, old disbonded coatings (hydrocarbons and Fusion Bonded Epoxy) were characterized by electrochemical impedance spectroscopy (EIS). The obtained results show that with time the coating resistance strongly decrease. This behavior was reproduced under CP simulated conditions in laboratory on industrial coatings. Additional work performed at IC have demonstrated the significance of taking into account alkaline ageing of coating when considering the overall performance of the coating when considering LE, FBE and 3LPE.

In this project, industrial coatings will be exposed during several months to environment representative of CP in soils. The coating resistance and/or aging will be characterized by a combination of methods: EIS and water uptake on free membrane and coated steel. In addition, coating delamination susceptibility to alkaline ageing will be assessed on specimens with unprotected edges and on coating with circular defects.

Project aims:

- To study the kinetic of coating degradation as a function of the pH and the temperature.
- To assess coating delamination due to alkaline ageing on coated steel.
- To better understand degradation and disbondment mechanisms due to alkaline ageing.
- To propose a representative accelerated tests for organic coating development and qualification, more resistant to alkali-induced cathodic protection environment.

BUILDING AND INFRASTRUCTURE

Project Title: **Worldwide exposures: Determination of corrosion in soil**	Acronym: **Worldsoil**
Research area: **Building and Infrastructure, Corrosion in soil**	Project period: **01/01/2022-31/12/2024**
Research leader: **Abdelkader Meroufel & Dominique Thierry** Abdelkader.meroufel@ri.se +46 73 047 2263	Source of funding: **Industrial funding** Keywords: Corrosion in soil, worldwide exposure, metallic coatings, stainless steel

The corrosion of ferrous metals in soils is a major problem for owners and managers within the infrastructure and energy sectors, such as water, sewerage, oil and gas distribution systems, solar energy parks etc.

In addition, due to the large number of parameters that influence corrosion in soil, it is rather difficult to fully simulate field conditions at the laboratory scale. Hence, the present project will focus on field exposures of materials in soils with different characteristics. The project will include sites with high and moderate temperatures and high and low moisture content. The project will focus on condition where cathodic protection is not applied.

Project aims:

- To evaluate the performance of different materials and coatings used for soil applications.
- To generate data on a worldwide basis that could be used as input data in modelling.

BUILDING AND INFRASTRUCTURE

Project Title: **Soilcomp II**	Acronym: **Soilcomp II**
Research area: **Building and Infrastructure, Corrosion in soil**	Project period: **01/10/2022 – 30/06/2024**
Research leader: **Abdelkader Moeroufel** Abdelkader.meroufel@ri.se +46 73 047 2263	Source of funding: **MRC Soil** Keywords: Corrosion, galvanization, soil, resistivity

The use of Zinc based coatings for buried support structure increased in terms of use for different applications including solar support structures. The performance of these materials in different soil types is an industrial need to get their performance versus traditional materials such as steel and pure zinc. Following an initial phase where the performance of these materials was studied in laboratory for both natural and artificial soil, the present project phase was focused to answer two main research questions i.e. performance in laboratory versus field exposure conditions, the effect of temperature. The effect of temperature was studied considering refrigerated exposure condition for the three considered soils i.e. sandy, clay and peat.

Key corrosion factors are assessed in both laboratory and field conditions to determine the gap extent that may exist and affect the results. Soil moisture, resistivity and temperature are monitored using gravimetry method, four pin method, and sensors. The corrosion rate is determined by weight loss method.

Project aims:

- Assess the corrosion rate of different zinc-based coating in laboratory and field exposure conditions.
- Determine the effect of temperature on corrosion rate of zinc-based coatings and carbon steel.

BUILDING AND INFRASTRUCTURE

Project Title: **Worldwide exposure of metallic coated steel panels**	Acronym: **Worldcoat II**
Research area: **Building and Infrastructure, Construction**	Project period: **01/01/2017 – 31/12/2027**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Zinc coated steel, field exposure

In 2011, a project was initiated at the French corrosion institute with the aims to define the corrosion behavior of hot-dip galvanized steel, ZnAl and ZnAlMg coated steel at 14 different field stations world-wide. 1, 2, 4- and 6-years data have been collected.

In addition, analyses of corrosion products have been performed after 2 and 4 years of exposure.

As indicated before although the project has generated very valuable results, they are still questions that remain. For instance, as the corrosion was highly localized on all metallic coatings, the measurements of mass loss are questionable and may not reflect the localized corrosion observed on all coatings.

In addition, new metallic coatings with addition of Al and Mg have been introduced recently on the market and were not included in the first investigation.

Project aims:

- To obtain the long-term (e.g. up to 10 years) behavior of ZnAl and ZnAlMg coated steel (in particular with respect to red rust) and compare it with hot-dip galvanized steel.
- To obtain a full picture of the performance of ZnAl and ZnAlMg coated steel worldwide.

BUILDING AND INFRASTRUCTURE

Project Title: **Investigation of pretreatment primers performance for coil coated steel**	Acronym: **PprimerCoil**
Research area: **Building and Infrastructure, Construction**	Project period: **01/01/2024 – 31/12/2026**
Research leader: **Nathalie Le Bozec** nathalie.lebozec@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Public Funding**
	Keywords: Pretreatment primers, EIS, FTIR-ATR Spectroscopy

The replacement of conversion coating and primer paint by a single step application of pretreatment primer is an attractive option for coil coaters, as it may allow for cost reductions and shortening of the coil coating lines. Indeed, any process involving energy saving technologies is of utmost importance under the actual situation on the energy sector in Europe. Paint and pretreatment suppliers have developed thin paints and thick pretreatments, respectively, with the ability to serve as integral solutions. However, these new technologies need a better understanding in the adhesion and corrosion mechanisms as well as long term data, before being deployed by the Steel Industry. From previous projects conducted at FCI, systems involving pretreatments primers showed a poorer resistance to blistering than conventional ones because of poor water stability of the metal / primer interface leading to loss of adhesion. It was also highlighted that the impact of the cleaning step was not sufficient to induce a significant change in the performance of the pretreatment primer systems. It is obvious that there are still gaps of knowledge on the mechanisms of protection of pretreatment primers.

Project aims:

The main aim of the project is to better understand the behaviour of pretreatment primers applied on Zn-0.2Al coated steel by the characterisation of the mechanisms occurring at the interface metal / primer. This will be elucidated by:

- Investigating the relationships between the barrier properties of the top-coat and the release of corrosion inhibitors from the pretreatment primers.
- Analysing the modifications induced by water and ions at the interface metal/polymer.
- Identifying key parameters of the system to define models of accelerated aging.

Project Title: **The International Co-operative Programme on Effects on Materials including Historic and Cultural Monuments**	Acronym: **ICP Materials**
Research area: **Building and Infrastructure, Cultural Heritage**	Project period: **01/01/1987 – Undefined**
Research leader: **Johan Tidblad** johan.tidblad@ri.se +46 10 228 48 78	Source of funding: **Public Funding (UN and The Swedish Environmental Protection Agency)**
	Keywords: Air pollution, Atmospheric corrosion, Atmospheric soiling, Atmospheric degradation, Cultural heritage

The International Co-operative Programme on Effects on Materials, including Historic and Cultural Monuments (ICP Materials) started in 1985. It was initiated in order to provide a scientific basis for new protocols and regulations developed within the Convention on Long-range Transboundary Air Pollution.

Project aims:

• Perform a quantitative evaluation (dose-response functions) of the effects of multi-pollutants such as S and N compounds, O3 and particles as well as climate parameters on the atmospheric corrosion and soiling of important materials, including materials used in objects of cultural heritage.

• Describe and evaluate long-term corrosion and soiling trends attributable to atmospheric pollution in order to elucidate the environmental effects of pollutant reductions achieved under the Convention and in order to identify extraordinary environmental changes that result in unpredicted materials damage.

• Use the results for policy purposes for the benefit of the Convention by i.a. mapping areas with increased risk of corrosion and soiling and for calculation of cost of damage caused by deterioration of materials.

Project Title: **Qualification of newly developed corrosion monitoring systems under ionizing radiation for the radioactive waste French underground laboratory**	Acronym: **SensIRAD**
Research area: **Building and Infrastructure, Cultural Heritage**	Project period: **01/05/2023 – 31/12/2024**
Research leader: **Erwan Diler / Johan Becker** erwan.diler@institut-corrosion.fr +33 (0)2 98 05 15 52	Source of funding: **Public fundings (ANDRA)**
	Keywords: Corrosion monitoring, electrical resistance sensors, carbon steel, storage and disposal of radioactive waste

The French deep geological repository solutions for the disposal of high and intermediate-level long-lived radioactive waste is studied since decades at the underground pilot laboratory (URL) managed by the French National Agency for Radioactive Waste Management (Andra). The URL is located in the East of France, 500 meters deep, in a stable Callovo-Oxfordian claystone layer, selected for its containment properties. The concept relies on a multibarrier approach including the use of a carbon steel (CS) casing inserted in microtunnels and in which sealed radioactive waste container will be then introduced. After insertion of the CS casing, a remaining technological gap between the Cox and the extrados of the casing is filled with a specific cement grout. This cement grout aims to buffer the acidic transient resulting from the release of acidity in the pore water due to the oxidation of sulfur-based minerals.

In this context, the Andra is conducting studies focusing on the corrosion and mechanical behavior of the CS casing, with particular interest for real-time corrosion monitoring solutions as an alternative to the common gravimetric method using reference coupons. Several techniques are investigated, including the electrical resistance (ER) raising several challenges to satisfy the requirements implied by the specific conditions of the disposal or radioactive waste in deep geological repository. This project focus on the qualification under irradiation of a newly developed ER corrosion monitoring system with i) investigations on the effect of gamma rays on the early ageing of the sensor materials and ii) the assessment of the ER sensor capacity to monitor corrosion under irradiation conditions.

Project aims:

• Qualify specific electrical resistance sensors under irradiation.

• Assess the effect of irradiation on the early ageing of sensor materials.

• Assess the effect of irradiation on the sensor operation.

Project Title: **Plastic Free Corrosion Protection for CX -environments**	Acronym: **PFCX**
Research area: **Building and Infrastructure, Paint**	Project period: **01/01/2021 – 31/12/2027**
Research leader: **Björn Tidbeck** Bjorn.tidbeck@ri.se +4672 734 08 17	Source of funding: **MRC Corrosion Protection**
	Keywords: Environmentally sustainable coatings, Microplastics

During 1972-1973, NASA carried out an extensive investigation comprising 200 different coating systems based on zinc rich coatings. One of the conclusions from the study was that zinc rich coatings perform better without topcoats. One possible mechanism explaining this result may be that water ingress into the zinc primer may degrade the primer prematurely in multicoat systems. And a better approach may be to use a topcoat with higher water permeability, see Figure 1.

In this study, alternative topcoats for zinc silicates will be trialed in an attempt to develop a completely inorganic, two coat CX system. It is envisioned that such a system would not attribute a source of microplastics whilst offering increased durability, lower VOC emissions, less chemical hazards, and less risk of fire compared to traditional systems based on epoxy and polyurethane.

The project has been preceded with a study on microplastic emissions from marine coatings. Initial trials have been very promising, see figure 2. This project includes more extensive evaluation by both accelerated and outdoor corrosion testing in CX environments.

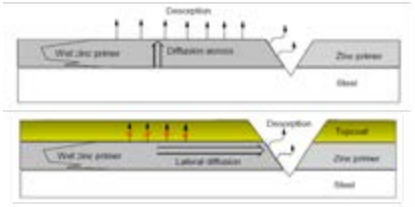

Figure 1. Drying of a zinc silicate without topcoat vs a zilicate with topcoat

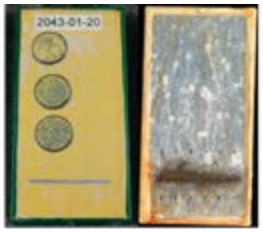

Figure 2. Initial trials after CX testing To the left: silicate topcoat. To the right reference

Project aims:

- To develop a plastic free coating system for CX/ offshore environments.
- To develop a CX coating system with reduced cost.
- Todevelop a CX coating system with reduced VOC emissions, chemical hazards and Risk of fire.
- To develop a CX coating system with reduced cost.

Project Title: **Smart monitoring of infrastructure asset health and performance in the drinking water distribution systems**	Acronym: **SMART-Infra**
Research area: **Building and Infrastructure, water distribution**	Project period: **01/10/2021 – 31/12/2024**
Research leader: **Charlotta Obitz & Johan Becker** charlotta.obitz@ri.se +46 73 088 76 75	Source of funding: **Public funding (Formas)**
	Keywords: Drinking water Infrastructure, monitoring, AI, digitalization, infrastructure maintenance, sensors

There is an important lack of online monitoring tools for controlling and predicting water distribution infrastructure durability. Unlike leakage detection and water quality monitoring systems, which are already quite developed, online corrosion and biofilm monitoring systems are still scarce and require more knowledge to determine how these aspects can be better evaluated in combination with other collected data. It is also important to underline that each aspect that is related to infrastructure health and performance (corrosion, biofilm, water quality, and leakage detection) is too often studied separately. It is therefore difficult to get an overview of the whole infrastructure status and there is a need to understand how collected data relate to each other and what complementary data must be monitored.

