

Corrosion and material protection in green and low carbon energy technologies

Teresa C. Diamantino



Index

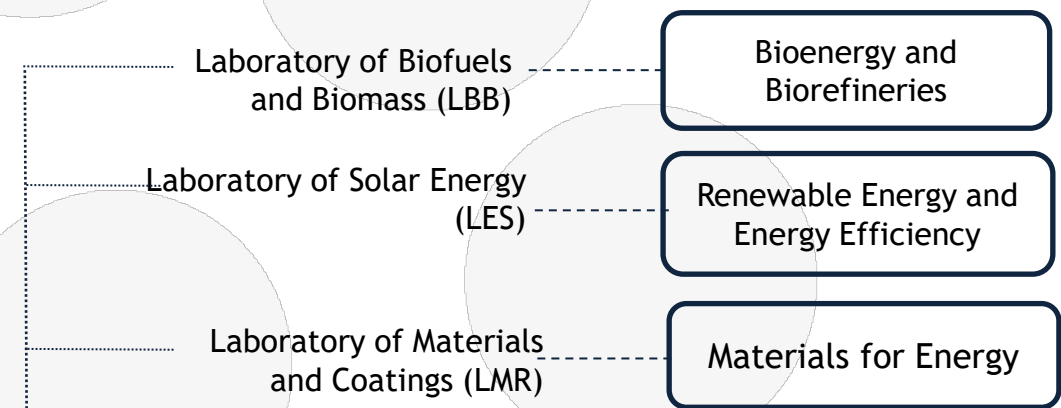
1. Brief presentation of LNEG and Energy Materials Unit
2. Presentation of the *Materials and Coatings Laboratory (LMR)*
3. Materials and Energy Technologies
4. Corrosion and Protection of Materials in Energy Technologies
5. Solar Thermal Power: Issues and Challenges
 - *Solar Absorbers / Reflectors*
 - *Thermal Energy Storage*
6. The importance of Corrosion: Final Considerations

-

1. Brief presentation of LNEG

Laboratório Nacional de Energia e Geologia, I.P. | www.lneg.pt

Under the banner of "Building a cleaner and better future", the LNEG's mission is to contribute independently to economic development and to improving the quality of life, placing knowledge in Energy and Geology at the service of society.



Accredited Laboratory Network (EN ISO 17025)

Campus São Mamede de Infesta, Matosinhos



Geology

Campus Alfragide, Amadora



Geology

Campus Lumiar, Lisboa

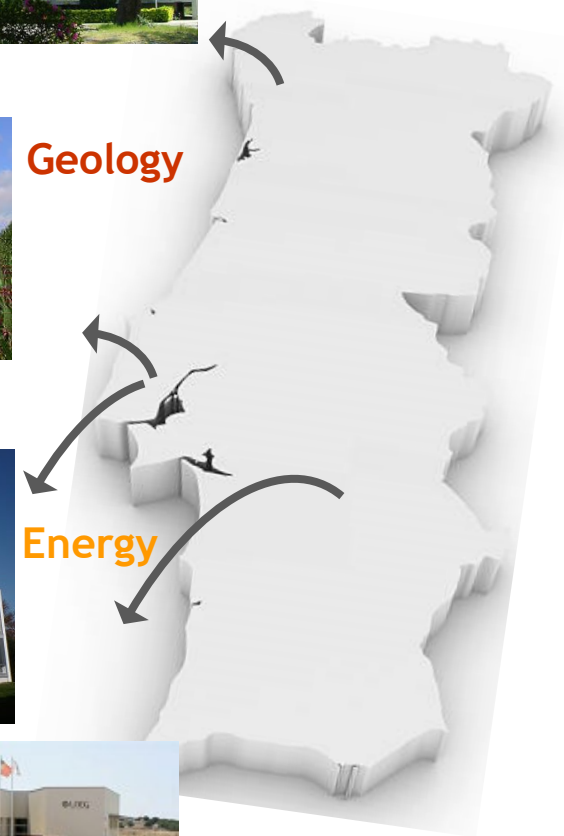


Energy



Campus Aljustrel

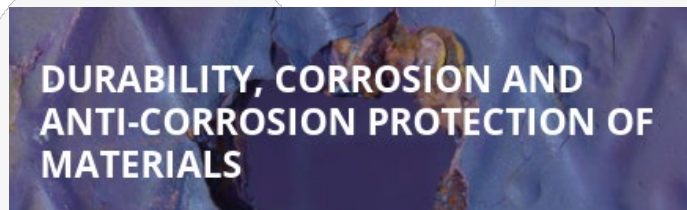
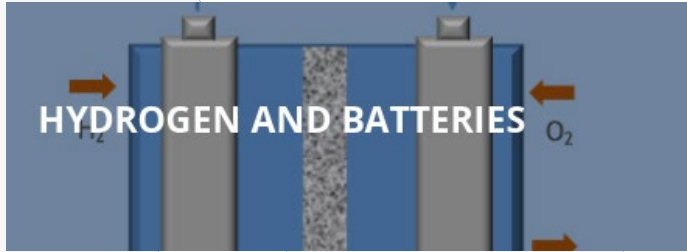
Geology



1. Brief presentation of UME

MATERIALS FOR ENERGY UNIT

Main Competence Areas



Main goals

Hydrogen as alternative fuel and as a key energy vector

- production of "solar" hydrogen by electrolysis, photocatalysis and co-electrolysis
- hydrogen storage and fuel cells for electric mobility

Battery technology

- development of electrolytes, cathodic and anodic materials
- performance tests for stability, durability and cyclability

Extraction, refining and metallic recovery from primary and secondary resources

- materials for energy technologies
- materials considered critical or strategic (sustainable use of resources)
- characterization of resources, development and optimization of processes and design of treatment diagrams, mainly by hydrometallurgy

Behavior and durability of materials, corrosion evaluation and anticorrosive protection

- technologies of renewable energy storage and conversion (solar and ocean energies)
- extreme applications such as high temperatures (e.g. solar concentration technologies) or saline environments (e.g. offshore technologies)

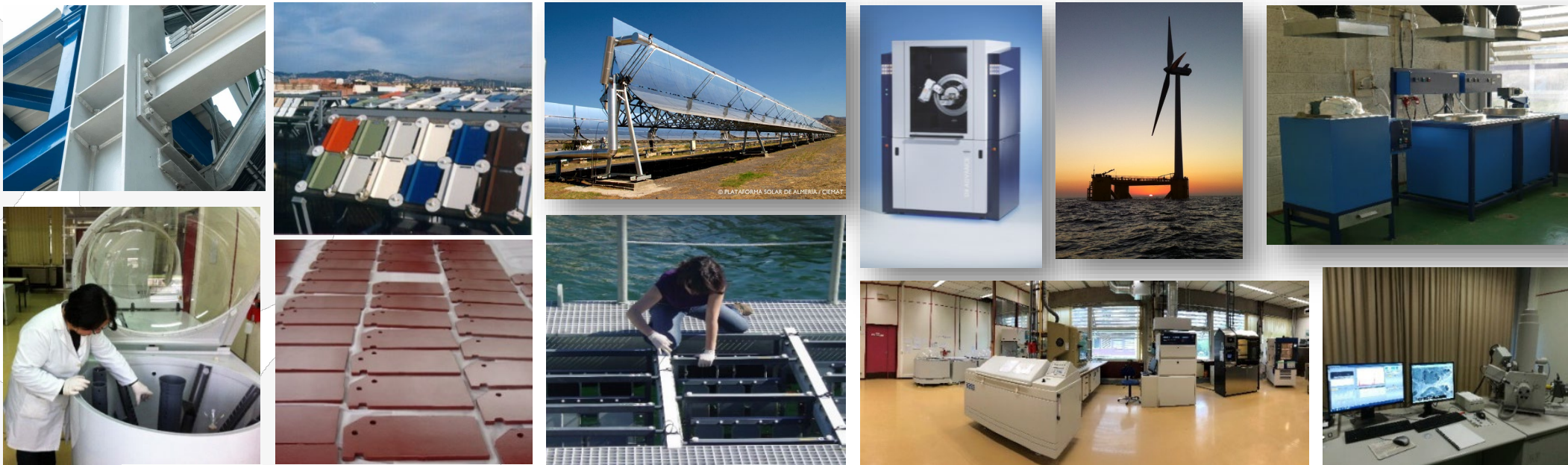
Development and characterization of materials for renewable energy technologies

- solar energy technologies (solar thermal conversion and photovoltaics)
- advanced ceramic materials for thermochemical reactions
- thermoelectric waste heat harvesting systems

2. Brief presentation of LABORATORY OF MATERIALS AND COATINGS (LMR)

R&D AND TECHNICAL AND TECHNOLOGICAL ASSISTANCE THROUGH BUSINESS CONTRACTS AND NATIONAL AND INTERNATIONAL CO-FINANCING

DURABILITY, CORROSION AND ANTICORROSIVE PROTECTION OF MATERIALS



IPAC
acreditação

LMR is a testing laboratory accredited according to NP EN ISO 17025 with IPAC Accreditation Certificate No. L0698.
http://www.ipac.pt/pesquisa/ficha_la_e.asp?id=L0698.

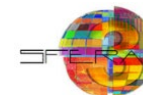
SUBCONTRACTING

INDIVIDUAL AND MULTI-CLIENT CONTRACTS - JIP

PROJETOS DE I&D:



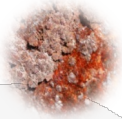
CONTRATOS DE I&D



SFERA III

EEN PORTUGAL

2. Brief presentation of LABORATORY OF MATERIALS AND COATINGS (LMR)



LMR

Main technical
and scientific areas



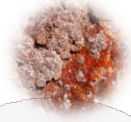
- + Paints, Varnishes and Organic coatings
- + Metallic materials and coatings
- + Polymeric materials

Materials Artificial Ageing

Corrosion and anticorrosive protection studies under accelerated aging environments with and without cycles of temperature, humidity, radiation (UV and Xenon-arc) and contaminants (salt spray, SO₂, NO₂).



2. Brief presentation of LABORATORY OF MATERIALS AND COATINGS (LMR)



High temperature furnaces (cyclic, static and dynamic conditions)

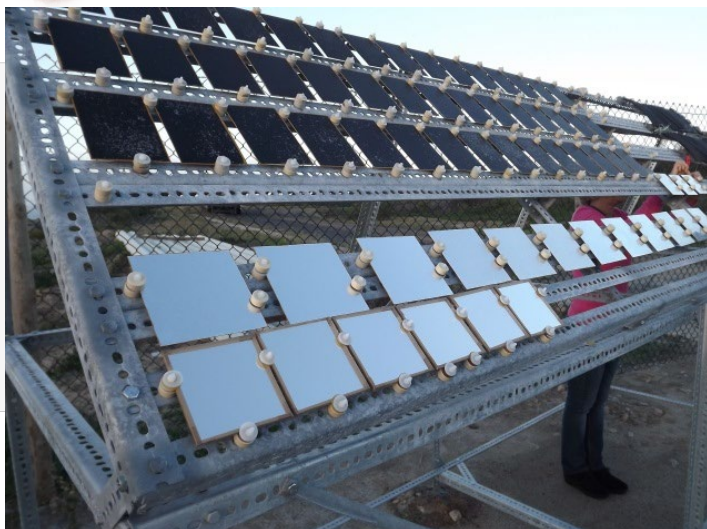
Compatibility and corrosion behaviour of materials in contact with the molten salts (MS) mixtures and chemical stability of MS.

cylindrical pot bath with and without mechanically stirred mixtures;



2. Brief presentation of LABORATORY OF MATERIALS AND COATINGS (LMR)

Durability of materials by exposure in two Outdoor Exposure Testing (OET) Sites



TWO OUTDOOR EXPOSURE TESTING SITES

- European reference test site for UV radiation with corrosivity C2/C3 - Lumiar/Lisboa
- Marine/industrial test site with very high/extreme corrosivity C5/CX - Sines

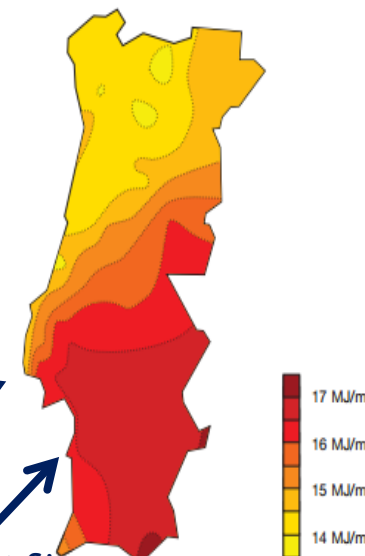


Monitored parameters:

- Temperature
- Relative humidity
- Wetness time
- Radiation
- Rain
- Chloride, Sulphur dioxide and Nitrogen oxides in atmosphere

Lumiar/Lisboa
Urban Test Site
Corrosivity C2/C3

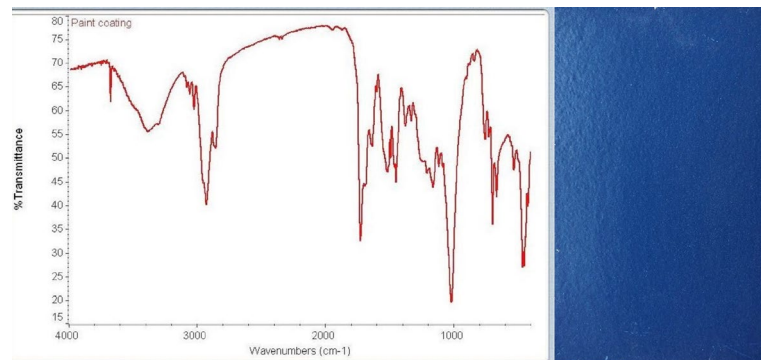
Sines
Marine Test Site
Corrosivity C5/CX