The available equipment is also not adapted to a wide range of dimensions or different types of materials. The cost per meter of inspected pipe is relatively high today, which means that regular/repeated condition inspection of large parts of the water pipe network seems unrealistic unless cheaper and more flexible technology is developed.

We believe that collaboration at the international level and with other sectors is a key to moving forward in the most effective way. That is why SMART-Infra gathers partners not only from Sweden but also from Spain and France and will use its communication channels to gather best practices within this area. The project intends to use close-to-market technologies or already marketed technologies that will complement data already collected by water utilities to be able to assess in a safe way the status of their infrastructure.

Project aims:

- Accelerate digital transformation in the drinking water distribution sector.
- Identify monitoring solutions to assess the status of the infrastructure health and performance.
- Develop tools to identify critical points in the infrastructure and manage the built environment in a smart way.
- Investigate new parameters, in addition to those already monitored in the networks, that could be utilized in the management process.
- Predictability algorithms with respect to sensors used will also be investigated to facilitate the identification of deviations in the networks. SMART-Infra will directly contribute to the development of quality, reliable, sustainable, and resilient infrastructure by upgrading technology capabilities and increasing resource-use efficiency.

BUILDING AND INFRASTRUCTURE

Project Title: **Corrosion resistance of brass**	Acronym: **BRASSCORR**
Research area: **Building and Infrastructure, water distribution**	Project period: **01/01/2022 – 31/12/2024**
Research leader: **Charlotta Obitz** charlotta.obitz@ri.se +46 73 088 76 75	Source of funding: **MRC Brass Alloys**
	Keywords: Brass, corrosion, water, acetic acid, glycol

The corrosion resistance of brass to chemicals is of importance in material selection and in failure analysis. The number of possible chemicals that may come in contact with brass is vast and it may be hard to find information on a specific chemical. Various lists containing a rating system for the suitability of brass alloys in contact with different substances are available, however, these tables are old and appropriate references behind the rating system are not clear. The assessments were made for traditional brass alloys before the introduction of new low-lead and lead-free alloys. Thus, there is a need from industry to update the lists from both the modern brass alloys perspective and to develop an experimental method for determination of the corrosion resistance. In addition to the test in liquids in the laboratory a long-term field test in different water distribution installation will be started to allow the evaluation of new lead-free brass alloys.

Project aims:

- Develop a method for assessment of the corrosion resistance of brass in different liquids.
- To publish a modern list for the corrosion resistance of brass to different liquids.
- Start a long-term field test.

BUILDING AND INFRASTRUCTURE

Project Title: **New Generation Lead-Free Brass Alloys**	Acronym: **NEWLEAF**
Research area: **Building and Infrastructure, water distribution**	Project period: **18/05/2022 – 18/02/2025**
Research leader: **Charlotta Obitz** charlotta.obitz@ri.se +46 73 088 76 75	Source of funding: **Public funding (Vinnova)**
	Keywords: Brass, lead-free, corrosion, drinking water, alloy development

The Swedish brass industry has built up a system where most of the production is based on recycled material. During the last few years, low-lead alloys have been developed and optimized through several research projects, to replace the traditional alloys containing 2-3% lead. Most efforts have been put on improving machining and productivity, as well as investigating methods to refine melt from lead. However, more stringent EU directives on lead and lead release to drinking water implies that the newly developed alloys risk not being accepted, which poses a serious threat to the brass industry. This project will focus on developing and modifying lead-free alloys adapted to the revised lead directives, using the learnings and outputs of the previous projects performed (e.g., the need for further developments regarding castability) as well as new studies to understand the relationship between corrosion mechanisms, alloys composition and microstructure and lead release to drinking water. Refining of brass melt from lead will also be further implemented through pilot-testing to ensure a circular approach. Finally, an analysis of carbon footprint for the different alternatives and production routes (LCA), of todays and tomorrow's regulatory requirements, of cost consequence for the different alternatives and of testing capacities available will ensure an overall system perspective, allowing to look beyond silos and have a holistic approach in choosing the alloys and production routes to be implemented.

Project aims:

- Maintain the circular Swedish brass industry while meeting revised EU directives and regulations and secure material supply for a lead-free future.
- Concepts for different alloys suitable for the different production routes of the project partners will be available for evaluation in approval processes and for future standardization.
- Plans about how a controlled transition to lead-free industry in Sweden without a significant increase in demand of new raw materials can be achieved.

Project Title: **Network for materials and Products in contact with drinking water**	Acronym: **DW network**
Research area: **Building and Infrastructure, water distribution**	Project period: **01/01/2024 – 31/12/2024**
Research leader: **Charlotta Obitz** charlotta.obitz@ri.se +46 73 088 76 75	Source of funding: **Industrial funding**
	Keywords: Drinking water, Materials, Products, Legislation

This network gathers relevant actors along the drinking water chain, such as manufacturers, industry associations, drinking water suppliers, authorities, and researchers, who are interested in the topic of materials and products in contact with drinking water.

The network offers the opportunity to exchange knowledge about current legislation, up-to-date research, industrial challenges as well as material and product development. The network maintains close contact with the European Commission and national authorities on the coming legislation and approval systems for materials and products in contact with drinking water. We also regularly invite other European stakeholders to present at our seminars (RTOs, industries, water suppliers) and exchange ideas and best practices in the field.

Our members get the opportunity to meet annually through two seminars. We also send a newsletter every year where essential information regarding materials and products in contact with drinking water is given. The network raises members' questions and needs in the area of materials and products in contact with drinking water.

Project aims:

- Have up-to-date information about legislation, regulations, industry challenges, research, and material and product development.
- Exchange of experience in this area.
- Develop contacts with other stakeholders incl. authorities.
- Possibility to present your own innovations and research.

Project Title: **Impact of heat tinted oxides from welding operation on the localized corrosion susceptibility of stainless-steel alloys**	Acronym: **SSWeld**
Research area: **Building and Infrastructure, water distribution**	Project period: **01/03/2022 – 01/09/2024**
Research leader: **Charles Leballeur** charles.leballeur@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Industrial funding**
	Keywords: Stainless steel, welding, localized corrosion, chloride.

Stainless steel alloys are widely used in different sector of activity involving all kind of water transportation, from drinking water application to seawater desalination. For all these applications, welding of stainless-steel products is very common. If the good practices for welding of stainless steel are widely known, the operating conditions can sometimes make them difficult to apply. End-user feedback has shown that numerous cases of pitting corrosion at welded areas are due to improper welding operation. Indeed, operating conditions can lead to difficulty to apply a perfect inerting which lead to the formation of heat tinted oxides. These oxides are known to potentially reduce the corrosion resistance of stainless steel. Pickling & repassivation of inner welding surfaces can be a solution to recover stainless steel corrosion properties. However pickling operations are sometimes not possible due to field constraints. Some authors have considered the existence of a chromium depleted zone beneath the oxide as the main cause of an observed decrease in corrosion resistance. However, other authors disagree and suggested other mechanisms explaining the presence or lack of a chromium-depleted zone. One practical factor often correlated to the corrosion resistance is the color of the tint. According to von Moltke et al, the color of the oxide is only an indication of the thickness of the oxide, not the composition or the corrosion resistance. In contrast, Kearns connected the corrosion resistance to the color of the heat tint, finding that a rose-colored tint had lower corrosion resistance than the straw colored. Enrichment of iron in the outermost oxide as well as in oxides above a certain thickness has been shown to decrease the corrosion resistance of stainless steels with heat tints in chloride environments. Standard AWS D18.2 classified different levels of tinted oxides as a function of the residual oxygen level from purging gas operation during welding. However, no relevant information can be found in the literature regarding the magnitude of tinted oxides on the corrosion resistance of stainless steel (i. e. lack of quantified engineering diagrams based on corrosion testing). Therefore, there is an interest to quantify the corrosion resistance decrease of stainless-steel welds as a function of the residual tinted oxides (i. e. as function of inerting quality).

For this study the corrosion susceptibility of selected stainless-steel grades will be investigated as a function of the heat tint levels achieved from controlled welding operation at different oxygen levels. Testing will be conducted with different chloride concentrations adapted to tested grades, with the aim to provide guidelines for the use of welded stainless steel with residual oxides in service conditions. The global aim is to provide engineering data and scientific knowledge to decide acceptable welding results when not achieved in perfect inerting conditions.

Project aims:

- Assess the corrosion resistance of different stainless-steel grades in chloride containing solution as a function of the controlled heat tinted levels.
- Determine criteria of acceptance for weld discoloration in term of corrosion resistance.
- Characterize the passive films properties to better understand the detrimental factors to be regarded.

BUILDING AND INFRASTRUCTURE

Project Title:	Acronym:
ReTestBrass	**ReTestBrass**

Research area:	Project period:
Building and Infrastructure, water distribution	**14/11/2023 – 30/06/2024**
Research leader:	Source of funding:
Charlotta Obitz	**Public funding (Vinnova)**
charlotta.obitz@ri.se	Keywords:
+46 73 088 76 75	Brass, accelerated test, lead-free, water

Corrosion-resistant brass alloys have been used in Swedish tap water systems since 1970. An accelerated test method described in standard SS-EN ISO 6509 is currently used to determine the dezincification resistance of alloys and components. However, this test method was developed for the old leaded brass alloys and not for the modern lead-free brass alloys. Results from testing of lead-free alloys according to ISO 6509, and from field exposures are not in agreement and there is a need to develop a test method that can be used to predict the corrosion resistance of the lead-free brass alloys. Without a suitable test method, there is a risk that products with reduced durability will be placed on the market and that the risk of water leakages in different installations will increase. The method development is performed by researchers and industry in close collaboration. The need for a suitable test method is urgent since no new products made of the traditional dezincification resistant alloys currently used in Swedish water installations will be allowed to be placed on the market after 31 December 2026.

Project aims:

- Development of a new test method or adjustments of the current method (ISO 6509) for evaluation of the corrosion resistance of lead-free brass alloys.

MARINE MATERIAL

Project Title:	Acronym:
Ecotoxicology analysis of cathodic protection to assess the chemical risk of elements released from galvanic anode (GACP) and impressed current (ICCP) on the marine environment and its food webs	**ECOCAP**

Research area:	Project period:
Marine materials, cathodic protection	**01/10/2021 - 01/10/2024**
Research leader:	Source of funding:
Charles Leballeur	**Public funding**
charles.leballeur@institut-corrosion.fr	Keywords:
+33 2 98 05 15 52	Cathodic protection, Marine, ecotoxicology, Wind turbine, Renewable Energy

To protect immersed marine structures against corrosion, cathodic protection, by galvanic anode or impressed current, is very often associated with an organic coating the use of cathodic protection recently raised the question of the release of potentially toxic chemical species into the environment.

Focus will be made on aluminium anode and ICCP system. Alumium speciation (proportion of dissolved or particulate forms) in seawater is complex to establish since this last depends on the total concentration of the element, on the pH and the presence of organic ligands. Moreover, the behavior of this element is no conservative and responsible of the presence of an instable colloidal fraction. The bibliographic review and results performed over FEM ANODE program (2019-2020) concluded that not enough data were available to assess the potential environmental risk for dissolved Al and suggested that more bioassays must be performed on various marine taxons representative of different trophic levels to refine its PNEC marine-water (PNEC - Predicted No Effect Concentration). ECOCAP proposes to go further by refining metals thresholds (particularly aluminum) through the ecotoxicological study conducted with the aim to determine if the anode could induce exceeded concentrations of metals into the marine environment.

Project aims:

- ECOCAP project main objective is to produce a knowledge base of the potential environmental impacts of cathodic protections in the context of industrial developments such as ORE.
  - o Build a conclusive chemical risk assessment for aluminum.
  - o Assess description of elements and compounds released from ICCP systems and their fate as a function of time.
  - o Compare impact of GACP and ICCP from an ecotoxicologic point of.
- Design a set of tools (models) available for the ORE stakeholders to (1) simulate GACP and ICCP elements dispersion with an enhanced model with adapted modularities and (2) investigate the potential transfer of released element in the food webs.
- Give guidelines for ORE stakeholders for the use of cathodic protections and coatings in future projects.

MARINE MATERIAL

Project Title:	Acronym:
Full-Scale Experiments to Determine the Long-term Effect of Cathodic Protection on Disbondment of 3LPP-coated tubes at bare zones (Bare Field Joint applications)	**BFJ**

Research area:	Project period:
Marine materials, cathodic protection	**01/02/2022 - 01/09/2024**
Research leader:	Source of funding:
Nicolas Larché	**Industrial funding**
nicolas.larche@institut-corrosion.fr +33 2 98 05 15 52	Keywords: Cathodic disbondment, bare field joints, cathodic protection, seawater, seabed, heat flux

To reduce drastically the cost of field operations, it may be considered to eliminate field joint coating completely on pipelines coated with an anti-corrosion coating such as three-layer polyethylene or polypropylene, regarding that bare areas are protected with cathodic protection (CP). This raises the question whether CP will lead to significant disbondment and at which rate.

Institut de la Corrosion developped a test methodology to evaluate CP-induced cathodic disbondement of full scale tubes in natural seawater and in natural seabed, with temperature control inside tubes.

In this new project the cathodic disbondment rate of bare zone of 3LPP-coated tubes will be investigated in natural seawater and in seabed, at different internal temperatures from 25°C to 90°C.

Full-scale tube lengths of diameter 8" are tested. The disbondment rates and associated mechanisms will be studied for exposure durations from 6 to 24 months. The results from full-scale bare zones will be compared to commonly used artificial defects used in standards.

Project aims:

The main aim of the project is to quantify the actual disbondment rates of full-scale tube bare field zones under CP, exposed under different conditions in seawater and in seabed.

MARINE MATERIAL

Project Title:	Acronym:
Industrial upscale of surface protection system & fibre optic-based condition monitoring for the Seasnake MVC	**SEASNAKE+**

Research area:	Project period:
Marine materials, coatings	**15/12/2023 – 15/12/2026**
Research leader:	Source of funding:
Konrad Tarka	**Public funding (Swedish Energy Agency)**
konrad.tarka@ri.se +46 10 516 56 80	Keywords: Antifouling; shape sensing; connecting devices; energy transport; Marine technology sensors and instrumentation; Cables and pipelines.

The main objective of SEASNAKE+ is to scale-up and demonstrate (TRL6-7) the dynamic medium voltage cable (dMVC) with improved lifetime by easy clean paint; in-line in-situ paint application chamber; in-situ cleaning robot; giving to the cable new and scalable protection system and monitoring system. The SEASNAKE+ dMVC will be validated first at small scale in nearshore condition in two different sites (Swedish west coast and Mediterranean Sea) and once the full-scale prototypes will be ready, in a real ocean environment in the Mediterranean Sea. SEASNAKE+ objectives and activities are based upon the learnings and proof-of-concept (TRL4) of a new lightweight (no armoring) and flexible cable carried out within the previous SEASNAKE (OCEANERANET COFUND). SEASNAKE+ expands those efforts on European level as key gaps and opportunities has been identified during the projects for scaling up the production and integrate the protection system application into the production along with new sophisticated and innovative ways to measure cables movement (shape sense) and failure modes in an integrated fiber optic solution.

SEASNAKE+ is breakthrough in cable development for offshore renewable energy, including interoperability in fish farming sector, setting new state of the art in terms of reliability, sustainability, cost addressing two identified challenges in stakeholder survey (CETP-SRIA) CH1.3.3 Floating Offshore Wind & Wind Energy Industrialization and CH1.8.2 Foundations, Connections and Mooring. SEASNAKE+ will become a key solution enabling global roll-out and up-scale of offshore energy technologies.

Project aims:

- Increase economic viability by reducing the Levelized Cost of Energy (LCoE).
- Scale up of surface treatment solutions in the production.
- Implement predictive conditioning solutions in the cable design.
- Minimised Environmental Impact & Increased Availability (reliability, maintainability and survivability).
- Demonstration of dynamic cable solutions.

MARINE MATERIAL

Project Title:	Acronym:
Improved, environmentally friendly and plastic free coating systems for offshore corrosion mitigation	**Green CX Coatings**

Research area:	Project period:
Marine materials, coatings	**01/01/2023 – 31/12/2025**
Research leader:	**Source of funding:**
Krystel Pélissier	**MRC Paint and Lining for Steel**
krystel.pelissier@institut-corrosion.fr +33 2 98 05 15 52	**Keywords:** ISO 12944-6, Low VOC, polysiloxane, zinc ethyl silicate

The application of coatings is an inescapable measure in the constant struggle against material ageing and corrosion. Several measures can be applied to delay corrosion phenomena, but the application of anticorrosive coatings remains one of the best options. The protective coating industry is in constant evolution mostly due to two major driving forces, i) the constant need of improvement of anticorrosive solution for long term performance (and ultimately less maintenance) and ii) the constant evolution of the market regulation (environmental, health) due to a general awareness of the impact of this industry sector. This constant evolution leads to the development of new anticorrosive technologies through the use of novel approach such as reduced content of Volatile Organic Compounds (VOCs) in the formulation. However, no tangible feedback still exists for this type of new technologies despite their increased incorporation in anticorrosive coating architectures (primer, intermediate, topcoat). Even though their low VOCs characteristics make them attractive in terms of environmental concerns, end users are still precautious when considering their uses, regardless of their potential good performance. Indeed, for example, high solid polysiloxane technology is considered as an interesting alternative to traditional polyurethane topcoat when the stability to weathering is considered. However, few studies exist on the performance (corrosion in addition to weathering) of this kind of topcoats tested in field exposure.

Another example of low VOCs coating which can be quoted is the use of waterborne zinc silicates. Studies conducted within RISE in the MRC Corrosion Protection have demonstrated the good performance of this type of primer when they were designed as a single coat system. This good behavior was observed both in accelerated testing and in field exposure. One of the drawbacks of this kind of system is the difficulty to design a multi-coat system where the waterborne zinc silicate primer is topcoated. Indeed, their good anticorrosive performance can be lost due to an incompatibility with the topcoat. In light of these findings and observations, a project on topcoats for waterborne zinc silicate will be launched within MRC Corrosion Protection in 2023. A unique opportunity to collaborate between the MRC Paint and the MRC Corrosion Protection is arising when both problematics can be studied together.

Project aims:

- To test different plastic free topcoats for zinc silicate technologies and to assess their performance for C5 and CX atmospheres.
- To assess polysiloxane performance and compare it with traditional polyurethane technology for C5 and CX atmospheres.

MARINE MATERIAL

Project Title:	Acronym:
Sustainable Concrete Material Leading to Improved Substructures for Offshore Renewable Energy Technologies	**WECHULL+**

Research area:	Project period:
Marine materials, Corrosion in concrete	**01/12/2023 – 30/11/2026**
Research leader:	**Source of funding:**
Pierre Ingmarsson	**Public funding (Swedish Energy Agency)**
Pierre.ingmarsson@ri.se +46706205290	**Keywords:** Blue Economy, concrete, testing sites, marine materials, prototypes, ocean energy, floating solar

The main objective of WECHULL+ is to demonstrate (TRL4-6) a new, sustainable, circular and reliable concrete material suitable for floating substructures in the offshore renewable energy sector; to model, test and validate it in the real ocean environment. WECHULL+ objectives and activities are based upon the learnings and proof-of-concept (TRL4) of a new sustainable concrete mix with high-performance in marine environment, carried out within the WECHULL project (TRL4). WECHULL+ takes these efforts to a European level, where experts in the field of material sciences, predictive modelling, field testing, critical loads assessment, biofouling, technology development, extreme load analysis, social sciences and environmental impact assessment, are brought together to validate and verify the WECHULL+ concrete material and its real application through sample ant prototype testing (lab and ocean).

Project aims:

- Minimised Environmental Impact & Increased Availability (reliability, maintainability and survivability).
- Industrialisation and scale up of local production processes.
- Improved Predictive Computational Modelling Tools for ORE concrete substructures.
- Increase economic viability by reducing the Levelized Cost of Energy (LCOE) by at least 25%.
- Establish recommendations and guidelines for standardisation for enhanced technology design and testing.
- Promote exchange of knowledge for technology uptake of new concrete materials.

MARINE MATERIAL

Project Title:	Acronym:
Impact of Hydrogen permeation in steel on polymer adhesion	**HAdoc**

Research area:	Project period:
Marine materials, hydrogen	**01/01/2022 – 31/12/2025**
Research leader:	**Source of funding:**
Flavien Vucko	**Public funding (CEFIPRA)**
flavien.vucko@institut-corrosion.fr +33 (0)2 98 05 15 52	**Keywords:** Hydrogen, permeation, coating, SKP, XPS

Organic coatings are typically used to protect external corrosion of oil and gas pipelines which are subjected to changing moisture content, oxygen and pH levels. Hydrogen produced either via cathodic protection of such pipelines or present as a fuel gas in pure (or mixture) form can adsorb, absorb and permeate through the steel from the inside. The diffusing hydrogen can emerge from the other side of the steel pipeline and can alter the surface chemical composition of the iron oxide. Since the oxide anchors the polymer coating, such hydrogen effusion can affect the adhesion of coatings leading to disbondment and failure. The mechanism by which such coating degradation happens due to hydrogen has not yet been explored to the best of our knowledge. The current proposal aims at understanding the macroscopic loss of coating adhesion due to changes in steel oxide chemistry upon hydrogen charging. To this aim, we will (a) deposit industrial coatings on steel membrane as well as model coatings on iron(oxide) thin layers (b) characterize bonding chemistry at the oxide/polymer interface (c) determine hydrogen flux necessary to initiate coating delamination (d) correlate loss of coating impedance to hydrogen flux (e) correlate corrosion potential in the air to hydrogen flux charged in-situ and ex-situ (f) carry out post-mortem pull-off adhesion tests after hydrogen ingress. Quantitative characterization of the influence of hydrogen effusion on coating/oxide interface stability will allow safe operation of existing pipelines as well as guide future design. The originality of the work is to combine efforts to apply several novel approaches like, for example, hydrogen permeation, Scanning Kelvin Probe (SKP), physical vapor deposition (PVD), electrochemical impedance, infrared (IR) and X-ray Photoelectron Spectroscopy (XPS), and use the ensemble of these results to develop an understanding of the operating physico-electrochemical processes, in order to predict failure and prevent it.

Project aims:

Quantitative characterization of the influence of hydrogen effusion on coating/oxide interface stability will allow safe operation of existing pipelines as well as guide future design.

MARINE MATERIAL

Project Title:	Acronym:
Biofilm-Induced corrosion of metal structures for Aquaculture Application and development pf Adapted Corrosion Sensors for Optimized Maintenance	**seaCHEM-DC2**

Research area:	Project period:
Marine materials, monitoring & sensors	**01/06/2023 – 01/06/2026**
Research leader:	**Source of funding:**
Mohammad Hassanzadeh	**Public Funding (HORIZON)**
mohammad.hassanzadeh@institut-corrosion.fr +33 2 98 05 15 52	**Keywords:** Seawater corrosion, biofilm, fatigue-corrosion, stainless steels, sensors, offshore seaweed aquaculture

The European Seachem DN project involves a total of 10 doctoral candidates (DC1-10) working on a same global challenge abut offshore cultivation and valorization of seaweed. This international training program, encompassing 7 intersectoral partners (5 academic, 1 non-academic) in 4 countries, focuses on innovative technological developments across a range of interdisciplinary fields such as construction engineering, materials science, (micro-)biology, (bio-)chemical engineering, environmental biotechnology and machine learning. The main scientific goal of SeaChem project is to uplift the underdeveloped EU seaweed aquaculture by developing and implementing the next generation of offshore cultivation technologies and advanced extraction processes, thus maximizing the value chain of offshore grown seaweed.

The doctoral candidate DC2 at Institut de la Corrosion will study biofilm-induced corrosion of metal structures for offshore seaweed aquaculture application, and development of adapted corrosion sensors for optimized maintenance. It includes the study of fatigue under crevice corrosion. Results will be combined and linked to DC3 (Mapping of corrosion around marine structures). The overall objective is to gain increased knowledge on biofilm-induced corrosion of stainless steels for seaweed aquaculture application and development of adapted corrosion sensors.

Project aims:

The main objective is to identify and analyse main corrosion risks that can be encountered in the concerned metal structures and to define, use and develop monitoring technologies for optimized maintenance regarding corrosion aspects.

MARINE MATERIAL

Project Title:	Acronym:
Environmental Impact of Material corrosion and Anti-corrosion Systems in Offshore Seaweed Aquaculture	**seaCHEM-DC4**

Research area:	Project period:
Marine materials, monitoring & sensors	**01/02/2023 – 01/02/2026**
Research leader:	**Source of funding:**
Caya de Leeuw Van Weenen	**Public Funding (HORIZON)**
caya.de.leeuw.van.weenen@institut-corrosion.fr	**Keywords:**
+33 2 98 05 15 52	Environmental impact, Offshore seaweed aquaculture, monitoring, corrosion and anti-corrosion systems, pollution, e-DNA

The European Seachem DN project involves a total of 10 doctoral candidates (DC1-10) working on a same global challenge about offshore cultivation and valorization of seaweed. This international training program, encompassing 7 intersectoral partners (5 academic, 1 non-academic) in 4 countries, focuses on innovative technological developments across a range of interdisciplinary fields such as construction engineering, materials science, (micro-)biology, (bio-)chemical engineering, environmental biotechnology and machine learning. The main scientific goal of SeaChem project is to uplift the underdeveloped EU seaweed aquaculture by developing and implementing the next generation of offshore cultivation technologies and advanced extraction processes, thus maximizing the value chain of offshore grown seaweed.

The topic for the doctoral candidate DC4 at Institut de la Corrosion is about the environmental impact of material corrosion and anti-corrosion systems involved in offshore seaweed aquaculture, both in terms of seawater pollution and seaweed quality. The main objective is to define, use and develop monitoring technologies for material and pre-existing structures as well as seaweed cultivation/harvesting structures. The monitoring science development will focus on increasing capabilities to both follow and predict materials corrosion and environment specific characteristics. Among others, the monitoring techniques to be explored and developed will be based on image analysis, environmental sensors and also on biomarkers such as e-DNA analysis. The obtained information can then be used in the probabilistic analysis for go/no-go decisions on O&M activities and to define optimal conditions for seaweed cultivation. The deterioration of materials and fouling/algae formation are related to the environment (pH, salinity, temperature etc) which means that DC4 will also gather data on environmental indicators including eDNA, to understand the environment that nurture the seaweed production that will contribute to the European and International Ocean Governance (IOG) ambitions for our oceans to be clean and healthy, resilient, productive and understood. The DC will share data with the other DC canditates of the seaCHEM project. The eDNA analysis could be combined with image of algae cultivation/growth rate/ to predict optimal environmental envelope for seaweed cultivation (using one or several biomarkers).