2. Brief presentation of LABORATORY OF MATERIALS AND COATINGS (LMR)

Chemical and Physical Characterization of Materials

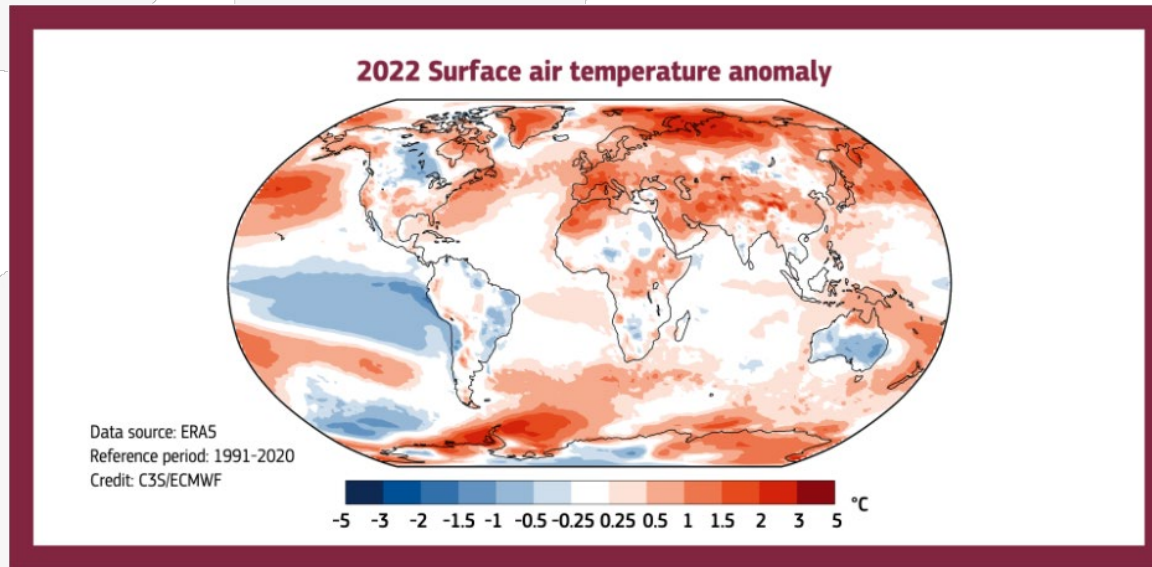
Metallographic microscopes
Digital microscope
SEM/EDS
XRD
tensile machines
SRET
EIS
FTIR
Thickness, Colour
Gloss,....



3. MATERIALS AND ENERGY TECHNOLOGIES

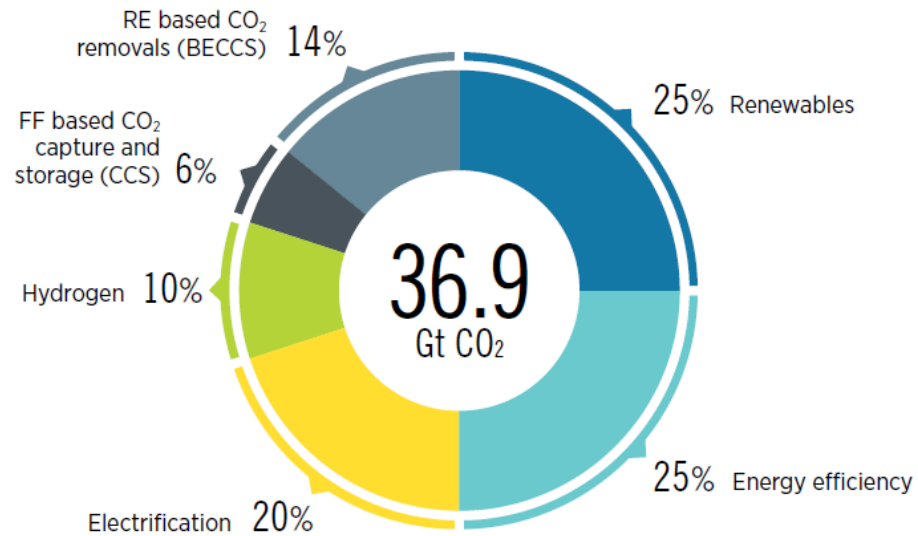
2022 WAS THE 5TH WARMEST YEAR GLOBALLY AND 2ND WARMEST YEAR FOR EUROPE

Copernicus: 2022 was a year of climate extremes, with record high temperatures and rising concentrations of greenhouse gases



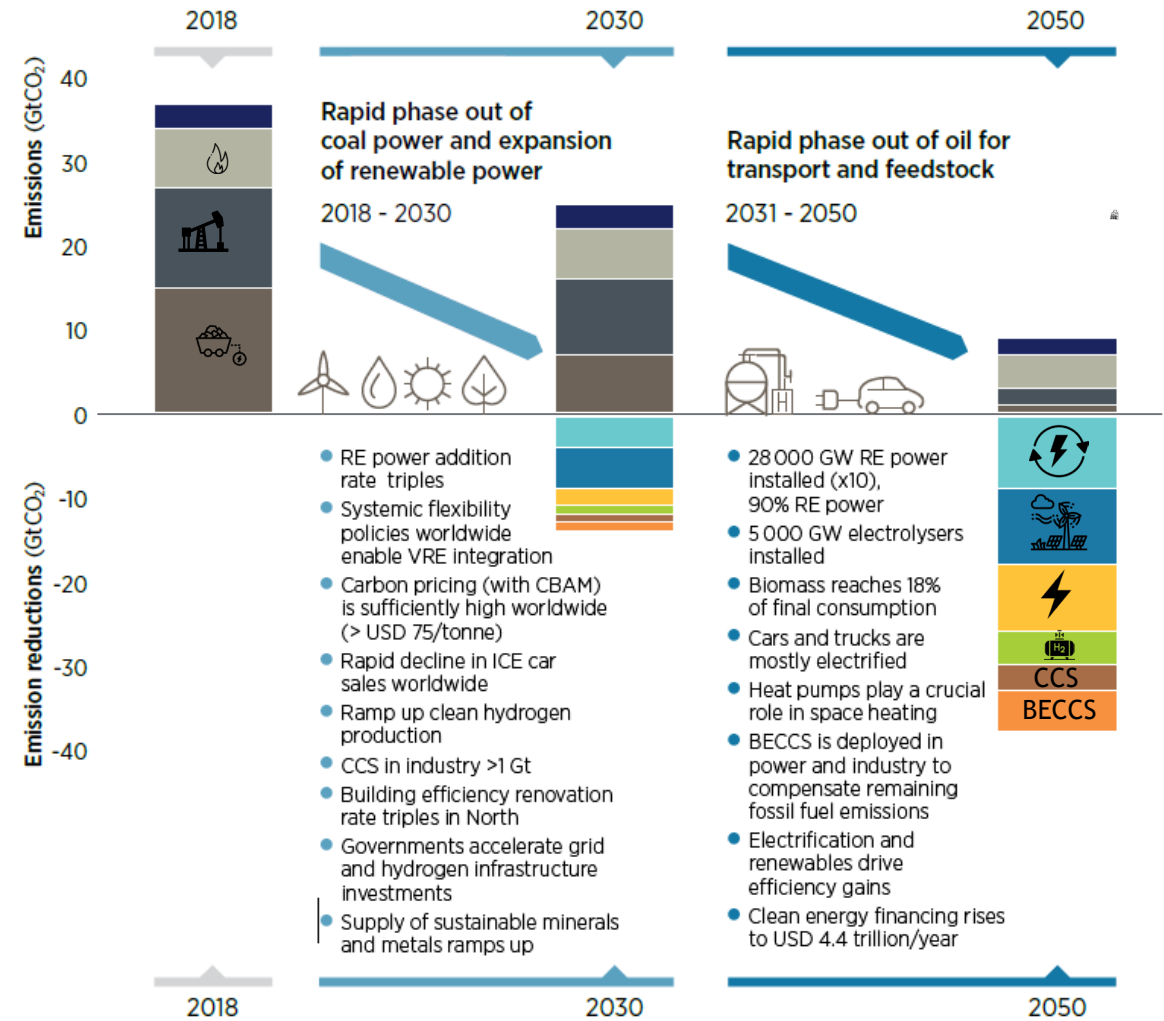
3. MATERIALS AND ENERGY TECHNOLOGIES

Reducing emissions by 2050 through six technological avenues



CCS carbon capture and storage
BECCS – bioenergy combined with carbon capture and storage

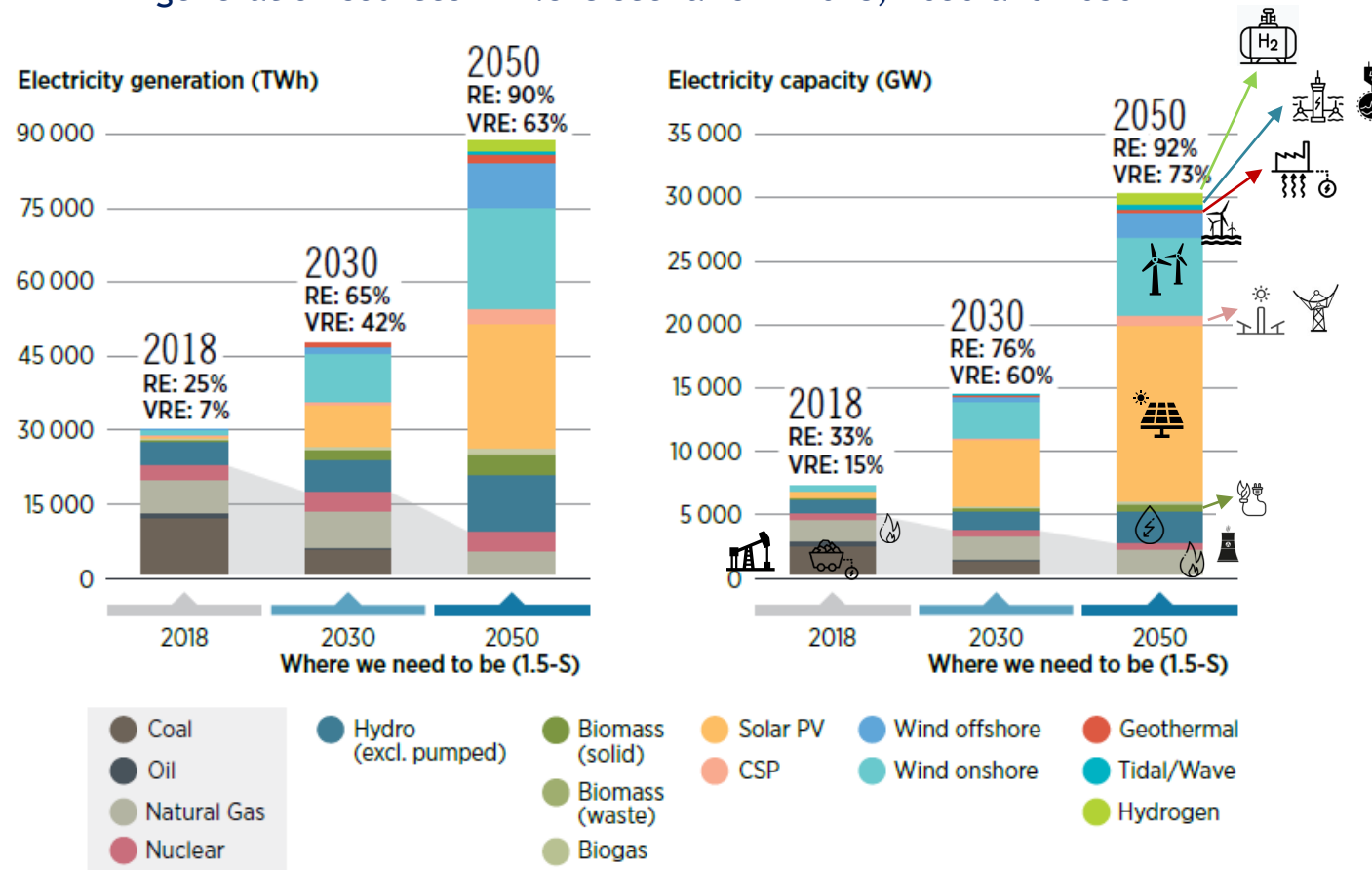
Evolution of emissions in accordance with the deployment of technological avenues 2018-2050



IRENA_World_Energy_Transitions_Outlook_2022

3. MATERIALS AND ENERGY TECHNOLOGIES

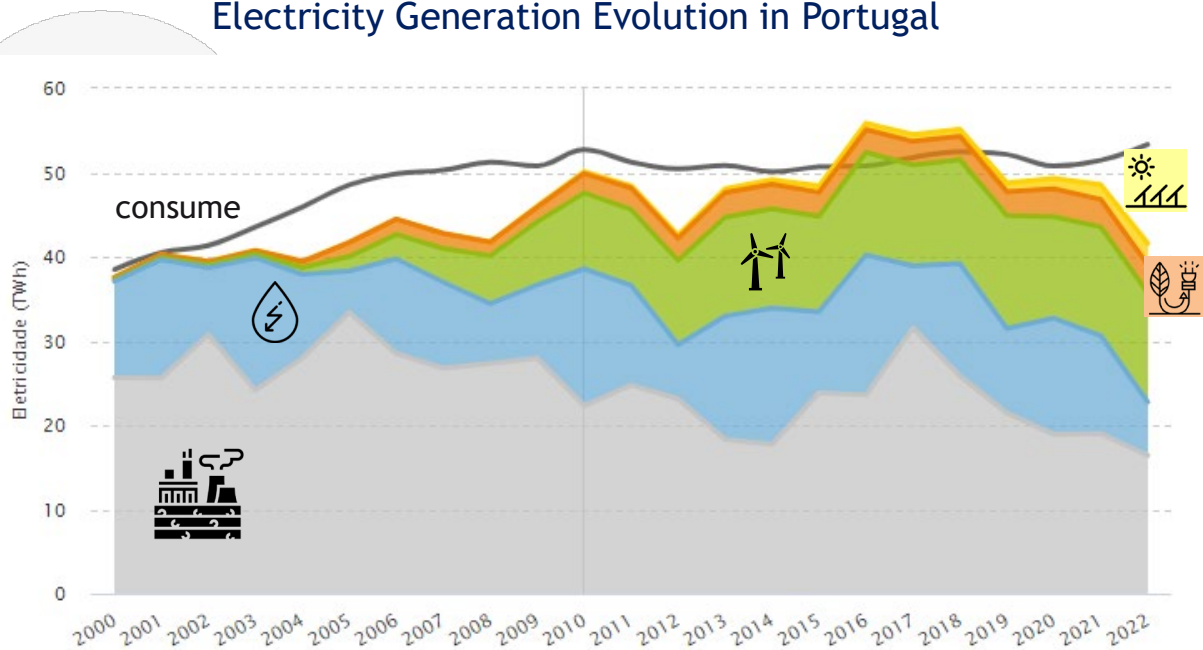
Global total power generation and the installed capacity of power generation sources in 1.5°C scenario in 2018, 2030 and 2050



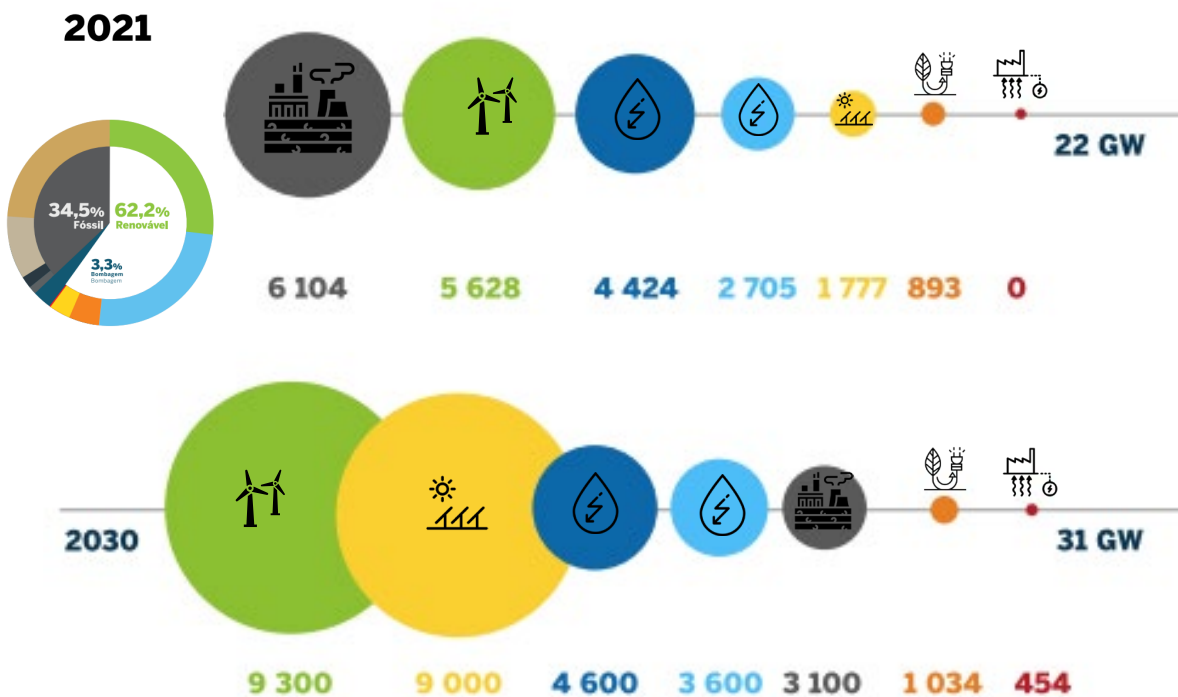
Note: 1.5-S = 1.5°C Scenario; CSP = concentrated solar power; GW = gigawatts; PV = photovoltaic; RE = renewable energy; TWh/yr = terawatt hours per year; VRE = variable renewable energy.

3. MATERIALS AND ENERGY TECHNOLOGIES

Electricity Generation Evolution in Portugal



Installed capacity of the power generation and goals for 2030

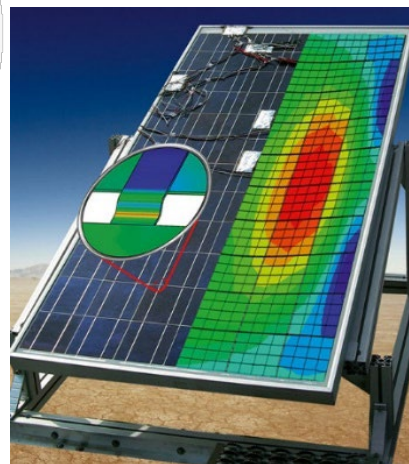
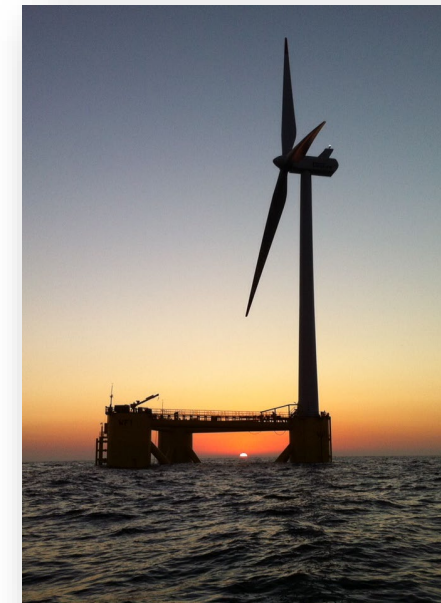
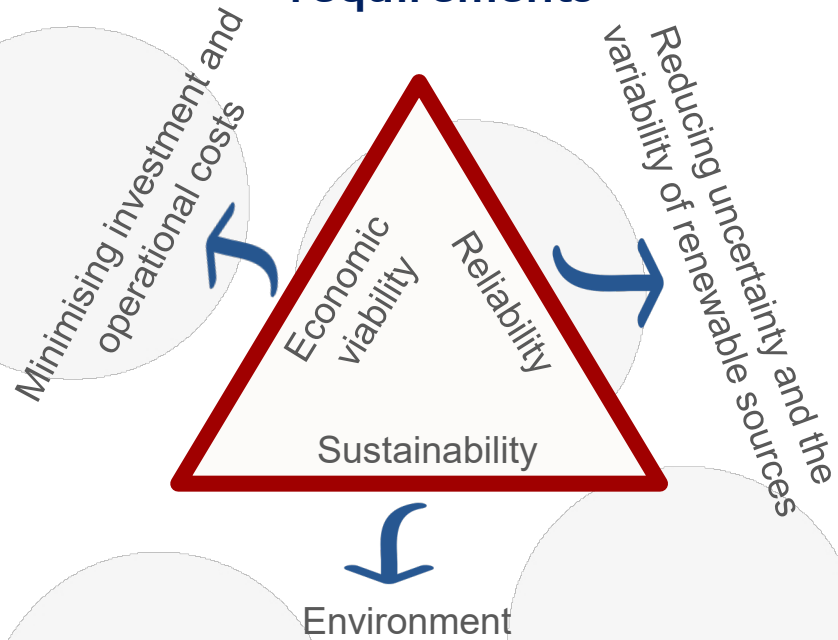


Fonte:  APREN Associação de Energias Renováveis

3. MATERIALS AND ENERGY TECHNOLOGIES

New Materials_Durability Guarantees

Future energy demand requirements



Renewable Energy

Hydric



Biomass



Wind



Solar

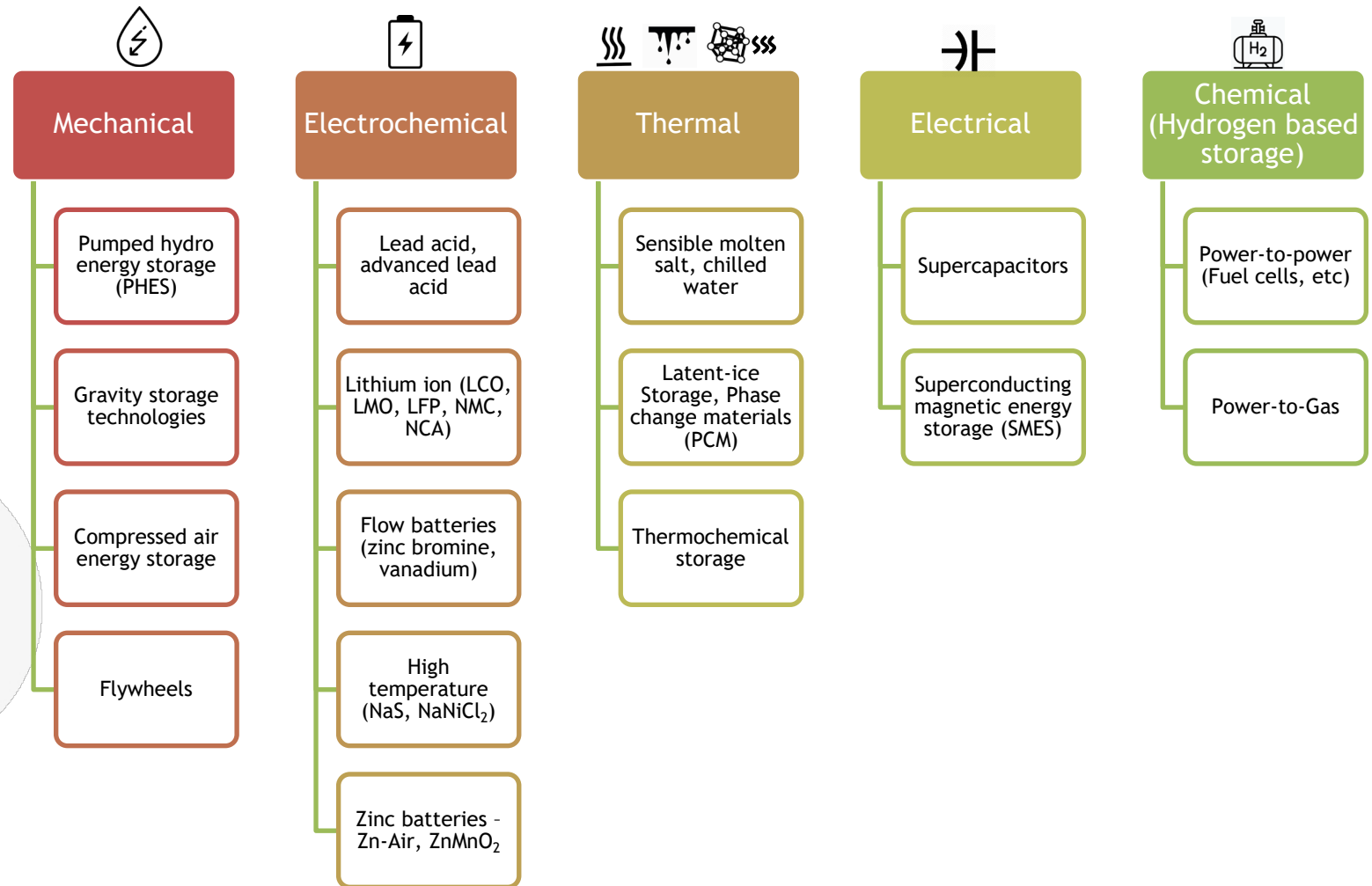


3. MATERIALS AND ENERGY TECHNOLOGIES

Energy Storage Technologies



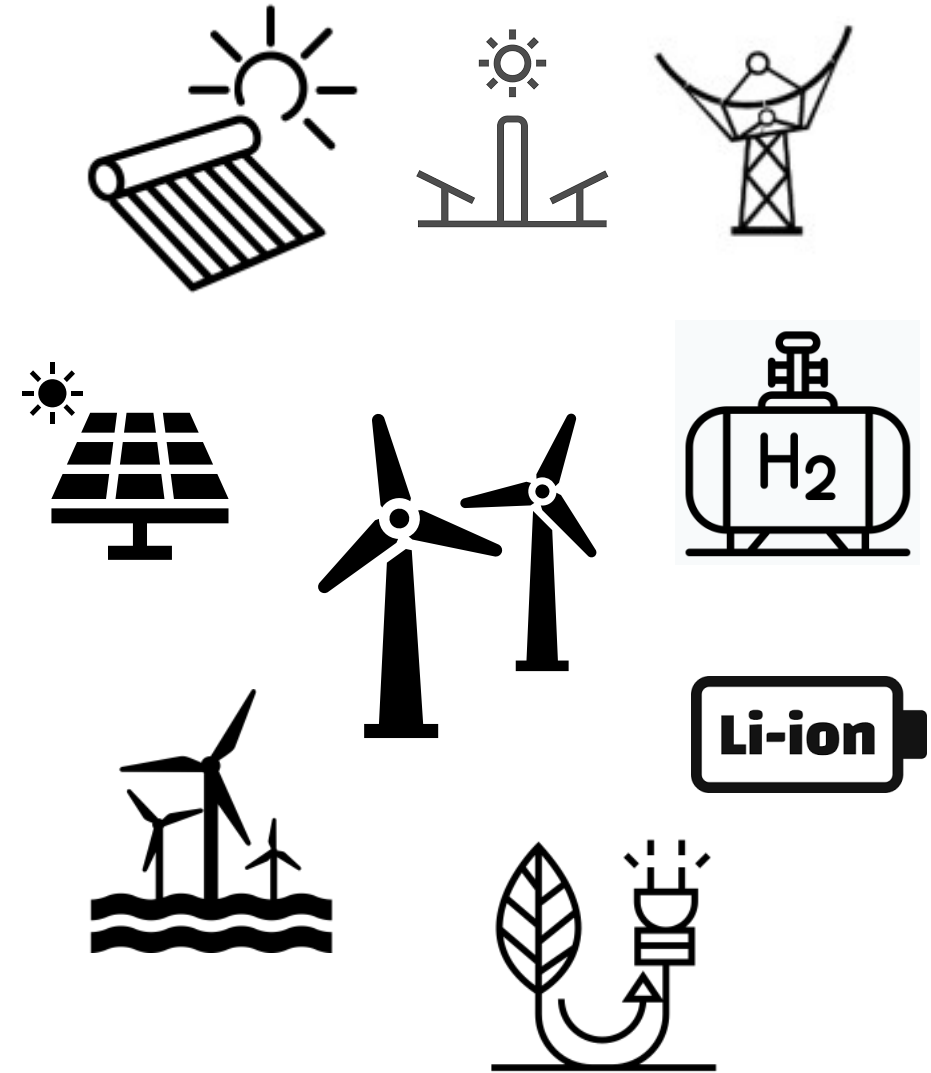
CLASSIFICATION OF ENERGY STORAGE TECHNOLOGIES



<https://etn.news/energy-storage/classification-of-energy-storage-technologies-an-overview>