Project aims:

Define and use novel monitoring technologies and/or developed methodology to quantify the environmental impact of corrosion and anti-corrosion systems in seaweed aquaculture and to predict the optimal environmental envelope for seaweed cultivation.

MARINE MATERIAL

Project Title:	Acronym:
Impact of seawater treatment on corrosion resistance of stainless steel and nickel base alloys	**TreatedSW**

Research area:	Project period:
Marine materials, offshore	**01/01/2024 – 31/12/2025**
Research leader:	**Source of funding:**
Charles Leballeur	**MRC Marine Corrosion**
charles.leballeur@institut-corrosion.fr	**Keywords:**
+33 2 98 05 15 52	Stainless steel, Marine, offshore, crevice corrosion, dissolved oxygen, chlorination

Low grade stainless steels and nickel base alloys with PREN < 40 are not recommended for seawater applications. They are known to be susceptible to localized corrosion in chloride-containing electrolytes. However, the use of these alloys can be considered under specific condition. For instance, in seawater injection well, low or very low dissolved oxygen content is reached. Under this specific condition, some low grades alloys have shown to be corrosion free at dissolved oxygen level below 20 ppb. For some applications, varying dissolved oxygen level can be encountered. Therefore, there is an interest to assess the behavior of different materials in natural seawater with reduced dissolved oxygen level. The corrosion susceptibility of several stainless steels and nickel base alloys as a function of the dissolved oxygen level have been investigated in a previous program and allowed to get relevant results. For additional treatment such as biocide treatment. Chlorination which is the most used biocide treatment is well known to increase the oxidant power of water and thus to increase the risk of corrosion initiation of stainless steel. Therefore, interaction between deaeration (fully or partially) and chlorination can significantly impact the localized corrosion resistance of stainless-steels and nickel base alloys. The impact of such treatment will be investigated for several alloys from low grade to highly corrosion resistant alloys.

Project aims:

- Assess the crevice corrosion susceptibility of different stainless-steel grades in aerated and deaerated seawater with and without biocide treatment.
- Complete existing guidelines (collected from previous studies) for material selection in treated seawater involving deaeration and chlorination.

MARINE MATERIAL

Project Title: **Definition and optimization of a short-term testing adapted to crevice corrosion of passive alloys II**	Acronym: **ShortCrev II**
Research area: **Marine materials, offshore**	Project period: **01/01/2024 -31/12/2025**
Research leader: **Charles Leballeur** charles.leballeur@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Marine Corrosion** Keywords: Stainless steel, Marine, offshore, crevice corrosion, test method

Commonly used quality control test such as standardized short term electrochemical test G61, G48 or G150 are not fully adapted to predict crevice corrosion results for stainless steel in seawater, particularly of corrosion resistant alloys (CRAs). From the experience of the French Corrosion Institute, immersion tests in simulated environments and involving crevice formers (ISO18070) are more suitable. The drawback of such testing performed at OCP is the time of test which is rather long (3 to 6 months).

Therefore, there is an interest to develop a new test method allowing to characterize the actual crevice corrosion resistance of stainless steels alloys in seawater within short or mid duration. A first program has allowed to define a test method consisting of successive steps at polarization of the material combined with the use crevice former as defined in ISO18070. The first results obtained with this method on duplex and superduplex have shown satisfying results with a good correlation to results obtained from long-term testing.

As a continuation of this program, further qualifications of the test method will be performed. The aim of this project will be to validate the relevancy of the results obtained with this method on additional alloys. The possibility to use this test method in synthetic seawater instead of natural seawater will also be investigated.

Project aims:

- Confirm the relevancy of the test method by testing different alloys.
- Assess the possibility to use synthetic seawater with the test method proposed.

MARINE MATERIAL

Project Title: **Assessment of low grade alloys in natural seawater**	Acronym: **LowPREN SW**
Research area: **Marine materials, offshore**	Project period: **01/01/2024 -31/12/2025**
Research leader: **Charles Leballeur** charles.leballeur@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **MRC Marine Corrosion** Keywords: Stainless steel, Nickel base alloys Marine, offshore, crevice corrosion, pitting corrosion, seawater, biofilm

It is widely admitted that stainless steels and nickel base alloys with PREN lower than 40 are not suitable for seawater applications. Nevertheless, for specific applications, a moderate or at least a lower risk of localized can be expected. For instance, during pre-commissioning operations, the material can be exposed to seawater for short periods in stagnant or with very low renewal rate. The seawater renewal rate is expected to impact the development of biofilm and thus the so-called ennoblement, knowing for its detrimental effect on the corrosion resistance of passive alloys. The impact of temperature is also known to affect the risk of localized corrosion initiation, as well as the geometrical condition. Crevice corrosion is the first root cause of corrosion failure for passive alloys. However, some applications can be exempt of geometry leading to crevice corrosion. Under this condition, the main risk is pitting corrosion which imply a lower risk of corrosion initiation. Therefore, the use of some of these “low grades” can be reconsidered depending on the actual environmental condition.

The content of this project will be to assess the pitting and crevice corrosion risk of selected alloys (stainless steels and nickel base) in natural seawater at different temperature ranging from 11 to 25°C. The impact of the renewal condition compared to stagnant or confined condition could also be investigated. New alloys, candidate for seawater applications will also be assessed.

Project aims:

- Assess the pitting and crevice corrosion risk of several candidate alloys in natural renewed seawater for temperatures ranging from 11 to 25°C.
- Assess the impact of stagnant and/or various seawater renewal rate on the ennoblement induced by biofilm settlement and thus on the localized corrosion risk.

MARINE MATERIAL

Project Title:	Acronym:
Next generation Marine Materials for Resilient Offshore Renewable Energy Devices	**MORE**

Research area:	Project period:
Marine materials, offshore	**01/12/2023 – 01/12/2026**
Research leader:	Source of funding:
Johan B Lindén	**Public funding (Swedish Energy Agency)**
johan.b.linden@ri.se	Keywords:
+46 10 516 6066	Marine Materials, Offshore Renewable Energy, Tribocorrosion, Multi-degradation

MORE (Next Generation Marine Materials for Resilient Offshore Renewable Energy Devices) proposes the creation of a new robust methodology with improved tools for material selection and validation to harmonize testing procedures able to generate the next generation of materials for Offshore Renewable Energy (ORE) devices to overcome the present energy and environmental challenges.

The MORE project will focus on harmonizing small- and large-scale multi-degradation rigs, to create a fast track for validation of materials, starting from, but not limited to, metallic materials and metal coatings typically suffering tribocorrosion and multi-degradation (passive metals), to enable the industrial uptake of these methods. MORE will demonstrate a multi-degradation validation pathway for materials and subcomponents to be used as a case study in the offshore renewable energy sector. While innovative marine renewable energy device technologies are gaining popularity, the technicalities of operating them in hostile environment remain complex and challenging jeopardizing the deployment of these very important technologies for the future generations.

MORE aims at enhancing zero emission power technologies (CEPT Challenge 2): wave energy has demonstrated a more efficient use of the surface area compared to wind turbines. By improving the material use in the systems and by developing better material qualifying protocol the MORE project aims at lowering technology production costs.

Project aims:

• Knowledge transfer from offshore O&G currently used solutions, material selection and testing protocols to offshore Renewable Energy power technologies.

• To develop a new testing methodology based on realistic and accelerated testing techniques simulating many years of actual operation that support and enforce go/no-go decisions on components and subsystems designed at early TRLs.

• Scale up and demonstrate the reliability of the new proposed testing methodology leading to a better material selection, resulting in a lower LCOE (5-10%) via substantial reduction of maintenance costs.

• To produce a first-of-a-kind practical implementation of the novel testing methodology for material selection and validation for critical subsystems common to offshore renewable energy devices.

• To establish new testing recommendations, guidelines and recommended practices for standardisation thus providing an important toolbox for enhanced material technology developments, qualification testing and system design.

• The case studies will evaluate the practical applicability and impact of the new material selection methodology both for cross-cutting environmental challenges and for critical components in wave energy technologies in both user cases.

MARINE MATERIAL

Project Title:	Acronym:
Sustainable production, processing and modelling of durable additive manufactured materials for enhanced performance and long-term service in complex environments.	**DurAMat**

Research area:	Project period:
Marine materials, AM stainless steel	**01/09/2023 – 28/02/2028**
Research leader:	Source of funding:
Dominique Thierry	**Public funding (Horizon)**
dominique.thierry@ri.se	Keywords:
+33676806676	AM, Stainless steel, marine corrosion, atmospheric corrosion

Additive Manufacturing (AM) presents an opportunity for developing economic eco-friendly metal products with enhanced long-lasting performance. Metal AM covers a wide range of technologies where a three-dimensional metallic component is manufactured by adding layer-upon-layer of material, also better-known as 3D printing. AM technology builds on the rational use of raw materials (through optimized product design and re-use of feedstock, reduced use of chemicals and lowered waste of resources), increased energy efficiency (by decreasing post-processing and assembly efforts), economic savings (reduced labour, storage and logistics, and little need for multi-assemblies), and faster processing times.

The work performed at RISE is part of a Doctoral network (MSCA Horizon) coordinated by VUB (Belgium). The work at RISE will be focused on atmospheric and fatigue corrosion, including hydrogen embrittlement (HE), of duplex steel alloys for marine applications.

Project aims:

• To study AM duplex stainless steel with different heat treatments for different final applications including atmospheric (infrastructure) and marine conditions (energy sector).

• To evaluate the risk of corrosion fatigue and hydrogen embrittlement on AM duplex stainless steel using different heat treatments.

The consortium is formed by the following partners: Vrije Universiteit Brussel (VUB, coordinator), RISE, University of Göteborg. Guarantee, HelmholtzZentrum Hereon, Warwick University, Universidade NOVA de Lisboa, TU Dresden, Endures, Small Materials and Technologies, Lda, Christian Albrechts University of Kiel, OnderzoeksCentrum voor de Aanwending van Staal. OCAS NV.

MARINE MATERIAL

Project Title:	Acronym:
Viable Seas	**Viable Seas**

Research area:	Project period:
Marine materials, Other	**01/12/2023 – 30/11/2026**
Research leader:	Source of funding:
Pierre Ingmarsson	**Public funding (Region Västra Götaland, VGR)**
Pierre.ingmarsson@ri.se	Keywords:
+46706205290	National Blue Economy Platform

Viable Sea's overall goal is to create the conditions for national and regional research and innovation to be implemented on a large scale and to accelerate the transition to a climate-neutral, circular and resilient society with a viable sea. The work takes place by establishing Viable Seas as a national strategic cohesive platform for marine research and innovation as well as linking and developing the innovation ecosystem at local, regional, national to European level from a marine perspective.

By creating a "fast track" for collaborations, to markets, financing and R&I resources at national and European level for the development of new solutions for entrepreneurs, business, academia and public activities, the western Swedish business community and the region's attractiveness and competitiveness are strengthened.

The project responds directly to several of the global sustainability goals, including SDG14, EU Mission Ocean and Swedish international commitments and bilateral agreements.

Project aims:

• A national unifying force for change and competitiveness. Number of new methods, tools and working methods; Nationally sanctioned platform.

• Interlinked, efficient marine innovation ecosystem at and between all levels from local to European. Number of private and/or public companies and organizations working together.

• Mobilize actors in new partnerships for the development and implementation of transformative solutions. Number of private and/or public companies and organizations working together.

ENERGY

Project Title:	Acronym:
Characterisation and surface treatment of battery foils for optimised metallic surfaces for battery production (rechargeables)	**Enyfoil**

Research area:	Project period:
Energy, Batteries	**01/11/2022 – 29/06/2024**
Research leader:	Source of funding:
Stefan Norgren & Erik Ekström	**Public funding (Vinnova)**
stefan.norgren @ri.se	Keywords:
+46 102 284 884	Aluminium, foil, rechargeable battery, current collector, cathode, anode, surface analysis, modification, IR, AFM

Focus of this study is to investigate the surface state of aluminium current collector foil materials, which are used to produce rechargeable wet electrolyte type batteries, taking a stance from various methodologies and surface analysis techniques, but also understand if surface activation may improve the foil surface quality.

In battery production current collector foils are coated with active cathode- and anode materials, then separated by an electrolyte and a polymeric membrane to make up the battery core. While focus was in developing these latter parts in battery design by the scientific community, we found there was a lack of understanding to what degree a battery foil surface could mean to their battery. What needs and requirements are there to enhance and optimize the surface of current collector foils prior to battery production and are there room for improvements?

Issues in battery production may be related to the surface condition of the current collector aluminium foil and may cause:w

• Limitations in electrode adhesion (less coating wetting) and induce electrode cracking.