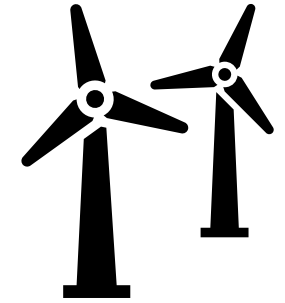
4. MATERIALS CORROSION IN ENERGY TECHNOLOGIES

- ④ **Hydrogen**
- ④ **Batteries (Li-ion)**
- ④ **Wind Turbines**
- ④ **Solar PV**
- ④ **Solar térmico**
- ④ **Concentrated Solar Power (CSP)**
- ④ **Biomass**



4. MATERIALS CORROSION IN ENERGY TECHNOLOGIES

End of service life
Under design conditions (t = 20 years)



Remaining life-time



- low (L) up to 7 years;
- medium (M) 7 years to 15 years;
- high (H) 15 years to 25 years;
- very high (VH) more than 25 years.

IEC61400-1: WIND ENERGY GENERATION SYSTEMS - Design requirements
Provides for a minimum service life of 20 years

6 External conditions

6.1 General

The external conditions described in this clause shall be considered in the design of a wind turbine.

Wind conditions are the primary external conditions affecting structural integrity. Other environmental conditions also affect design features such as control system function, durability, corrosion, etc.



4. MATERIALS CORROSION IN ENERGY TECHNOLOGIES



Reference materials		Carbon steel	
Samples orientation		NW	S
Corrosion rate (g/(m ² .a))		3535.76	1346.01
Corrosion category (ISO 9223:2012)	Category	CX	C5
	Reference values	1500 < r _{corr} ≤ 5500	650 < r _{corr} ≤ 1500

South orientation



NW – prevailing wind



ATMOSPHERIC ZONE

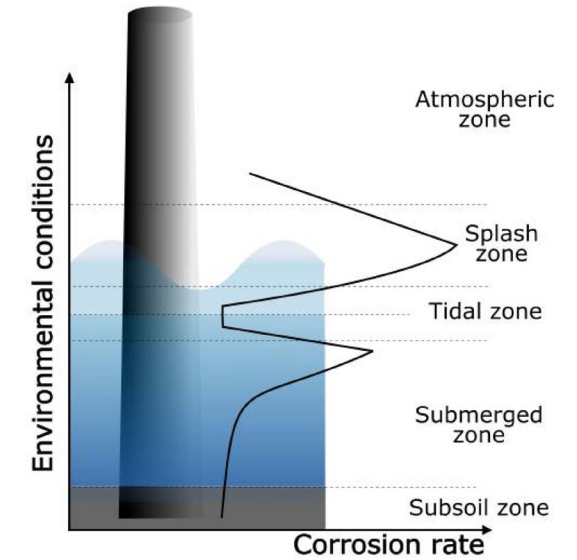
SPLASH ZONE

TIDAL ZONE

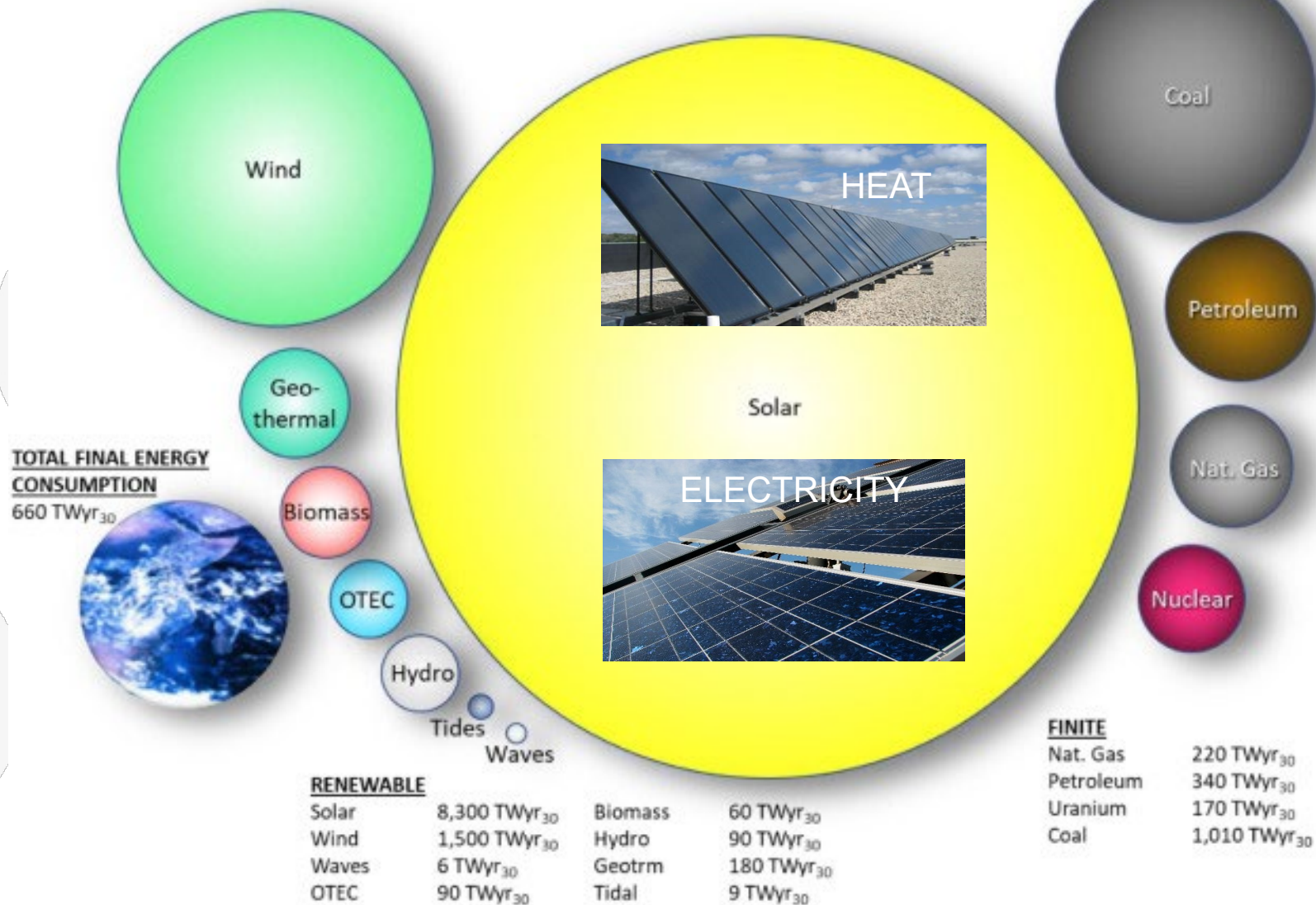
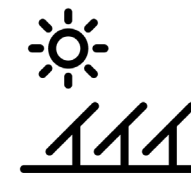
SUBMERGED / SUBSOIL ZONE

Different types of corrosion :

- ▶ Uniform corrosion
- ▶ Localized corrosion
- ▶ Biocorrosion (MIC)
- ▶ Pitting corrosion
- ▶ Crevice corrosion, erosion, SCC

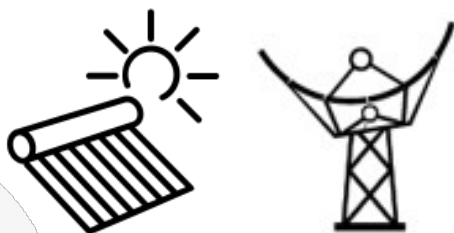


4. MATERIALS CORROSION IN ENERGY TECHNOLOGIES

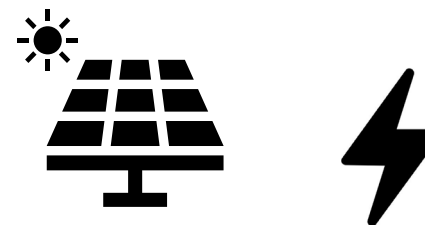


<https://doi.org/10.1016/j.seja.2022.100014>

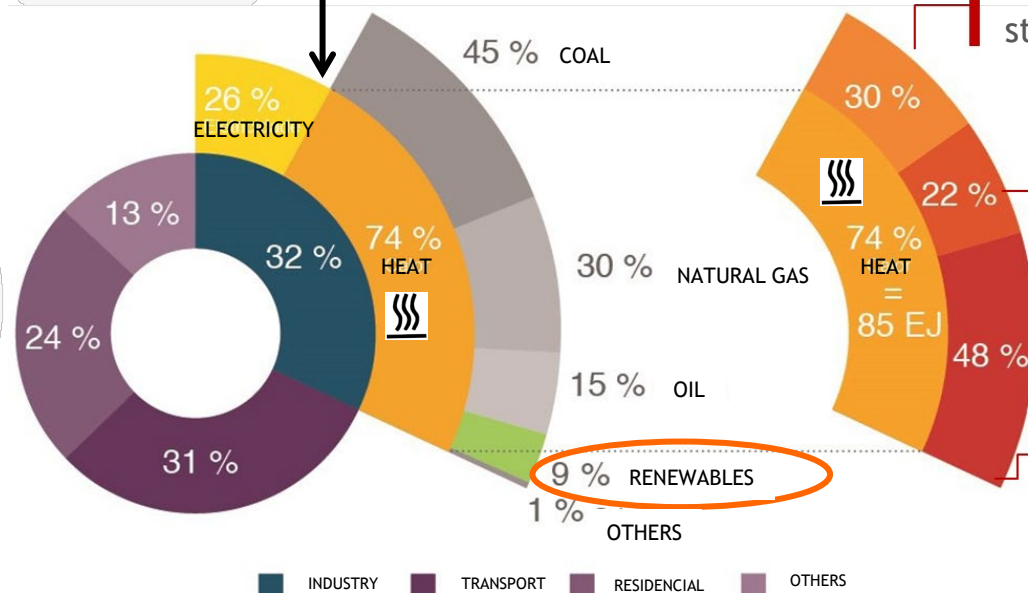
4. MATERIALS CORROSION IN ENERGY TECHNOLOGIES



Solar Collectors
HEAT PRODUCTION



Photovoltaic modules
ELECTRICITY PRODUCTION



Low temperature heat (below 150°C) (pasteurisation, sterilisation, cleaning, drying, washing, bleaching, steaming, descaling, cooking)

Medium temperature heat (150°C-400°C) (distillation, nitrate melting, dyeing, compression)

High temperature heat (above 400°C) (material transformation processes)

Solar Payback Project (<https://www.solar-payback.com/>)

5. SOLAR THERMAL POWER: ISSUES AND CHALLENGES

100°C



200°C

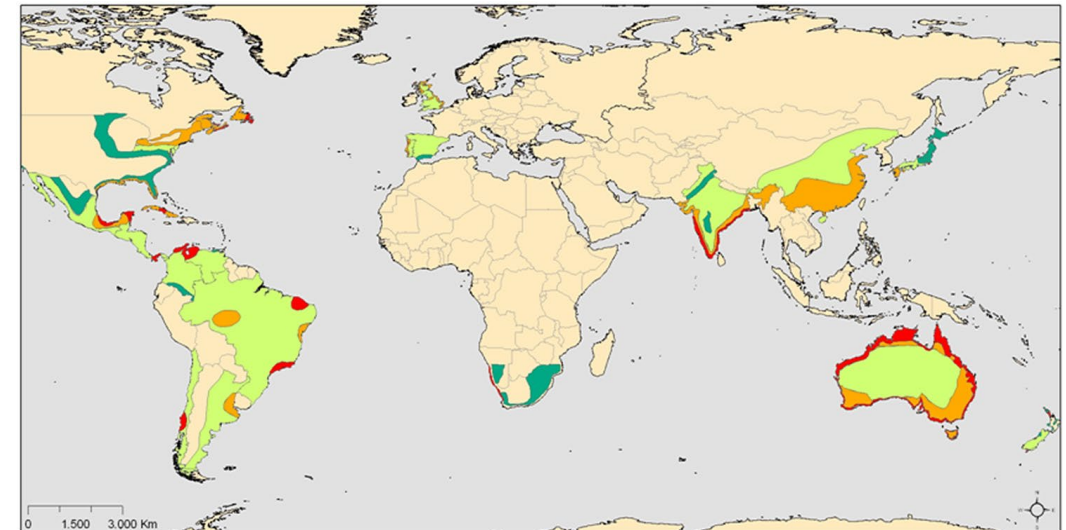
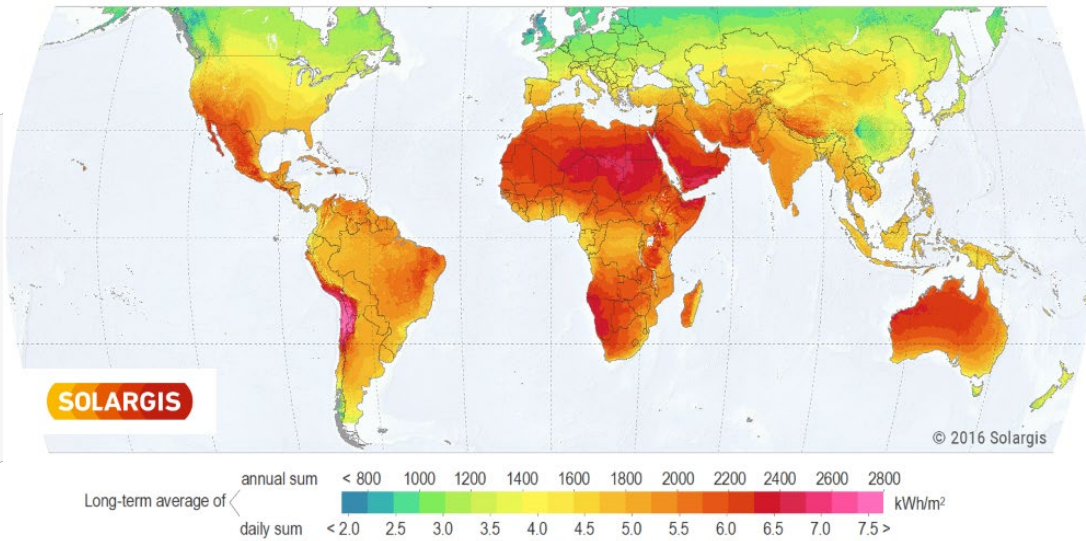


300°C



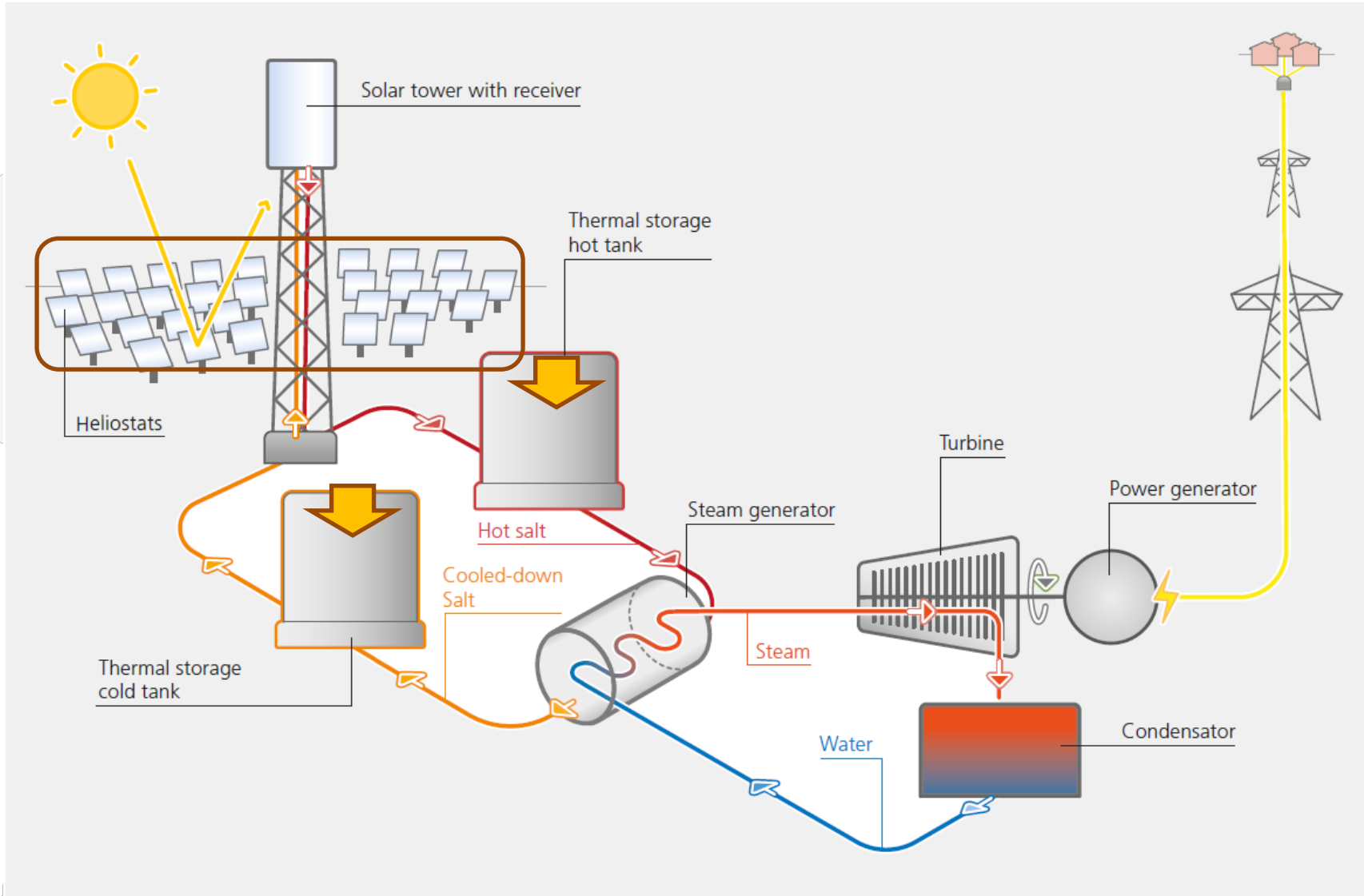
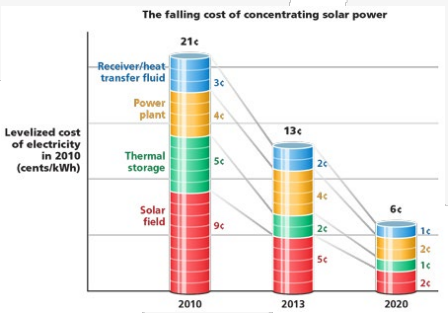
400°C

GLOBAL HORIZONTAL IRRADIATION



K.Slamova et al.. *Photon. Energy.* 2(1), 2012
<http://dx.doi.org/10.1117/1.JPE.2.022003>

5. CONCENTRATED SOLAR POWER (CSP) : ISSUES AND CHALLENGES

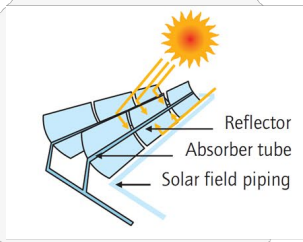


How a solar thermal power plant works, shown here for a solar tower power plant. Image: DLR

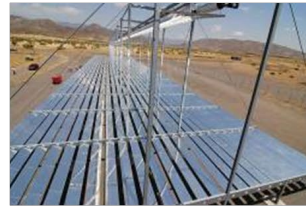
<http://www.renewableenergyworld.com/>

5. CONCENTRATED SOLAR POWER (CSP) : ISSUES AND CHALLENGES

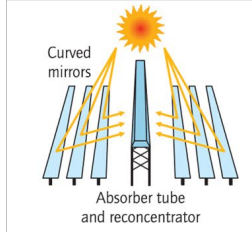
Parabolic Trough



Linear Fresnel



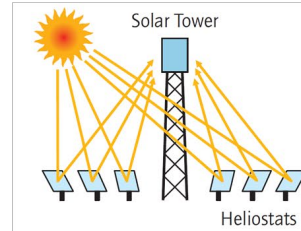
Line Focus



Solar Tower



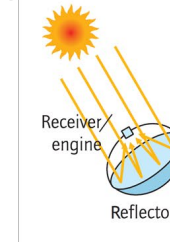
Point Focus



Dish Systems



Point Focus



5. SOLAR THERMAL POWER: ISSUES AND CHALLENGES

KEY COMPONENTS FOR SOLAR THERMAL ENERGY

100°C

200°C

300°C

400°C

SOLAR THERMAL ENERGY WITHOUT CONCENTRATION



water heating

Selective absorber coatings

SOLAR THERMAL ENERGY WITH CONCENTRATION (CSP/STE)



Reflector coatings

Industrial process heat technologies
Electricity production

MOST IMPORTANT PART REGARDING PERFORMANCE OF SOLAR THERMAL SYSTEMS

A vital aspect is to maintain high conversion efficiency from solar to thermal which may be compromised if the solar facility is located near an industrial and/or marine environments.

5. SOLAR THERMAL POWER: SELECTIVE ABSORBERS AND REFLECTOR COATINGS



REAL OPERATING CONDITIONS

Outdoor exposure test sites



LABORATORY

Artificial aging tests

Accelerated / Simulation test



5. SOLAR THERMAL POWER: SELECTIVE ABSORBERS COATINGS

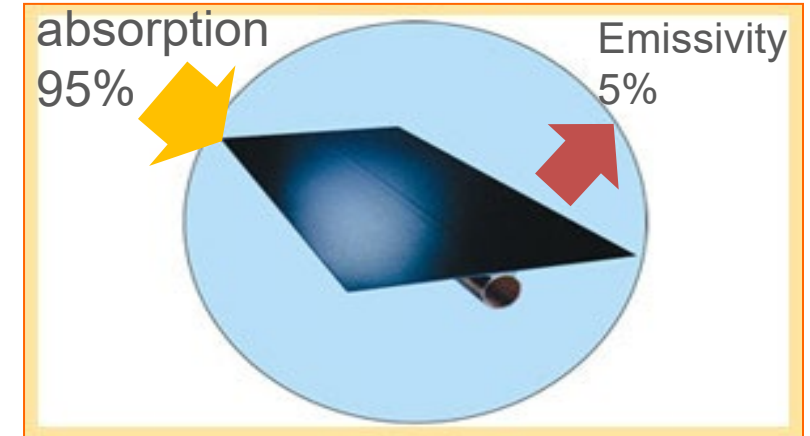


- Vacuum deposition methods (e.g. PVD coatings)
- Spectrally selective paints coatings

**Absorber surface qualified
=
Durability exceeding 25 years!!**

ACCELERATED AGEING TESTS

- 1) Thermal stability (600h)
- 2) Resistance to condensed water (600 h)
- 3) Resistance to high humidity air containing sulfur dioxide (SO₂) (540h)



INTERNATIONAL
STANDARD

ISO
22975-3

First edition
2014-07-01

Solar energy — Collector components
and materials —

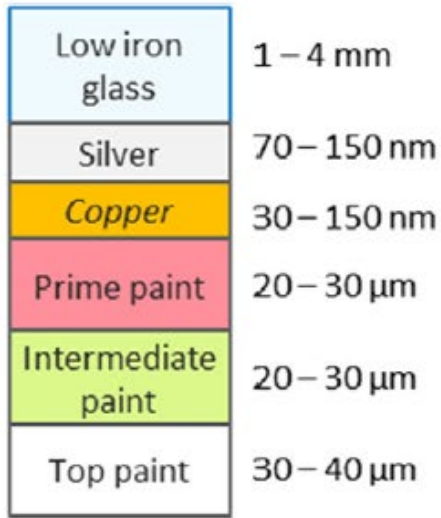
Part 3:
Absorber surface durability

*Energie solaire — Composants et matériaux du collecteur —
Partie 3: Durabilité de la surface de l'absorbeur*

5. SOLAR THERMAL POWER: REFLECTOR COATINGS

Goals for solar reflector materials

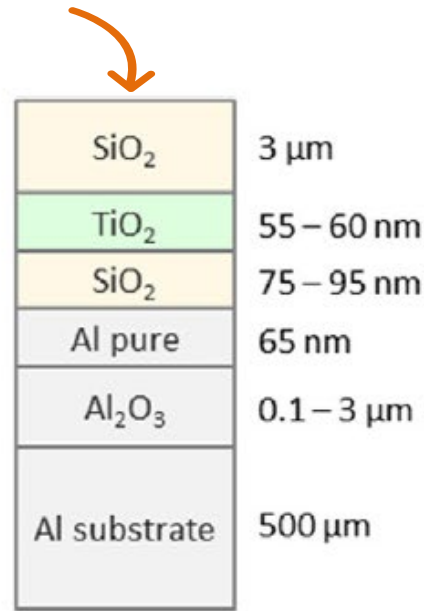
- 30 years lifetime
- >95% specular reflectance ($\varphi = 7.5$ mrad)
- specular reflectance loss <1% over lifetime
- low manufacturing cost < 10 €/m²



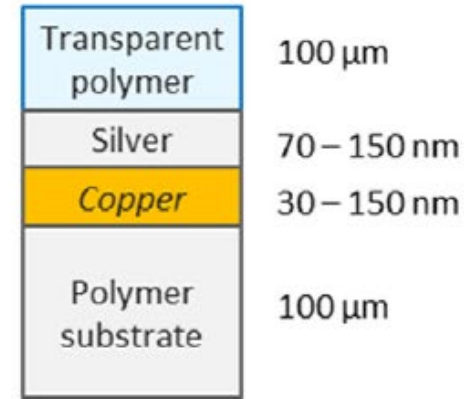
Monolithic glass



Laminate glass



Aluminium



Polymer mirrors



International Electrotechnical Commission

IEC 62862-3-6 ED1

Accelerated aging tests of silvered-glass reflectors for concentrating solar technologies

5. SOLAR THERMAL POWER: SELECTIVE ABSORBER AND REFLECTOR COATINGS



REAL OPERATING CONDITIONS



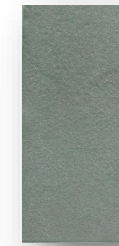
LABORATORY



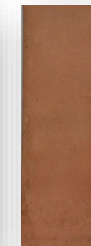
Neutral Salt Spray
continuous and discontinuous