• Aluminium foil corrosion at high voltage (perhaps linked to above factor).

These factors may impair both production and product quality with reduced battery performance upon charging/recharging cycling as well as limit possible charge densities. Current collector foils made of aluminium alloys are rolled using thin and evaporative lubricants between two polished steel rolls to reduce their final thickness down to 10-15 micrometer in full hard temper and the surface quality may vary depending on process conditions.

The production of rechargeable batteries based on Li-ion battery technologies has skyrocketed, but also new types based on sodium-ion or zinc ion has recently found attraction, all which needs the aluminium foil. Hence, requirements of a good current collector will ensure us to make better and more affordable batteries (charge density, durability and safer).

Project aims:

• Bring to the battery community a better understanding what surface analysis- or characterisation methods are useful to describe the foil surface most effectively. Aluminium foils from different production and batches will be analysed.

• Correlate output from surface characterisation with battery performance to understand the potential toward more optimised coating- and battery quality.

• From trials on surface activation and eventually modification compare if these can improve adhesion coating and battery performance compared to virgin rolled foil surfaces.

Project Title:	Acronym:
High temperature corrosion resistance of CRAs in condition simulated biomass treatment	**BioCorr**

Research area:	Project period:
Energy, Biorefinery and biomass	**01/07/2022 – 31/12/2023**
Research leader:	Source of funding:
Christophe Mendibide	**Public funding**
christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Keywords: Biomass, HT-corrosion

Biomass and more generally waste valorization represents a source of energy, increasingly used in most countries to lower fossil fuels consumption. Different processes have been developed since years to produce heat and/or electricity, involving combustion, gasification. The environments produced in these processes are very complex, involving mixtures of gas, solid particles, fused salts which induce high damage to metallic parts at high temperatures.

With respect to biomass, waste combustion, Chlorine-Induced (CI) corrosion through the presence of KCl as fused salt or gaseous HCl, has been identified as one of the key degradation processes in the temperature range 500-650°C. Short term interactions involving the degradation of oxide layers (primary barrier) formed on high temperature materials have been extensively studied in the literature. More recently, studies aiming at understanding the long-term behavior of the materials have been conducted, stressing the interest of increasing knowledge on the reaction kinetics after primary protection (secondary stage). The layers formed during this secondary stage are complex including oxides, chlorides, potentially internal sulfides and carbides, depending on the environment composition.

This work is intended to address the CI corrosion domain (500-650°C). The work is particularly focused on:

- The effect of metallurgical ageing.
- The effect of alloy pre-oxidation, through its impact on the first and secondary stages.

Different commercial alloys are considered in the study, with different Ni, Cr, Fe, Si contents.

Project aims:

- Evaluate the primary corrosion effect on the HT-corrosion behavior of different alloys.
- Estimate the susceptibility to HT-corrosion of different alloys in conditions simulating biomass treatment.

Project Title:	Acronym:
Next Generation Advanced Flexible Biomass Power Plants	**FlexGEN**

Research area:	Project period:
Energy, Biorefinery and biomass	**01/02/2023 – 01/02/2026**
Research leader:	Source of funding:
Rikard Norling	**Public funding (Swedish Energy Agency)**
rikard.norling@ri.se +46 10 228 48 89	Keywords: Corrosion, Combined Heat and Power, Renewable Energy

The future renewable energy system will call for a flexible system with a plethora of different production means and energy storage to meet the demand for the security of supply and affordability. A large part will be non-dispatchable, such as wind and solar energy, and therefore require replacement capacity. Today's heat and power plants in Sweden cannot decouple the electricity and heat production. Hence there is a flexibility limitation coupled with the heat demand. This needs now to be decoupled. The first step in decoupling can be to introduce a condensing tail with a suitable set of valves and a heat sink. Further, the flexibility and efficiency can be increased with improved starting- and stopping capability, maximized load flexibility, and new advanced plant configurations.

Corrosion is one of the critical limiting factors to achieve this, in particular while maintaining an acceptable plant efficiency. It is well known that boilers using biomass or waste as fuel are challenged by high temperature corrosion. Biomass contains high amounts of corrosive species, primarily alkali metals and chlorine. These corrosive species initiate corrosion which can cause wall thinning and pitting, resulting in catastrophic failure of components, especially the boiler water walls and superheater tubes. Future power plants will require higher steam temperatures to increase energy efficiency in steam turbines. This change will impose new challenges on the materials along the whole system.

Project aims:

- To evaluate possible material options at hand. Reaching the targets may require coatings on high-strength materials or composite tubes, which will be evaluated.
- To find smart plant configurations that decouple positions with high corrosivity from high material temperatures and to identify next generation boiler material concepts suitable for these configurations.
- New plant configurations which include hydrogen firing in addition to biomass will be evaluated and the related new difficult material challenges caused by the changed gas composition and firing conditions will be investigated.

Project Title: **Effect of the presence of CO contamination in CO_2 on the risk of SCC in CCUS application**	Acronym: **COscc**
Research area: **Energy, CCUS**	Project period: **01/01/2022 – 01/12/2024**
Research leader: **Christophe Mendibide** christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **ARCOR MRC CCUS & H_2S**
	Keywords: Carbon capture, Stress corrosion cracking, CO_2, CO

In Carbon Capture, Utilization and Storage (CCUS) applications, the industrial process is generally divided into 3 different stages:

- Carbon capture generally through a so-called “amine unit”.
- Transportation of the captured CO_2 in pipeline, generally in dense phase or supercritical state.
- Storage or utilization of the gas.

After the capture stage, CO_2 is produced with a non-negligible level of impurities like, NOx, SOx, CO, O2, H^2S…

From the literature and experience, particularly in heat-exchanger applications, it is well-known that the presence of CO in pure CO_2 can generate a pseudo-passive state of the carbon- and low alloy steels generally active in pure CO_2 environments. This pseudo-passivity can therefore promote a stress corrosion cracking phenomena at room temperature (SCC).

The project focuses on the evaluation of the risk of SCC in CO_2 saturated solution when the gas is contaminated with CO. Electrochemical and SCC experiments are conducted in solution saturated with CO_2-CO that mimic the in-service exposure during the transport of CO_2 in pipelines.

Project aims:

- Estimate if the presence of CO contamination in CCUS process can promote SCC.
- Estimate what are the critical level of CO that triggers the SCC cracking.
- Evaluate the effect of other contaminants like O2.
- Evaluate the behavior of standard pipeline steel in CO_2-CO-O2 atmospheres.

Project Title: **Assessment of the corrosion resistance of CRAs in environments simulating the shutdown at the CCUS injection sites.**	Acronym: **CRAInject**
Research area: **Energy, CCUS**	Project period: **01/01/2022 – 01/12/2024**
Research leader: **Christophe Mendibide** christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **MRC CCUS & H_2S**
	Keywords: Carbon capture, Stress corrosion cracking, localized corrosion, crevice corrosion, corrosion resistant alloys

In Carbon Capture, Utilization and Storage (CCUS) applications, the industrial process is generally divided into 3 different stages:

- Carbon capture generally through a so-called “amine unit”.
- Transportation of the captured CO_2 in pipeline, generally in dense phase or supercritical state.
- Storage or utilization of the gas.

The storage can be made in depleted oilfield that are build with many different carbon steels and corrosion resistant alloys.

In standard operation, a literature review conducted before starting this project highlight that there is no significant risk of corrosion in the injection area. However, during shutdown operations, the formation or aquifer waters can flowback and contact the metallic components used for the injection process. A brine containing a high level of chloride, saturated with CO_2, generally in a supercritical state, can therefore contact the metals, leading to possible corrosion of carbon steels or of the CRA grades used in the infrastructures.

The objective of the project is to estimate if the CRAs typically in place storage site can suffer from corrosion and stress corrosion cracking due to this phenomenon.

Project aims:

- Evaluate the corrosion resistance of CRA in conditions simulating the water flowback at CCUS storage sites.
- Qualify the resistance of a couple of CRA grades regarding the risk of localized & crevice corrosion as well as SCC.

Project Title: **Protective coatings prepared by electrodeposition**	Acronym: **Electrodep**
Research area: **Energy, Electrolyser**	Project period: **01/01/2024 – 31/12/2024**
Research leader: **Michel Prestat** michel.prestat@institut-corrosion.fr +33 298 05 15 52	Source of funding: **Public funding**
	Keywords: Coatings, electrodeposition

Electrodeposition is an atmospheric-pressure electrochemical method that consists of depositing thin or thick layers on conductive substrates. Usually, the technique is based on the cathodic reduction of cations from dissolved precursors salts, such as chlorides, sulfates and nitrates. The features of the electrodeposited coatings (thickness, morphology, microstructure...) can be tailored as a function of the experimental conditions (potential, pH, precursor concentration...) making this technique very versatile. Furthermore, it is cost-effective compared to vacuum-based methods, like PVD and CVD, and easily scalable at the industrial level. Examples of applications are decorative coatings, surface lubricants, electrical contacts in printed circuits... etc... In the field of corrosion, electrodeposited films can notably be used to fabricate protective coatings in form of metals, oxide, hydroxides...

Project aims:

- Developing a setup for electrochemical deposition of thin protective films in aqueous solutions.
- Synthesizing first coatings for relevant applications and/or ongoing projects (e.g. protection of bipolar plates for proton exchange membrane water electrolysis).

Project Title: **Catalytically active and corrosion resistant thin films**	Acronym: **Fun Mat II**
Research area: **Energy, Fuel cells and electrolysers**	Project period: **01/01/2019 – 31/12/2024**
Research leader: **Clara Linder** clara.linder@ri.se +46 70 562 47 04	Source of funding: **Public funding**
	Keywords: Catalysis, oxygen reduction reaction, corrosion, thin film

Water recombination-based devices are one of the alternatives for the production of green electricity. These devices however rely heavily on electrocatalysts to increase their efficiency. In today's industrial devices precious and costly metals such as platinum (Pt) are used as catalysts. Other more abundant and cheaper alternatives, for example, cobalt and manganese oxides, are therefore being investigated.

In this project, pure cobalt (Co) thin films were synthesised to investigate if thin films can be used for the catalysis of ORR. This was successfully carried out by electrochemically modifying the magnetron sputtered thin films and growing catalytically active hexagonal cobalt oxide nanoparticles.

Multicomponent system CoCrFeNi is an emerging alloy system with high research interest for its high corrosion resistance suitable for harsh environments in which the applications for water recombination are found. In this project, CoCrFeNi and CoCrFeMoNi were synthesised as thin films. The corrosion resistance of the films was investigated in addition to their catalytic activity. The effect of Fe and Mo content on these properties was also studied. The presence of Fe was crucial for the electrochemical activation of films and catalytic activity towards ORR. The addition of Mo improved the corrosion resistance in simulated PEM fuel cell environment.

In the continuation of the project, the thin film structure will be tailored to further improve the catalytic and corrosion resistance. Mn will be investigated as an alternative to Co. The synthesised materials will also be tested in small-scale alkaline batteries and fuel cells.

This project is a PhD project and a collaboration between RISE and Linköping University. Details of the project results can be found in Clara Linder's licentiate thesis (2022).

Project aims:

- Investigate corrosion properties of thin film in alkaline and acidic environments.
- Investigate catalytic activity towards water recombination of corrosion resistant thin films.
- Combine catalytic activity and corrosion resistance in one material system synthesised as a thin film.

Project Title: **Fuel cell bipolar plates with aluminium as base material**	Acronym: **Balbas**
Research area: **Energy, Fuel cells and electrolysers**	Project period: **01/11/2023 – 31/03/2024**
Research leader: **Karin Beaussant Törne & Michel Prestat** karin.b.torne@ri.se +46 10 228 48 81	Source of funding: **Public funding (Department of energy)**
	Keywords: Bipolar plates, aluminium, PVD coating

Bipolar plates are used in fuel cells as current collectors. The current state of the art hydrogen fuel cells, proton exchange membrane fuel cells (PEMFC), employs bipolar plates made from graphite, titanium or stainless steel. Replacing these materials with aluminium bipolar plates reduces the weight and environmental load of the fuel cell as well as costs. BALBAS aims to investigate whether coated aluminium alloys can be used for bipolar plates in fuel cells (BPP).

Two demands need to be fulfilled for the plate to function. The contact resistance needs to be low and the corrosion resistance high during the life of the product. The environment in a fuel cell is very corrosive with low pH (~3) and high temperature (60 °C).

The available standards for ex situ evaluation of bipolar plate material recommends electrochemical testing where the sample is immersed in sulphuric acid solution. However, in real life the plates are exposed to atmospheric corrosion, not immersion. For this reason, the corrosion resistance of the coated aluminium will be measured by both traditional electrochemical techniques and by exposure in climate chambers. For comparison, and to verify the results in-situ test in real fuel cells will be performed by RISE energy conversion.

Project aims:

The aim of this project is to investigate the corrosion properties of coated aluminium in a simulated hydrogen fuel cell environment.

Project Title: **Thin protective titanium suboxide coatings for next-generation porous transport layers of PEM water electrolyzers**	Acronym: **PROTIS**
Research area: **Energy, Fuel cells and electrolysers**	Project period: **01/03/2023 – 31/08/2026**
Research leader: **Michel Prestat** michel.prestat@institut-corrosion.fr +33 298 05 15 52	Source of funding: **Public funding (ANR)**
	Keywords: Proton exchange membrane water electrolysis, thin films, porous transport layers

Proton exchange membrane water electrolysis (PEMWE) is one of the low temperature processes for producing hydrogen by electrochemically splitting the water molecule. However, the high capital expenditures (capex) due to the use of expensive corrosion-resistant materials limit the economic competitiveness of this technology compared to the well-established fossil fuel-based hydrogen production, like steam reforming, that generates intensive CO^2 emissions. In particular, on the anode side, the state-of-the-art porous transports layers (PTL), that are metallic elements distributing water, gas and electrons, are made of titanium protected by precious metal coatings (Pt, Au) in order to withstand the acidic conditions and the high electrochemical potential.

Two main corrosion-related strategies can therefore be considered in order to significantly decrease the PEMWE capex: replacing titanium by other alloys, such as stainless steels, and developing novel cost-effective coatings. The PROTIS project combines these two approaches by investigating the protection of 316L stainless steels by thin layers of titanium suboxides.

This project, coordinated by IC, is carried out in collaboration with the LEMTA (Laboratoire d'Energétique et de Mécanique Théorique et Appliquée, Université de Lorraine, France) and the Laboratory of Materials for Energy Conversion of Empa (Swiss Federal Laboratories for Materials Science and Technology, Switzerland).

Project aims:

- Synthesizing thin titanium suboxide films by physical vapor deposition and atomic layer deposition on porous stainless steel PTL.
- Developing accelerated stress tests for evaluating the long-term behavior of the protective coatings.
- Implementing the novel coated PTL in PEMWE cells and assessing their effect on the electrolysis performance and durability.

Project Title: **Influence of mineral deposits and dynamic mechanical stresses on corrosion in geothermal conditions, mineral scaling, and mechanical stresses on geothermal corrosion**	Acronym: **GeosteelCorr**
Research area: **Energy, Geothermy**	Project period: **01/01/2022 – 31/12/2025**
Research leader: **Christophe Mendibide** christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Public Funding (ANR)**
	Keywords: Geothermal Energy, Stress corrosion cracking

For reduction of greenhouse gas emissions, investment in the infrastructures of green energy sources is necessary. Geothermal energy is one of the promising ways to achieve this objective by delivering both thermal and electrical energy. However, due to the high corrosivity and scaling ability of geothermal fluids, the selection of proper metallic materials is a big challenge for the safe and reliable development of this non-carbon energy source.

Until now, limited efforts have been devoted to understand the stress corrosion mechanisms by taking into account the effect of mineral scaling on the steel surfaces. Even after the injection of anti-scaling additives in the geothermal field, the reliability of their long-time efficiency is not guaranteed. Furthermore, no valuable information on the incidence of typical geothermal scales such as silica, calcium carbonate, magnesium silicate, is available on the corrosion behavior of passive and non-passive steels. More investigations are necessary to understand the interaction effects of mineral scales deposits deposited on both the steel surface reactions (passivity for stainless steels) and on the initiation – propagation of stress corrosion cracks.

In this context, the project GeoSteelCorr aims to build a methodology for better understanding the role of mineral scaling on the risk of surface corrosion and environmentally assisted cracking of these steels. The work will be conducted after the implementation of a SSRT test bench on an autoclave equipped with a feeding loop and a specific device is used to generate artificial mineral scaling (a temperature up to 300 C and a pressure up to 200 bars). Additionally, for a more in-depth knowledge regarding the mechanism of crack initiation and growth, advanced post-mortem local tests (e.g. SEM, TEM and EDX) will be performed in the frame of this project.

This work is a collaborative research between The FCI, IFPEN, Ecoles des Mines de Saint-Etienne and Insa de Lyon.

Project aims:

- Develop a SSRT test bench allowing to perform testing under hydraulic pressure.
- Develop a specific system allowing the reproduction of mineral scaling in the laboratory.
- Evaluate the role of mineral scaling on the cracking susceptibility of CRA in a geothermal environment.

Project Title: **Comparison between test methods for toughness evaluation of pipeline steels under hydrogen pressure**	Acronym: **ToughHy**
Research area: **Energy, Hydrogen**	Project period: **01/01/2022– 31/12/2024**
Research leader: **Laura Moli Sanchez** laura.moli.sanchez@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **MRC Storage and Transportation of Hydrogen**
	Keywords: Hydrogen, Pressure, Crack Propagation, toughness

There is today no unified test method for material qualification in gaseous hydrogen environments. ASME B31.12 and PBVC documents are specifying test conditions for toughness (KIH) and fatigue evaluation (da/dN=f(DK)) referring to international standards like ASTM E1681. This test method can however hardly be applied to low strength carbon steels for several reasons:

- It is impossible to be compliant with geometrical validity checks specified in ASTM E1681 due to test pressure vessels and pipeline wall thickness limitations. Therefore, the test results obtained on pipeline steels according to this standard can often not proceed under linear elastic crack propagation.
- The test is performed under constant applied strain leading to very small crack propagation lengths due to relaxation effects after upon propagation. Also, bolt load specimens are used which need to be loaded in oxygen-free atmospheres.
- The standard test duration for low strength steels specified in ASTM E1681 should be 10000 hours which is not acceptable for standard industrial practices.

Another test method is under study at the French Corrosion Institute based on incremental step loading (ISL) in conditions inspired from the standard ASTM F1624. The objective of the project is to compare both test methods and make an environmental screening for KIH.

In a first task, both ASME and ISL test results performed on in the same environment will be compared to validate the methodology. Then, in the next tasks testing of different grades in different environments (different H^2 pressure, effect of contaminants…) will be considered. Several pipeline grades will be considered (X65, X70, X100).

This work is conducted in collaboration with IFPEN.

Project aims:

- Define a reliable test method for KIH evaluation under hydrogen pressure.
- Perform a screening of the severity of different environments under H^2 pressure.

Project Title: **Characterization of the cracking susceptibility of stainless steels and CRA under H^2 pressure at low temperature**	Acronym: **CryoH₂**
Research area: **Energy, Hydrogen**	Project period: **01/01/2022 – 31/12/2024**
Research leader: **Laura Moli Sanchez** laura.moli.sanchez@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **MRC Storage and Transportation of Hydrogen**
	Keywords: Hydrogen Pressure, Corrosion Resistant alloys, cryogentic SSRT and Fatigue

In the frame of the development of the hydrogen industry, the question of the behavior of stainless steels and other CRAs under H^2 pressure is raised, particularly for automotive and aeronautic applications. From the results already published in the literature, it seems that the critical temperature for the most common stainless steels, in particular the austenitic grades, is around 0°C to -80/-100°C.

To allow the screening of different material in different environments (mainly to allow for screening the effect of the gas composition), a specific test device is proposed. It consists in round tensile specimens (named hollow-specimen) with a cavity machined in the gauge length allowing to pressurize it internally and test on standard cryo-test benches without safety issue. In a second step testing with pressurization of standard specimen at low temperature will be considered.

The work is divided into several tasks:

- Development of the hollow-specimen test method.
- Reproduction of published data with the test method to assess the reliability of the measurement.
- Material and environmental screening.
- In a second step, testing of standard specimen at low temperature.

SSRT is considered in a first approach but fatigue should also be possible.

Project aims:

- Define a reliable test method for cryogenic test under H^2 pressure using hollow specimens.
- Perform a screening of the severity of different materials and environments under H^2 pressure.

Project Title: **Hydrogen permeation through metal under H^2 pressure**	Acronym: **PermH₂**
Research area: **Energy, Hydrogen**	Project period: **01/01/2022 – 31/12/2024**
Research leader: **Christophe Mendibide** christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **MRC Storage and Transportation of Hydrogen**
	Keywords: Hydrogen Pressure, Permeation, pipeline steels

One key parameter to assess the severity of an environment regards hydrogen assisted cracking is the hydrogen uptake and fluxes in the material exposed to embrittling media. If permeation test through metals from liquid media is of common practice, also under pressure (ie.g. Devanathan and Stachurski test method), there is no common practices to perform testing in a H^2 gas media under pressure. Mainly, the test procedure is very important and can lead to large discrepancies. The detection method is also often discussed because the sensitivity can be too low in some media.

This project focuses of the development of a test method for permeation test through carbon steel under H^2 gas pressure. The objective is first to propose a standard test procedure allowing to make measurement with an acceptable reproducibility, before to screen different pipeline steels in different environment. Mainly the effect of contaminants would be considered after having established a robust test procedure.

Project aims:

- Development of a reproducible test method for hydrogen permeation under gas pressure.
- Screening of the severity of different atmosphere (variable H^2 pressure, effect of contaminants….).

Project Title: **Hydrogen applicability of steels in gas storage facilities**	Acronym: **StoreH₂**
Research area: **Energy, Hydrogen**	Project period: **01/01/2023 – 01/12/2025**
Research leader: **Laura Moli Sanchez** laura.moli.sanchez@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Hydrogen, Fatigue, Toughness

In order to achieve the climate targets, there is political consensus on the central role of hydrogen use in all sectors. The storage of hydrogen is the basic requirement for sector coupling because centralized energy storage in underground storage facilities (UGS) enables a secure and long-term supply of hydrogen. Due to the highly fluctuating production of hydrogen from various sources and the equally expected highly fluctuating demand, UGS will play a central role in the future energy system. The required conversion of existing underground gas storage facilities to hydrogen or the storage of natural gas-hydrogen mixtures makes special demands on the technical equipment (well completion), several aspects of which have not yet been sufficiently investigated. An essential aspect in this context is the suitability of underground pipe sections (typically API steels) and their corrosion and mechanical properties when exposed to hydrogen. The suitability of the material itself, as well as the suitability of the welded joints (and welding procedures and heat input by welding) must be investigated. The study described here is intended to provide answers to these questions.

The work is divided in 2 main tasks.

1.An exhaustive literature review including analysis of the existing standard for material qualification under H^2 pressure and their limitation.

2.A qualification program on alloys that could find a possible application in underground storage but whose properties under H^2 atmosphere are poorly documented.

This work is a collaboration between the French Corrosion Institute (France), The University of Leoben (Austria) and the Frauenhofer (Germany).

Project aims:

- Literature review and standard analyses to determine the materials that are already used for H^2 service and the gap in data needed to allow the use of candidate materials with limited documentation of their properties in H^2 environment.
- Qualify for service a couple of materials selected from the literature review and not documented in the literature. Different test methods are considered in the program: toughness, fatigue, constant and ripple load, permeation.

Project Title: **Assessment of the possible use of different steel grades in hydrogen transport and storage applications**	Acronym: **TroPhy**
Research area: **Energy, Hydrogen**	Project period: **01/01/2022 – 31/12/2024**
Research leader: **Laura Moli Sanchez** laura.moli.sanchez@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Hydrogen, pipeline, transportation and storage

In anticipation of a strong increase in hydrogen in the global energy mix, the retrofitting of natural gas grid is anticipated with an introduction of the hydrogen fraction in the network.

Hydrogen is well known to diffuse easily in steels and lead to a weakening of their mechanical properties, even generating cracks in some cases. While the mechanisms and kinetics of hydrogen entry into steels are fairly well known in certain corrosive aqueous media or in environments consisting of gaseous hydrogen at high temperature, this is less the case in the presence of gaseous hydrogen at temperatures close to ambient temperature and in the presence of impurities such as can be encountered in underground transportation and storage.

The objective of the R&D in progress is to assess the impacts of gaseous hydrogen in different field conditions and at ambient temperature on representative steels from storage collections and natural gas transport pipelines. The experimental program will aim on the one hand to compare the kinetics of hydrogen loading in steels subjected to different environments, and on the other hand to check whether these exposures are likely to affect the mechanical properties. The results will be used to feed computer codes using the principles of fracture mechanics in order to assess the acceptability of defects in metallic structures for the transport and underground storage of natural gas.

This work is operated in collaboration with IFPEN.

Project aims:

- Screen the cracking susceptibility of different pipeline material in hydrogen containing atmospheres.
- Make a risk assessment analysis of standard pipeline steels in standard and degraded conditions.

ENERGY

Project Title: **Hydrogen embrittlement of pipe, casing and tubing materials used in underground storage of gaseous hydrogen**	Acronym: **HyMF**
Research area: **Energy, Hydrogen**	Project period: **01/01/2024 – 01/09/2026**
Research leader: **Christophe Mendibide** christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Hydrogen, storage, H^2S

In the perspective of hydrogen underground storage, the behavior of the metallic materials used in the infrastructures (pipe, casing, tubing) shall be evaluated under hydrogen pressure to ensure the safety of the facilities. In a design perspective, at least two properties need to be investigated: the toughness and the resistance to the crack propagation under fatigue loading.

Moreover, considering the presence of liquid phases and the possible bacterial activities developing underground, the hydrogen possibly stored can be exposed to water vapor and contaminated with H^2S gas. The objective of this project is to evaluate if H^2S and water vapor can modify the behavior of metallic materials under hydrogen pressure.

Project aims:

- Screen the mechanical behaviour of metallic materials used in underground hydrogen storage assets.
- Evaluate the possible effect of H^2S contamination and water vapor in hydrogen on steels.