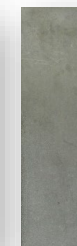
Dry and Wet



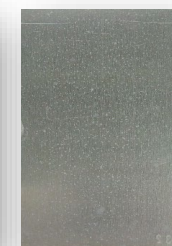
Steel



Cu



Zn



Al



SO₂



SO₂ and/or NO₂
[]



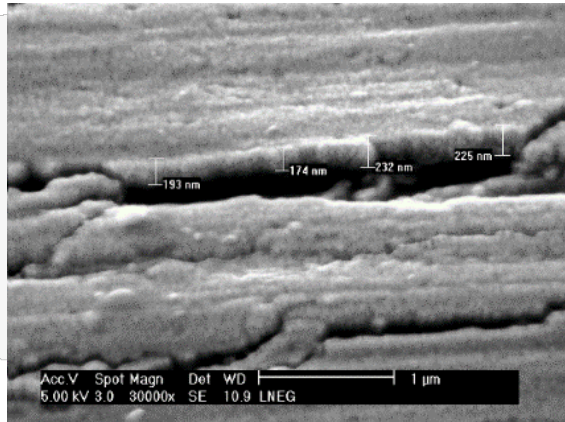
New aging tests involved all the contaminants (NSS + SO₂ + NO₂ + DW) temperature, humidity, dry and wet



Temperature and Humidity

5. SOLAR THERMAL POWER: SELECTIVE ABSORBERS AND REFLECTOR COATINGS

SELECTIVE ABSORBERS COATINGS



<http://dx.doi.org/10.1016/j.solmat.2016.10.015>



SEM/EDS



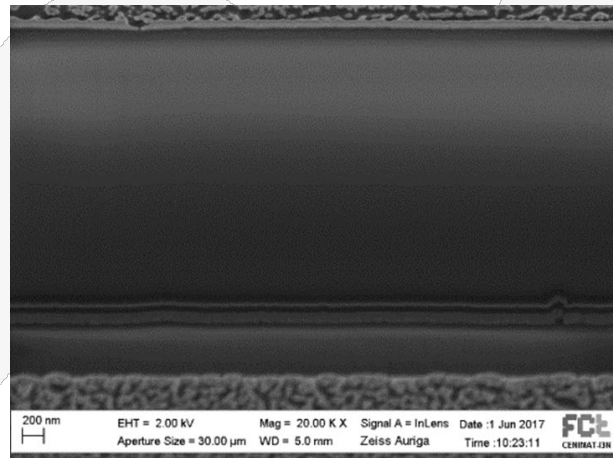
Adherence tests



XRD

Figure of Merit $FM = \alpha_s - 0.44 \epsilon_T$

REFLECTOR COATINGS



SiO₂ sol-gel coating

PVD coatings

Al anodized coating

- Solar absorptance (α_s)
- Thermal emittance (ϵ_T)

$$K = \frac{\% \text{ decrease of } FM}{\text{time}}$$

- Hemispherical reflectance ($\rho_{\lambda,h}$)
- Specular reflectance

Corrosion rate (CR) of Reference Materials

Acceleration Factor




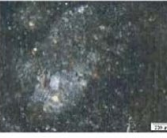





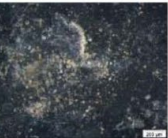


$$AF_{(FM)} = \frac{K_{OET}}{K_{AAT}}$$

$$AF_{(CR)} = \frac{CR_{OET}}{CR_{AAT}}$$









5. SOLAR THERMAL POWER: SELECTIVE ABSORBERS COATINGS

OUTDOOR EXPOSURE TESTING SITES

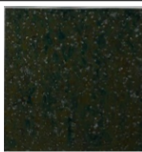

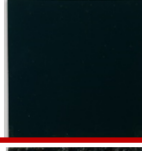
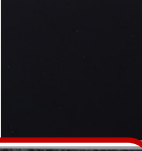

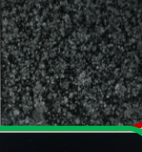


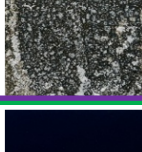
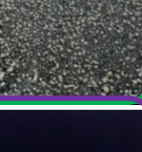
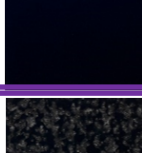


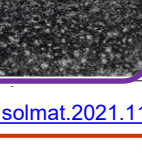
	PVD1	PVD2
Before Exposure		
After 12 months in Sines OET site	 	 
After 12 months in Lumiar_Lisboa OET site	 	 

T.C. Diamantino et al. 2017 (<http://dx.doi.org/10.1016/j.solmat.2017.03.004>)

LABORATORY

Absorber Coating	Aging test (test time)			
	NSS (120h) Test 1	SO ₂ (120 h) Test 2	NSS + TDW (240 h) Test 3	TDW (240 h) Test 3.1
PVD1				
PVD2				

- There is a direct relationship between corrosion and change in optical performance;
- Higher susceptibility to environments with chlorides than with SO₂;
- A worse behaviour in NSS with DW than NSS with DW and gases. The gases, specifically NO₂ stabilizes the coatings degradation

Aging test (4 cycles – 672 h)	PVD1	PVD2
NSS+SO ₂ +NO ₂ +DW Test 4		
SO ₂ +NO ₂ +DW Test 4.1		
NSS + DW Test 4.2		
SO ₂ + DW Test 4.3 10ppm		
NSS + SO ₂ + DW Test 4.4 10ppm		
NO ₂ + DW Test 4.5 10ppm		
NSS + NO ₂ + DW Test 4.6 10ppm		

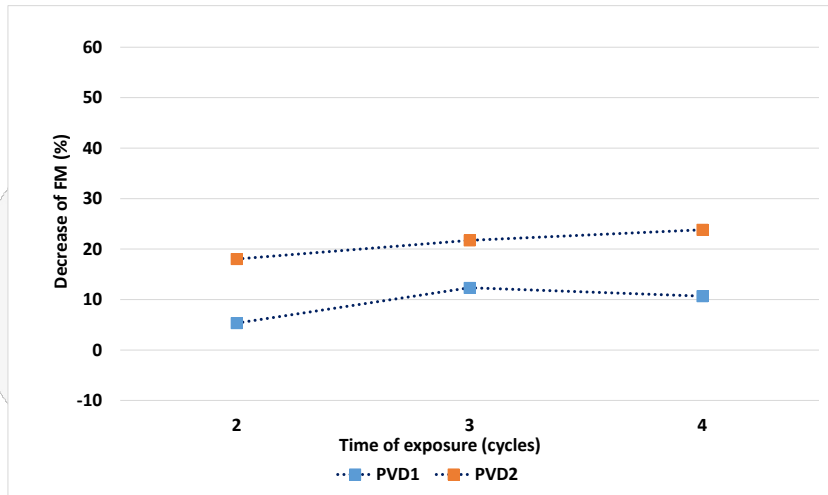
T.C. Diamantino et al. 2021 (<https://doi.org/10.1016/j.solmat.2021.111320>)

5. SOLAR THERMAL POWER: SELECTIVE ABSORBERS COATINGS AND REFERENCE MATERIALS

Acceleration Factor (AF)

Alternative Cyclic artificial aging test

Optical properties

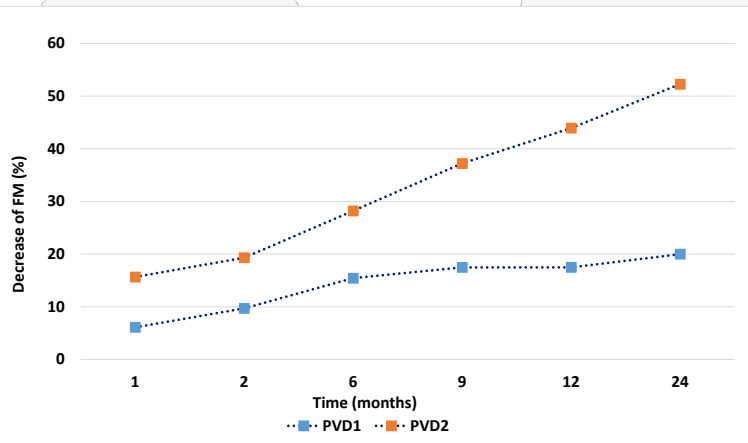


OET/AAT and OETs	Acceleration Factor (AF)	
	PVD1	PVD2
Sines (2 month) / test 4 (3 cycles)	0.27	0.31
Lumiar_Lisboa (9 month) / test 4 (3 cycles)	0.041	0.049

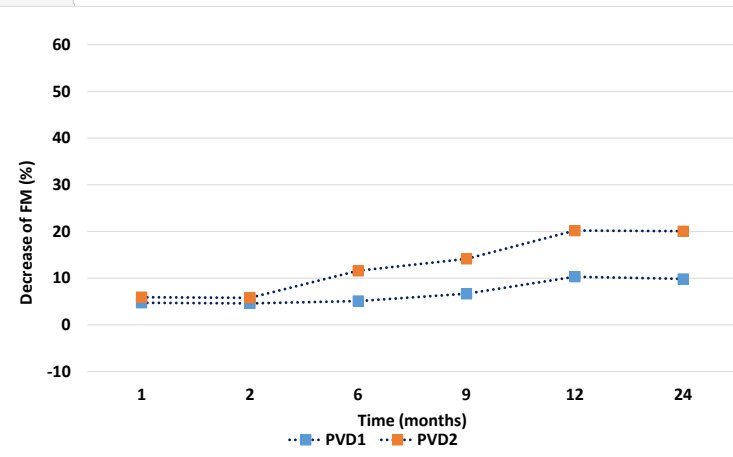
OET/AAT	Acceleration Factor (AF _{CR})		
	Steel	Copper	Aluminium
Sines/test 4	0.26	0.22	0.25
Lumiar_Lisboa/test 4	0.039	0.048	0.023

T.C. Diamantino et al. 2021 (<https://doi.org/10.1016/j.solmat.2021.111320>)

Sines OET site



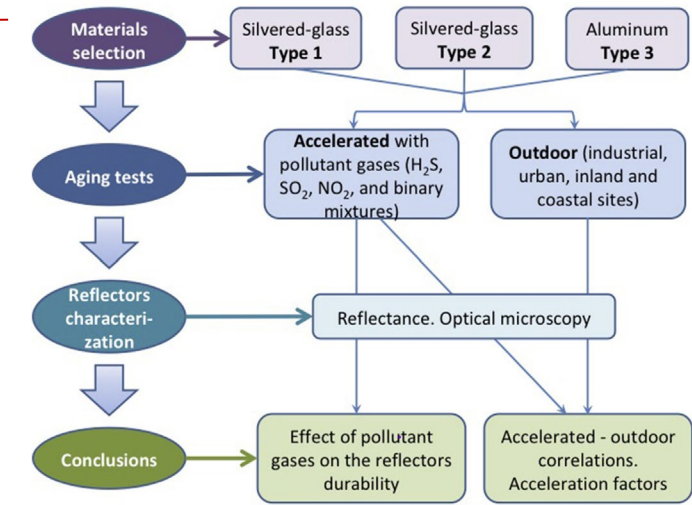
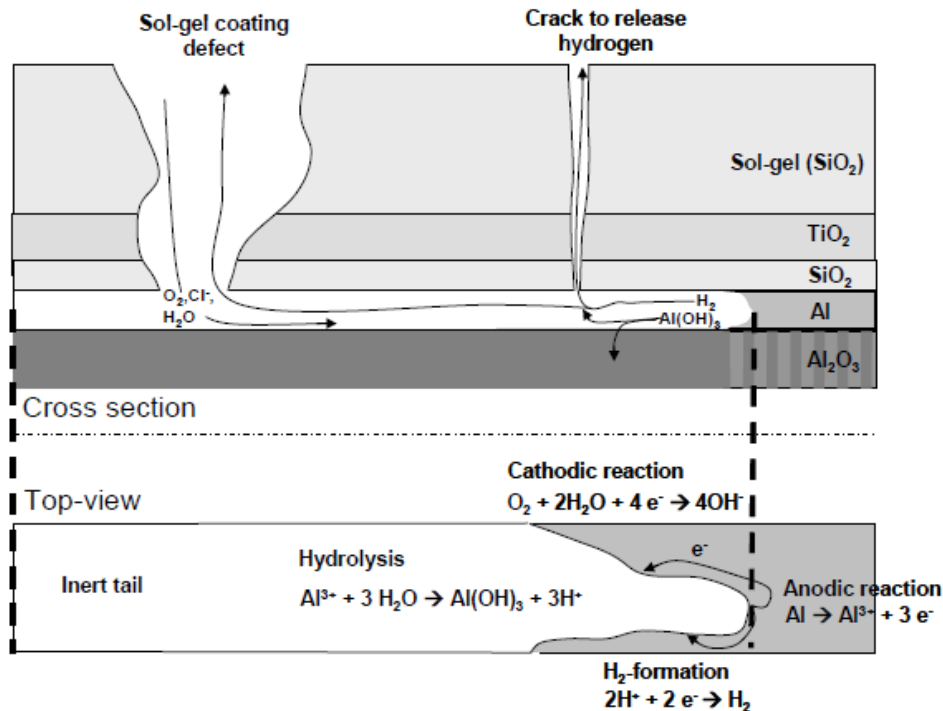
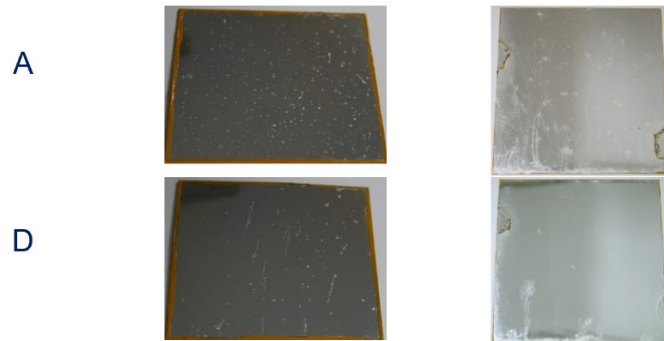
Lumiar OET site