ENERGY

Project Title: **Mn austenitic stainless and non-stainless steels for hydrogen applications: production, transport and storage**	Acronym: **Hystory**
Research area: **Energy, Hydrogen**	Project period: **01/06/2024 – 31/12/2028**
Research leader: **Laura Moli Sanchez** laura.moli.sanchez@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **European funding (RFCS)**
	Keywords: Hydrogen, pipeline, transportation and storage

The goal of the HYSTORY project is to develop Mn austenitic stainless and non stainless steels via high throughput metallurgy screening. The project targets the development of innovative grades for hydrogen production (PEM electrolysers), cryo-compressed hydrogen storage and compressed hydrogen transport. Therefore, the susceptibility to hydrogen embrittlement and the interaction between hydrogen and the microstructures will be deeply studied. The positioning of the novel developed grades versus current steel solutions (austenitic stainless 316L and ferritic line pipe grade) will be assessed in terms of hydrogen embrittlement susceptibility and steel manufacturing competitiveness. In addition, key performance indicators defined for each studied property and weight algorithm will assist the optimization of the metallurgies and the alloys comparison.

The project aims at progressing a development between TRL2 to TRL4 over the project duration.

Project aims:

- Define an optimized composition of Mn austenitic non-stainless steel for hydrogen applications.
- Produce a selection of experimental heat at an industrial scale.
- Screen the properties under hydrogen of the novel developed grade (toughness, FCGR, permeation, SSRT).

Project Title: **Development, supply and support of corrosion monitoring systems for the radioactive waste French underground laboratory**	Acronym: **SensAndra**
Research area: **Energy, nuclear waste disposal**	Project period: **01/01/2022 – 31/12/2025**
Research leader: **Erwan Diler &Johan Becker** erwan.diler@institut-corrosion.fr +33 (0)2 98 05 15 52	Source of funding: **Public funding (ANDRA)**
	Keywords: Corrosion monitoring, electrical resistance sensors, carbon steel, Storage and Disposal of Radioactive Waste

In the context of the high_level radioactive waste disposal, the in-situ corrosion rate of the infrastructure must be evaluated and monitored. In France, it is envisaged to dispose of high and intermediate level long-lived radioactive waste at about 500 m depth in a deep geological disposal, drilled in a very stiff clay Callovo-Oxfordian claystone (Cox). To do so, 100 m length carbon steel casing will be inserted inside disposal cells which are horizontal tunnels drilled in the Cox. In the current concept, a specific cement grout will be injected between the carbon steel casing and the claystone. This cement grout aims to pass through the acidic transient - due to the release of acidity into the pore water by destabilising the sulphur-bearing minerals (pyrite) which were oxidized during the excavation phase of the cells - without high corrosion process on casing.

All the experiments and prototypes aiming to validate and improve this concept are currently performed in the French Underground Research Laboratory (URL) (Bure, France). The corrosion rate of the carbon steel casing will be assessed and monitored using a set of electrical resistance sensors, compatible with high temperature and alkali environment. The specifications also require a long distance between the sensors and the acquisition, as well as a long-life span, a high accuracy and an integration to global URL monitoring system.

Project aims:

- Develop a specific solution in terms of acquisition and sensor.
- Deploy this solution at the URL.
- Assess in-situ the corrosion rate.

Project Title: **Study of hydrogen effects for the casing and overpack foreseen in the high-level waste geological disposal**	Acronym: **Stresscorr**
Research area: **Energy, nuclear waste disposal**	Project period: **01/09/2022 – 31/07/2024**
Research leader: **Nicolas Bulidon** nicolas.bulidon@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Hydrogen embrittlement, permeation, nuclear waste, geological repository, hollow sensor

The French concept for the storage of high activity long lived nuclear waste is based on deep geological repository using a multi-barrier system. This concept consists in a glass matrix containing calcinated high level radioactive wastes (HLRW) that is introduced in a stainless-steel container placed in a low-alloy carbon steel over pack (grade P285NH). The pack is then stored in an alveolus drilled in a very stiff clay formation, which casing is produced with an API 5L X65 pipeline steel. The steels grades used in the concept have been selected from previous research programs and have shown good resistance to environment assisted cracking (EAC).

The main objective of this study is to complement the knowledge related with EAC of the steel grades selected, with an evaluation of the influence of the cold work on the hydrogen uptake to assess the risk of hydrogen assisted cracking. Two different experimental techniques are used. The first is a common Devanathan and Stachurski permeation twin cell allowing to perform measurement through membranes submitted to an applied stress to control the cold-work. The second is the so-called “hollow sensor”. This technique consists in tensile specimen in which an inner cavity is drilled that allows to collect the hydrogen permeating through the specimen wall-thickness during stress cracking tests. The hydrogen entering the material during the experiment is diffusing through the specimen and accumulates in the cavity leading to a pressure raise that is measured with an electronic pressure sensor.

In this study, the effect of several different plastic strain levels on the hydrogen uptake is evaluated as well as the effect of the presence of dissolved H^2S. Indeed, this chemical has been detected by ANDRA in some on-site tests of the concept and is a well-known hydrogen uptake promoter.

Project aims:

The objective of this program is to study the influence of hydrogen on the mechanical behaviour of low-alloy steels using permeation tests with and without applied stress.

ENERGY

Project Title: **Corrosion potential monitoring of different material in environment simulating nuclear waste storage**	Acronym: **PotWastCorr**
Research area: **Energy, nuclear waste disposal**	Project period: **01/06/2023 – 30/06/2025**
Research leader: **Nicolas Bulidon** nicolas.bulidon@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Nuclear waste, geological repository, hydrogen production, free potential.

At the Aube storage center, packages of short-lived low and medium activity waste are stored in gravel structures or concrete structures. Inside waste packages, metals potentially highly reactive with hydraulic binders are subject to a specification which imposes the completion of the technical test to determine the acceptable metal surface in the packages regarding the production of hydrogen by corrosion in an alkaline environment.

The study will be limited to the chemical reactivity of metal waste placed in solutions representative of the pore water of a cement matrix. The tests to be carried out on the different materials (brass, lead, zirconium, zinc) are measurements of free potential in a pH range representative of healthy/degraded concrete, in aerated/deaerated conditions. For each environment, this includes measuring the water reduction potential and measuring the metal free potential. The objective is to compare these potentials to the water reduction potential to specify the test conditions (aerated/deaerated) to be adopted for an exhaustive list of reactive metals.

Project aims:

The main objective of this project is to determine the free potential of different metallic materials in the pore water of cement-based matrix.

ENERGY

Project Title: **Study of corrosion of metallic materials in organic acids environments**	Acronym: **Morgacor**
Research area: **Energy, nuclear waste disposal**	Project period: **01/06/2023 – 30/06/2025**
Research leader: **Nicolas Bulidon** nicolas.bulidon@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Nuclear waste, geological repository, corrosion rate, organic acid.

In the context of the radioactive waste disposal CIGEO, some nuclear waste packages may contain organic and metallic materials. Organic materials are present in technological waste and in process waste produced during operation, maintenance or dismantling operations carried out in fuel cycle installations. Some mechanisms for the degradation of organic matter can lead to the formation of carboxylic acids.

The objective of this study is to evaluate the effect of formic and oxalic acids on the corrosion of stainless steels (304L and 316L) and carbon steel (X65). The influence of the temperature and the acid concentration will be assessed. The tests will be performed in aerated and deaerated solutions. Weight loss measurements and free potential monitoring will be carried out.

Project aims:

The main objective of this project is to assess the corrosion resistance of the metallic materials in organic acid environments.

ENERGY

Project Title: **Study of corrosion on the carbon steel X65 in the disposal of high-level radioactive waste**	Acronym: **Corracim3**
Research area: **Energy, nuclear waste disposal**	Project period: **01/06/2023 – 30/06/2025**
Research leader: **Nicolas Bulidon** nicolas.bulidon@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **Industrial funding**
	Keywords: Nuclear waste, geological repository, corrosion rate, corrosion products, cement

Since 2014 the multi-barriers concept developed for storage of high activity long life nuclear wastes, includes a cement layer. This cement-based grout material will be injected to neutralize the potential acidity resulting from the host rock oxidation induced by the drilling process of the disposal cell.

- Mass loss to evaluate the corrosion rate.
- SEM examinations and Raman analyses to determine the nature of the corrosion products.
- Chemical analysis of the water in contact with the cement material.

These results will be compared with those already obtained with the previous tested composition of filling material (cement-bentonite grout). Additional tests will be performed to evaluate the influence of argillite fragments and the effect of cracking in the cement layer.

Project aims:

- To assess the corrosion resistance of the carbon steel in a new cement environment.
- To define the cement grout material which will be the most fitting in the deep geological storage.

ENERGY

Project Title: **Effect of the acetates content in test solution on the cracking susceptibility of OCTG material during sour qualification test**	Acronym: **AcetaSSC**
Research area: **Energy, Oil & Gas**	Project period: **01/01/2022 – 01/12/2024**
Research leader: **Christophe Mendibide** christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Source of funding: **MRC CCUS and H_2S**
	Keywords: Geothermal Energy, Stress corrosion cracking

The project aims in evaluating the corrosion of the casing (API5L X65) in contact with new cement grout material compositions in aerated environment (water).
After each exposure time (from one month to 18 months), the following analyses will be performed:

Project aims:

- Develop a technique for hydrogen permeation monitoring during standard SSC test.
- Evaluate the effect of the acetates content on SSC test result of one selected material.
- Correlate the test results with permeation, electrochemical and SEM data.

Project Title:	Acronym:
Impact of H^2S fugacity on hydrogen charging and SSC of carbon steels	**Fugacity II**

Research area:	Project period:
Energy, Oil & Gas	**01/04/2022 – 01/12/2025**
Research leader:	Source of funding:
Christophe Mendibide	**Industrial**
christophe.mendibide@institut-corrosion.fr +33 4 77 40 00 45	Keywords: Stress corrosion cracking, H_2S, Permeation

As the total pressure of oil & gas production environments increases, thermodynamic calculations using perfect fluids simplifications are not valid anymore. For acid gases such as H^2S, this involves the use of fugacity instead of partial pressure. However, most industrial standards related to H^2S cracking are using partial pressure scales. It is also a common practice to perform H^2S qualification tests at low total pressure, at the same H^2S partial pressure as the one of the production environment, disregarding the potential effects of fugacity.

In a first JIP conducted during the period 2019-2021, the potential impact of fugacity on the risks of H^2S cracking was studied. The proof of concept of the fugacity effect was assessed using hydrogen permeation techniques at high pressure (up to 300 bar). We observed 2 different effects depending on the range of pH and pH^2S:

- Either the permeation flux at high pressure is lower than the one obtained at atmospheric pressure under the same pH/pH^2S node.
- Or, due to variation in scale protectivness, a so-called “inversed fugacity effect” was observed leading to a higher hydrogen charging flux at high pressure rendering the standard qualification test possibly not enough conservative.

This new project aims at complementing the results obtained in the first program, mainly through the use of cracking tests (HIC/4PB and DCB) together with permeation.

Project aims:

- Evaluation of the possibility to qualify material using the fugacity concept through testing at atmospheric pressure.
- Estimate in which pH/pH^2S conditions the inverse fugacity effect can be observed.
- Estimate the possible effect of buffer system on the results.
- Proof of concept of the fugacity effect above the bubble point (work in full liquid systems).

Project Title:	Acronym:
Verification through Accelerated testing Leading to Improved wave energy Designs	**VALID**

Research area:	Project period:
Energy, Wave energy	**01/12/2020 – 31/05/2024**
Research leader:	Source of funding:
Pierre Ingmarsson	**European funding (Horizon)**
Pierre.ingmarsson@ri.se +46706205290	Keywords: Accelerated testing, test rig, design convergence, low TRL, reliability, performance, methodologies, cost reduction, exchange of knowledge

The VALID project will develop and validate a new test rig platform and procedures for accelerated hybrid testing that can be used across the wave energy sector to improve the reliability and survivability of the components and subsystems that form Wave Energy Converters (WECs). The methodology for accelerated hybrid testing combines both physical testing (physical test rigs) and virtual testing (simulated environment, numerical models and data). The VALID Hybrid Test Platform (VHTP) will become the interface that allows for seamless accelerated hybrid testing. With the long-term goal of establishing a standard for future use and making a step-change impact on the sector, the new test rig platform and methodology will be validated for a variety of WECs, critical components and subsystems through three different user cases.

Often faults in component and subsystems are detected through extensive and costly sea testing in late stages of device development (high TRLs) and finding a problem at late development stages can add significant cost and delays to initial schedules, eventually leading to company’s bankruptcy. Sound testing methods are thus needed to reduce the uncertainties, increase confidence in results, assist and guide the concept and subcomponents design, and thus largely assist in the decision-making progress.

The new hybrid testing platform with open access for models, testbeds and improved data management are all necessary to lower the cost on future technologies. VALID assembles the full value chain required from methodology and platform development, technology development, LCOE to certification bodies in order to develop an integrated solution with support from RTO and academia.

Project aims:

- To develop a new testing methodology based on accelerated hybrid testing techniques that supports and enforces go/no-go decisions on components and subsystems design at early TRLs.
- To build a novel prototype test rig (the VALID Hybrid Test Platform) and customise four existing test rigs unique for the wave energy sector.
- To quantify and reduce the uncertainties behind scaling effects and design loads, thus making accelerating hybrid testing in lab conditions feasible.
- To produce a first-of-a-kind practical implementation of the novel testing methodology and VALID Hybrid Test Platform on three critical subsystems common to wave energy devices.
- To establish new testing recommendations and guidelines for standardisation for enhanced technology design and testing.
- To promote exchange of knowledge and inform on the progress of the scientific understanding of ocean energy.

To establish an ambitious strategy and exploitation plan to successfully exploit VALID project results.

ENERGY

Project Title: **Hydrogen embrittlement resistant new steel links solutions for offshore wind turbines**	Acronym: **HELIX**
Research area: **Energy, Wind energy**	Project period: **01/07/2022 -31/01/2026**
Research leader: **Nicolas Larché** nicolas.larche@institut-corrosion.fr +33 2 98 05 15 52	Source of funding: **Public Funding (RFCS)**
	Keywords: Hydrogen embrittlement, bolting, wind energy, cathodic protection, coatings

To increase the use of electricity produced from renewables the full potential of Europe's offshore wind energy has to be developed. To unlock Europe's offshore potential, the number of installed offshore wind turbines is expected to rise in the coming years. Cost reduction and efficiency are still imperative in this technology and the industry is thus designing larger power generators, up to 10 MW. This trend will lead to larger foundations due to higher mechanical demands. Flanged connections are still an integral part of any offshore developments with fasteners being the primary means for assembly.

Fasteners with diameters over M48 are becoming common and bolts already used can be as high as M72. Therefore, a technical and research effort is needed in the fasteners field to support the ever-increasing size of offshore wind turbines. On one hand, HELIX will develop, test and provide fasteners able to withstand high applied stresses under harsh environmental conditions typical of large offshore wind turbines. This will be achieved by developing and optimising a novel high strength steel grade in qualities 10.9 and 12.9 and new protecting zinc-flake based coatings. On the other hand, HELIX will contribute to unravel how atmospheric and immersed conditions, material composition and microstructure, surface treatment and previous corrosion affect hydrogen embrittlement of high strength steels. HELIX will use advanced characterization techniques as well as traditional techniques under both atmospheric and immersion conditions, to advance in the knowledge of hydrogen absorption in high strength steels under cathodic protection and in atmospheric conditions. This knowledge will not only allow tailoring the steel and coating microstructure to achieve both excellent corrosion protection ability and low risk of hydrogen embrittlement but also influence on policy and practice in the offshore wind sector.

Project aims:

- To optimize new lower cost high strength steel composition with improved hardenability, high toughness and high hydrogen embrittlement resistance.
- To identify the mechanisms of hydrogen absorption/desorption of the optimized steels.
- To develop coatings based on zinc flakes and different topcoat materials to protect the steel and to reduce hydrogen production in service.
- To study the interaction of the optimized steel, the novel coatings and the environment on the hydrogen absorption mechanisms.
- To demonstrate the higher performance of the developed fasteners in real environments.

PROCESS INDUSTRY

Project Title: **Effect of chloride on corrosion behaviour of different alloys in simulated biorefinery process**	Acronym: **CorrBioref**
Research area: **Process industry, Biorefinery and biomass**	Project period: **01/01/2022 – 31/12/2024**
Research leader: **Rikard Norling** rikard.norling@ri.se +46 10 228 48 89	Source of funding: **MRC Biorefinery**
	Keywords: Corrosion, Biorefinery Process, Corrosion-resistant Alloy

Biorefinery is an emerging technology and a continuously growing business sector with a continuous development of new advanced processes. Many of these processes are highly demanding regarding the corrosion resistance of the alloys used in biorefinery plants. This makes it challenging to introduce the new advanced processes on a large commercial scale and to benefit from their full potential. This requires significant extent of effort and knowledge not only related to the processes, but also to material selection to avoid corrosion of components used in such challenging environments.

Among other corrosive species, chloride has been known to cause failure due to corrosion for metallic components. Information on material compatibility, based on corrosion rate and stress corrosion cracking susceptibility, in chloride containing environment, with different pH and at high temperature above 200 °C is still known to be limited. Therefore, more information on material compatibility relevant to biorefinery processes, e.g., high temperature testing in chloride-containing aqueous solution, is of interest and beneficial.

Project aims:

- To obtain information on corrosion behaviour of different alloys in simulated conditions with aqueous solution of salts at high temperature and pressure with varied chloride concentrations and pH.
- To establish data on materials compatibility in simulated biorefinery processes.

Project Title: **Corrosion assessment of pressure vessel and piping of Chemical Plants**	Acronym: **CorrRBI**
Research area: **Process industry, chemistry**	Project period: **01/01/2022 – 31/12/2025**
Research leader: **Jocelin Poinsot & Vincent Martin** Jocelin.poinsot@institut-corrosion.fr +33 7 87 70 58 53	Source of funding: **Industrial funding**
	Keywords: Corrosion assessment, Risk Based Inspection, Chemical process

A large proportion of equipment of piping of chemical plants are submitted to regulations linked with high pressure service and/or dangerous products. It may represent of a few tens up to thousands of items in only one facility. To ensure the reliability of these items and reduce the probability of failures, relatively short frequency of action is required by the different regulation: external and internal visual inspection, non-destructive testing, integrity control, etc.

French regulation allows plants owners to decrease inspection frequencies following a Risk Based Inspection (RBI) methodology. RBI goal is to link inspection frequency to risk assessment (Risk = Probability of failure x Consequence of failure) for each equipment.

The first input needed to perform such an analysis is a quantification of all the damage modes. Contrary to Oil&Gas applications, where an internationally recognized standards does exist (API 581), the diversity of chemical plants and processes does not enable to use standardized models. Moreover, chemical industry offers a huge number of materials (carbon steels, stainless steels, nickel-based alloys, Glass Reinforced Thermoset Composites, Thermoplastic polymers, Glass lined steel…) and corrosive environments (neutral aqueous, acids, caustics, solvents, high temperature…).

The corrosion assessment first requires gathering all process, mechanical and case history data. The output is usually a division of the plant piping and equipment into “corrosion loops” where the damage mechanisms are considered as identical in type and in quantification. It can also enable to define “Integrity Operating Windows”: batch of process parameters to monitor to avoid the appearance of new damage modes (temperature, pH, impurities content…).

When industrial plants don’t have enough internal competency to write or update their Corrosion Control Documents, the help of MECM Materials and Corrosion specialists is more and more requested. MECM specialists are able to link theoretical corrosion assessment (based on standards, technical or scientific literature) to the process conditions and the observed damage modes. The legal deadlines of this action will lead a strong development of this activity from late 2023 to 2025 for MECM Team, associated with rationalization of the methodology.

This method is also considered by plant owners as an input for equipment integrity management.

Project aims:

- To analyze the process to identify potential damage modes, analyze recorded damaged modes.
- To recommend critical process parameters to be recorded.
- To recommend nondestructive testing consistent with recorded and potential damage modes.
- The final results is to improve reliability and safety of items through relevant and detailed analysis.

This analysis is capitalized in a written «Manual of Damage Modes».

Project Title: **Industrial Online Corrosion Monitoring – Acoustic Emission and Electrochemical Probes**	Acronym: **CorrMon**
Research area: **Process industry, chemistry**	Project period: **01/01/2022 – 31/12/2025**
Research leader: **Clément Boissy & Simon Depardon** clement.boissy@institut-corrosion.fr +33 6 78 21 57 88	Source of funding: **Industrial funding**
	Keywords: Chemical Process Industry, Industrial Corrosion Assessment, Online Monitoring, Acoustic Emission, Electrochemical probe

Corrosion monitoring is a key point for process industry. It aims to be able to follow corrosion propagation or detect corrosivity deviation in order to anticipate maintenance operation and optimize OEE. Moreover, corrosion monitoring enables evaluation of the corrosion in operative environment as an extension of laboratory work. MECM regularly proposes the use of coupons to evaluate corrosion rate, but this technique is very limited. Online corrosion monitoring by acoustic emission is also currently proposed (mature technology still under development) and use of electrochemical probes is under development.

Acoustic Emission (AE) defines the elastic energy which is released in material in the form of transitional ultrasonic elastic waves, resulting of internal micro displacement. Many developments occurred in recent decades alongside advances in electronics and IT, since 1950 with the works of J. KAISER. Applications of AE technique could be gathered in two families: control of structure integrity and online monitoring. It’s in this second family that MECM offers and develop its skills for industry. It consists in monitoring equipment during process without external intervention. AE enables to assess potential active damage (SCC, intergranular or pitting corrosion, fatigue…) evolution depending of process parameters and process management. AE is a powerful nondestructive and nonintrusive technique allowing online volume monitoring in severe conditions, for example: chloride stress corrosion cracking in DSS decanter, thermal fatigue phenomena in the bottom of polycondensation calves and mechanical fatigue on the supports of crystallizers.

Electrochemical Probe offer on the market tends to shrink with withdrawal of major company in Europe. It has been developed for Oil and Gas industry and have difficulties to be adapted for process industry considering the wide range of process and materials that requires adaptability and electrochemical expertise. Commercial systems are rather inexpensive but without any adaptability. For this reason, MECM is collaborating with ORIGALYS in order to develop a system that could be used as a potentiostat but also as a datalogger for weeks of recordings. Materials have been tested in the lab in 2023 and first industrial tests are planned for 2024, these should permit to validate the performances of the equipment. The next step would be to adjust equipment in order to be more integrable into plant environment.

Project aims:

- To develop online monitoring of active corrosion and damages.
- To replace offline corrosion monitoring with coupons.
- To provide data to industrial customers in order to help them in decision making for process management or maintenance operation scheduling or investment.

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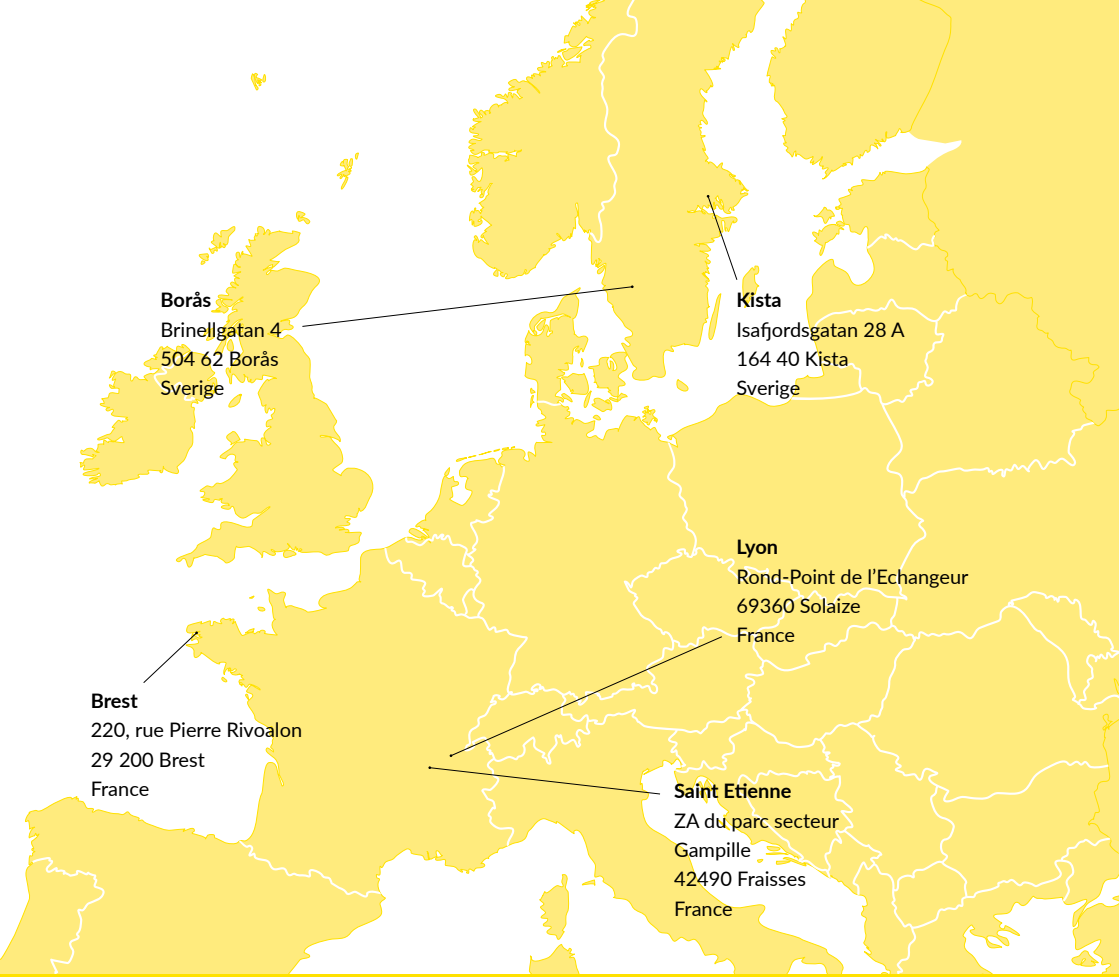

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