- Good correlation between natural exposure and accelerated aging tests (optical properties and corrosion mechanisms);
- Cyclic variation of corrosion promoting gases, higher humidity, salt spraying and drying is an aging test that reflects the different environments to which the solar thermal collectors are exposed.
- Values of acceleration factor (AF) are very similar obtained with decrease of FM (optical properties) and with CR (corrosion rate);

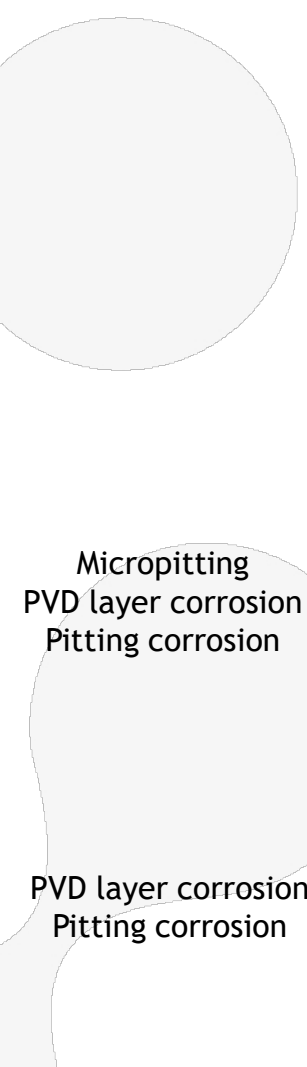
5. SOLAR THERMAL POWER: REFLECTOR COATINGS

References Alternative AAT Sines OET site (24 months of exposure)



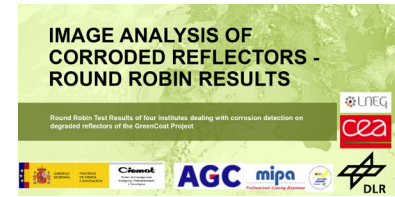
[García-Segura et al. 2019 . Solar Energy Materials and Solar Cells 200 \(2019\) 109955](#)

Reflectors in the presence only with polluting gases (H₂S/SO₂/NO₂) without salinity do not suffer significant degradation and other factors such as humidity and salinity are more harmful for these materials



5. SOLAR THERMAL POWER: ISSUES AND CHALLENGES FOR SELECTIVE ABSORBER AND REFLECTOR COATINGS

- Durability issues of key materials have to be known before commercial application.
- Importance of pre-normative research work.
- Good correlation between natural exposure and accelerated aging tests (optical properties and corrosion mechanisms);
- Accelerated ageing tests to guarantee the durability of materials and coatings (absorbers and reflectors) must include the main contaminants and drying and wetting cycles that determine the atmospheric corrosivity;
- Mechanistic models are complex and are under study but need to be defined for reference environments where the solar systems will be placed.



IEC CD 62862-3-6 © IEC 2022

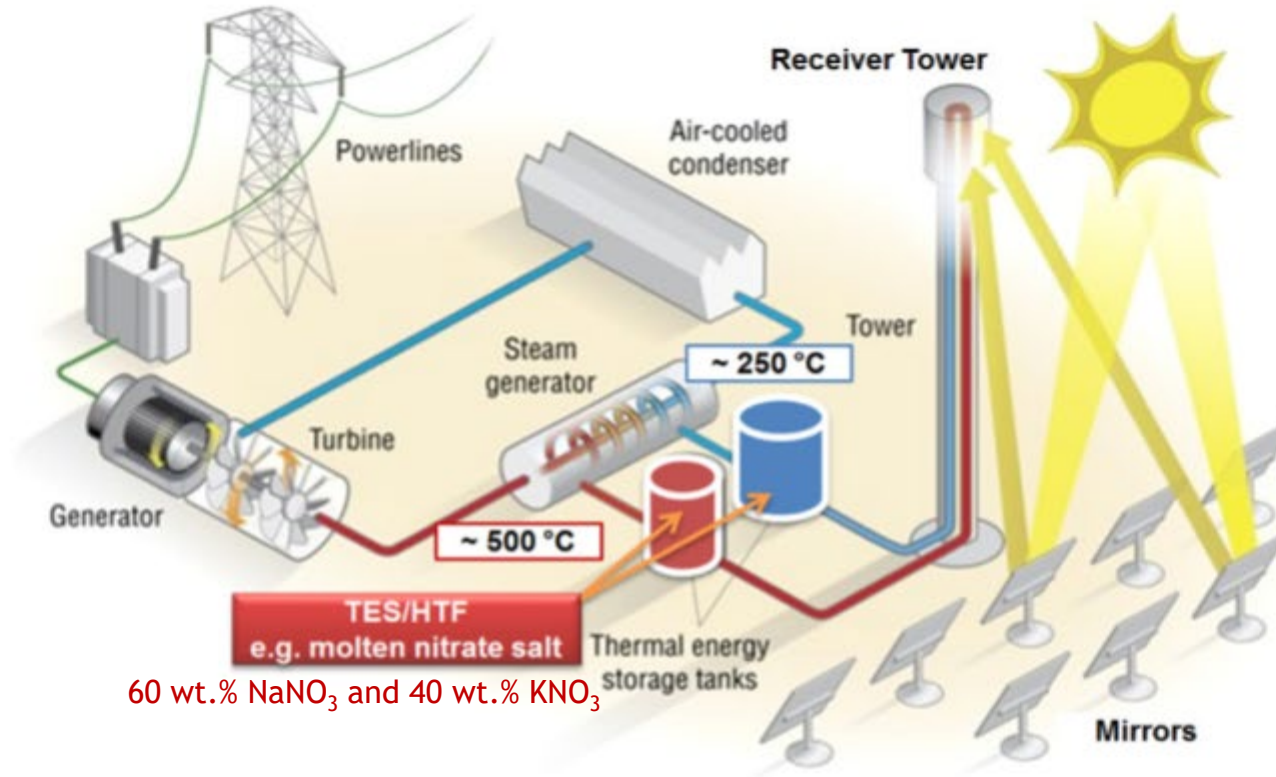


5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)

W. Ding et al.

Solar Energy Materials and Solar Cells 193 (2019) 298–313

The CSP approach has gained particular interest for large scale applications due to its potential efficiency and relatively low environmental impact, as well as the possibility of including thermal energy storage systems



What materials to choose both in terms of functionality but also in terms of durability

Fig. 1. Concentrated solar power plants with molten salts as TES and HTF materials.
(source: US Department of Energy Report: The Year of Concentrating Solar Power, DOE/EE-1101, May 2014).

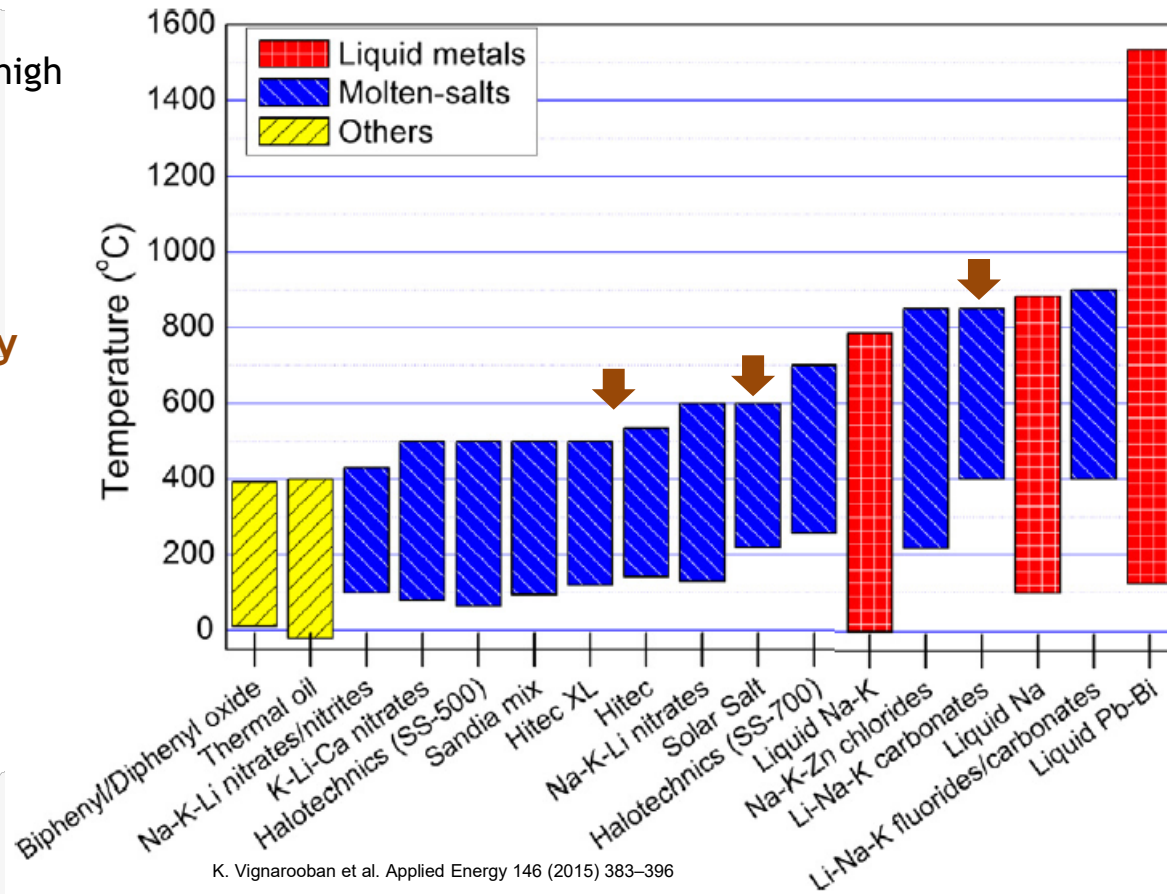
5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)



High operating temperature is necessary to improve efficiency in the CSP system and molten-salts have been revealed the most promising HTF candidates at high temperatures.

- Low melting point
- High specific heat
- High thermal conductivity
- High boiling point
- Low pressure value
- Low viscosity
- Low reactivity
- Low cost
- Economic availability
- Low corrosivity

OPERATING TEMPERATURE RANGE FOR VARIOUS HTFs



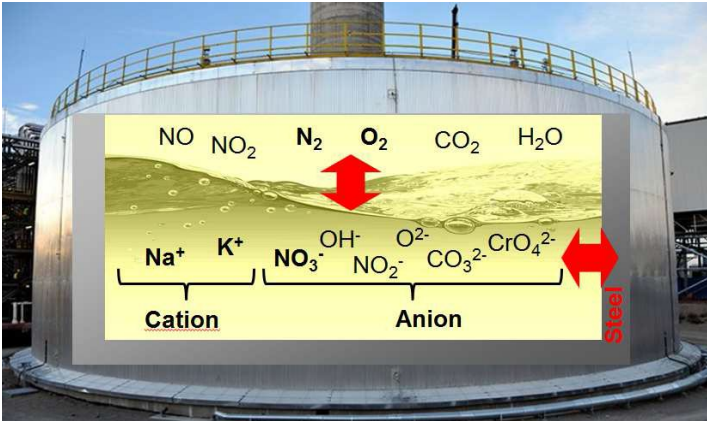
K. Vignarooban et al. Applied Energy 146 (2015) 383-396

Corrosion issues are more significant in CSP plants operated with molten-salts compared to other HTFs, mainly because of the high operating temperatures.

For reliable long-term application and in particular high temperatures (e.g. $\geq 500^{\circ}\text{C}$) there is still a lack of knowledge about corrosion mechanisms and results and methodologies are inconsistent about steel corrosion rates in molten salts

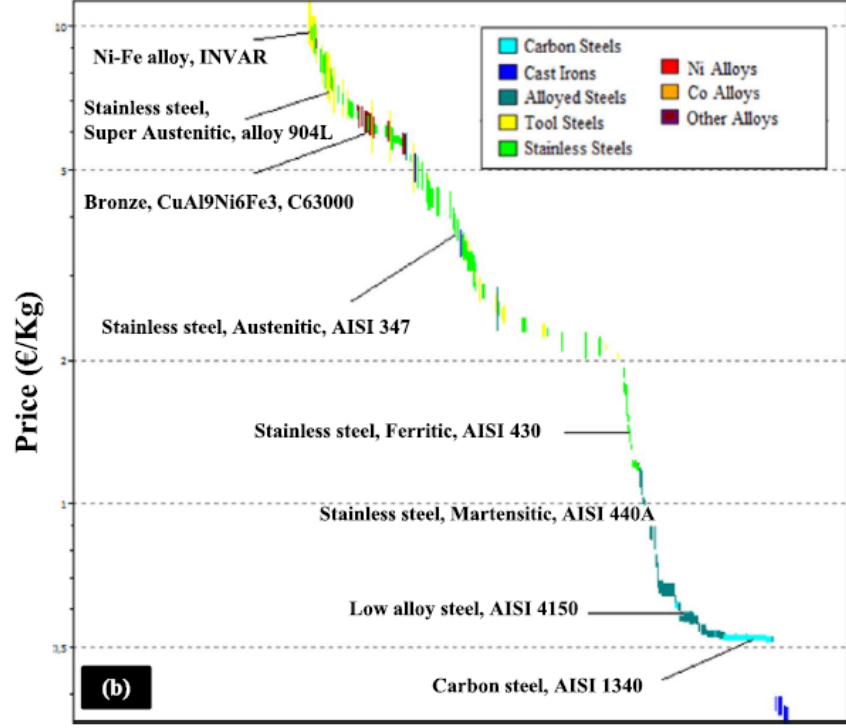
5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)

Alloy type	Advantage	Disadvantage
Carbon and low alloy steel	<ul style="list-style-type: none"> - Sufficient mechanical properties - May be tolerant to low concentration of chloride impurities - Low relative cost 	<ul style="list-style-type: none"> - May require protective nitrogen atmosphere during exposure to molten salt to control corrosion rate - Corrosion rate increases when operating temperatures increases - May be intolerant to chloride impurities
Stainless steel	<ul style="list-style-type: none"> - Good mechanical properties tend to be maintained at the higher temperatures - Better corrosion performance than carbon steel - Little effect of chloride impurities on corrosion rate - Low cost relative to Ni-base alloys 	<ul style="list-style-type: none"> - Corrosion rate increases with operating temperature - Risk of localized corrosion
Ni base alloys	<ul style="list-style-type: none"> - Resistance to localized corrosion and SCC superior to SS 	<ul style="list-style-type: none"> - Similar corrosion rate to SS - High relative cost



Stability of metallic materials in contact with HTF is a crucial parameter for the longevity of CSP systems.

what steel and what is their lifetime



F.J. Ruiz-Cabañas et al. Solar Energy Materials & Solar Cells 163 (2017) 134-147



5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)

Renewable and Sustainable Energy Reviews 86 (2018) 22–44



Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Carbon and low alloy steels
Stainless steels
Nickel alloys

Materials corrosion for thermal energy storage systems in concentrated solar power plants

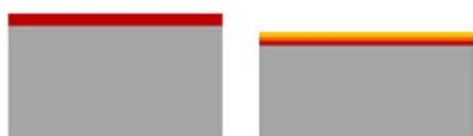
Magdalena Walczak^{a,b,*}, Fabiola Pineda^{a,c}, Ángel G. Fernández^d, Carlos Mata-Torres^b, Rodrigo A. Escobar^{a,b}



General corrosion



Hot corrosion



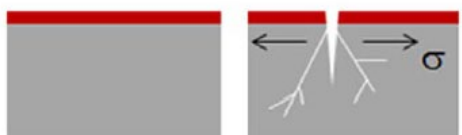
Localized corrosion (pitting)



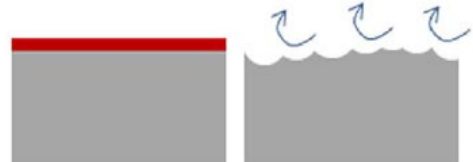
Localized corrosion (crevice)



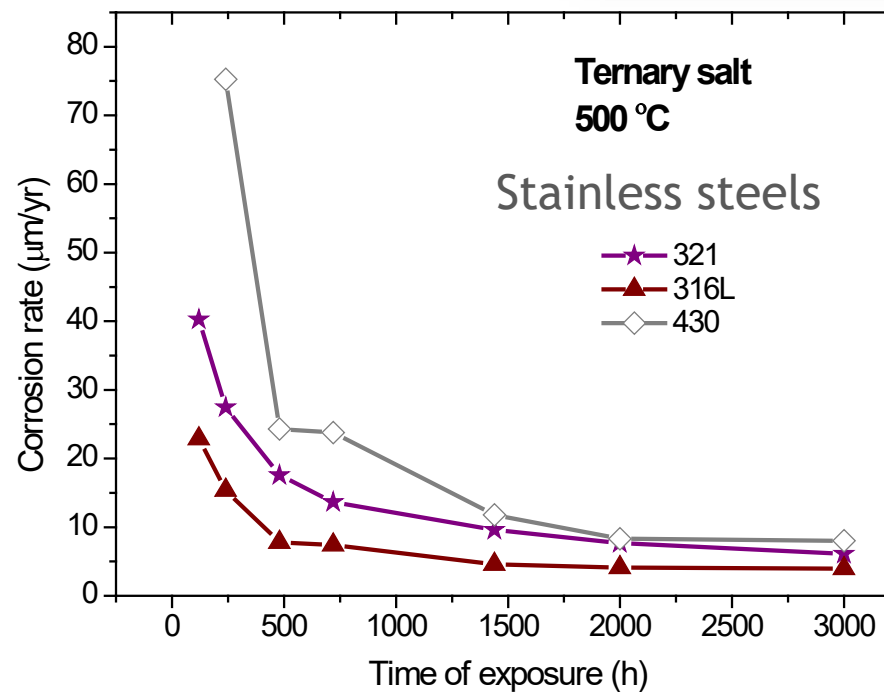
Stress corrosion cracking



Flow accelerated corrosion



Summary of corrosion mechanisms identified in metallic alloys exposed to molten salts

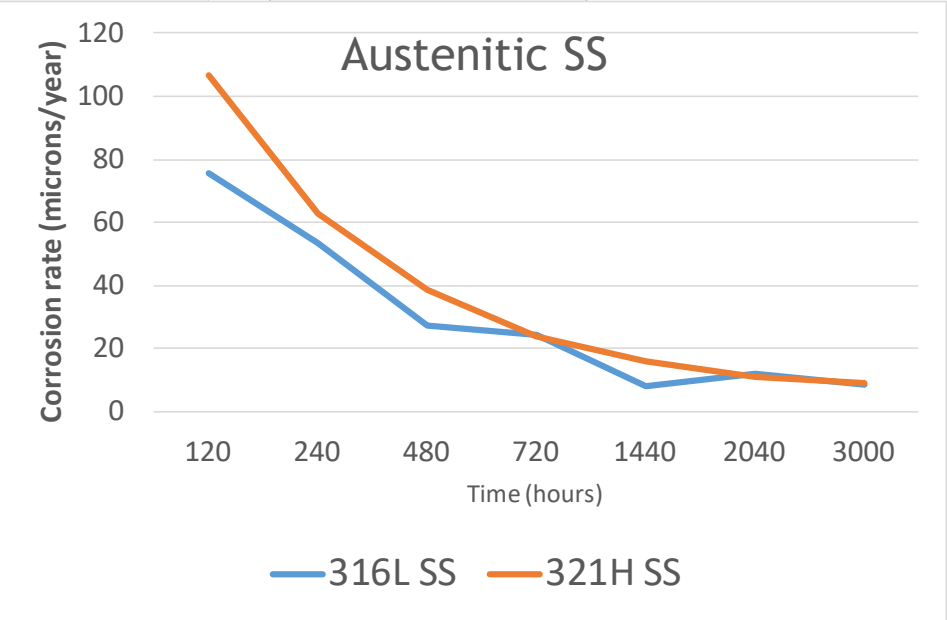


5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)



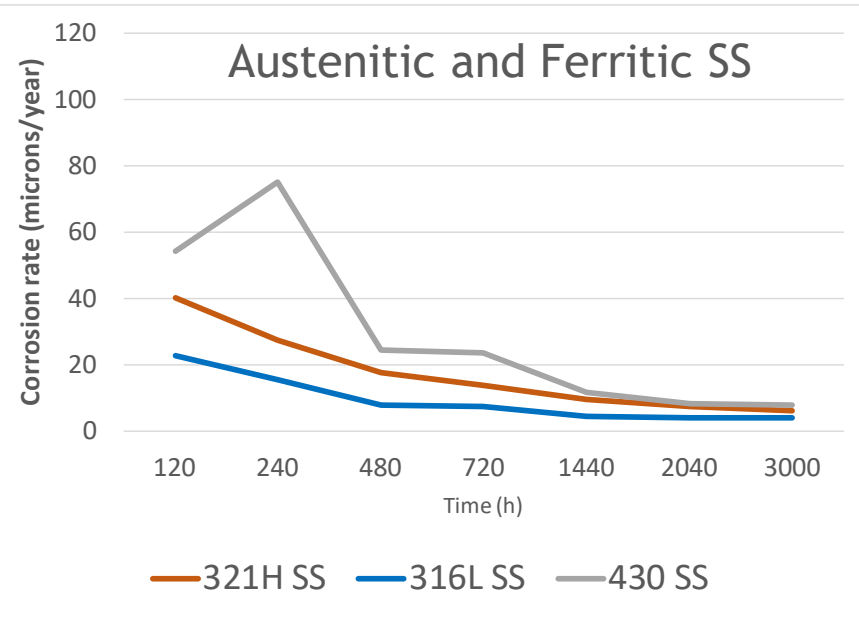
Corrosion rate in contact with Solar Salt (550°C)

40% NaNO₃, 60% KNO₃



Corrosion rate in contact with Ternary Nitrate Salt (500°C)

15% NaNO₃, 43% KNO₃ and 42% Ca(NO₃)₂



These salts are compatible with austenitic stainless steel with corrosion rate between 4-10µm/year.

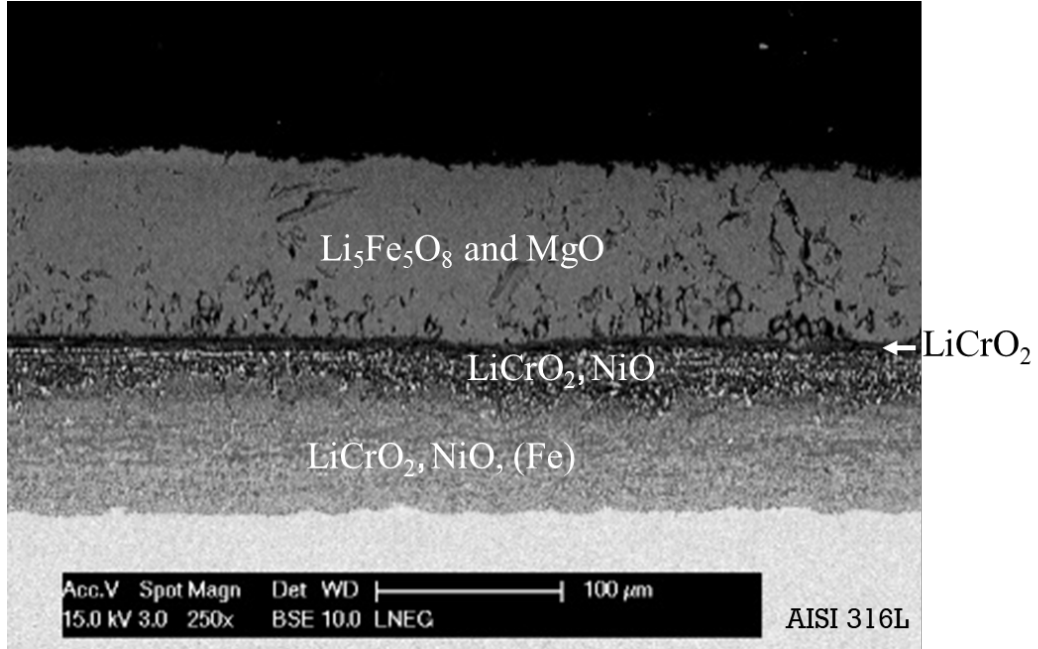
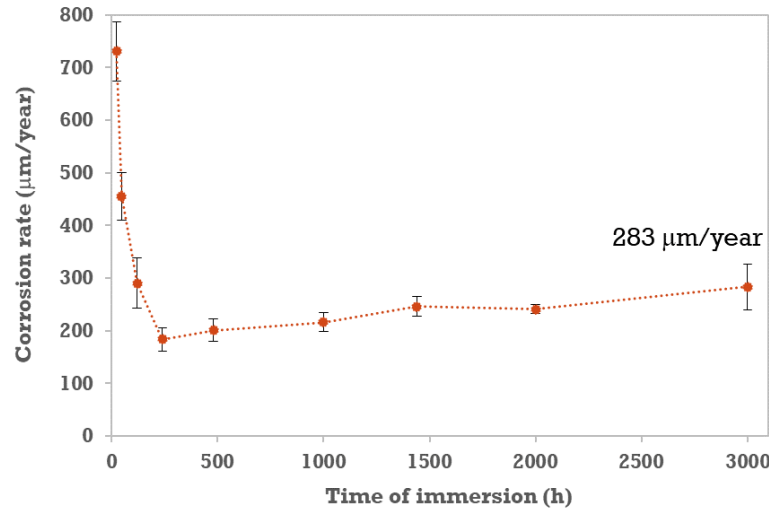
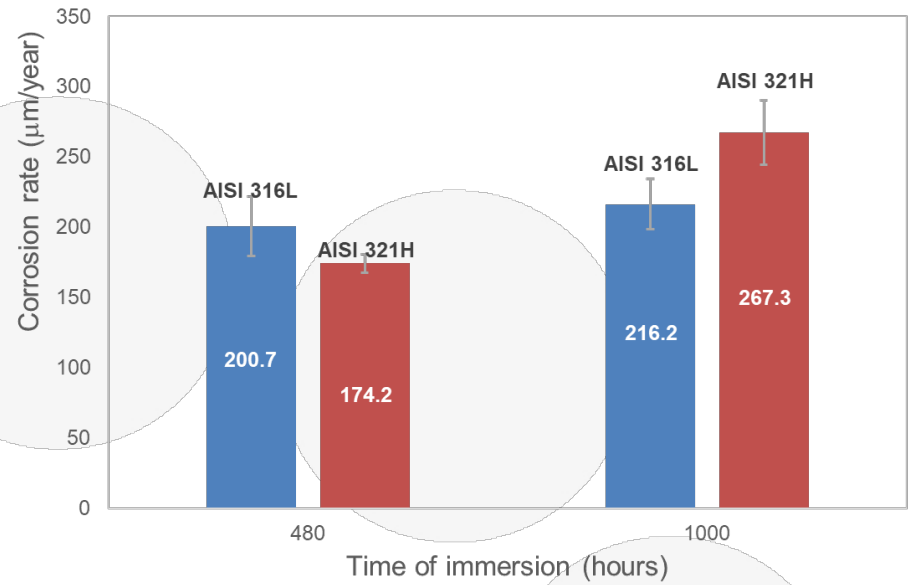
A lower corrosion rate in ternary nitrate salts were obtained relatively to solar salt

Solar Energy 177 (2019) 408-419
<https://doi.org/10.1016/j.solener.2018.11.019>



5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)

Corrosion of stainless steels in contact with LiNaK carbonates (eutectic mixture)(650°C)



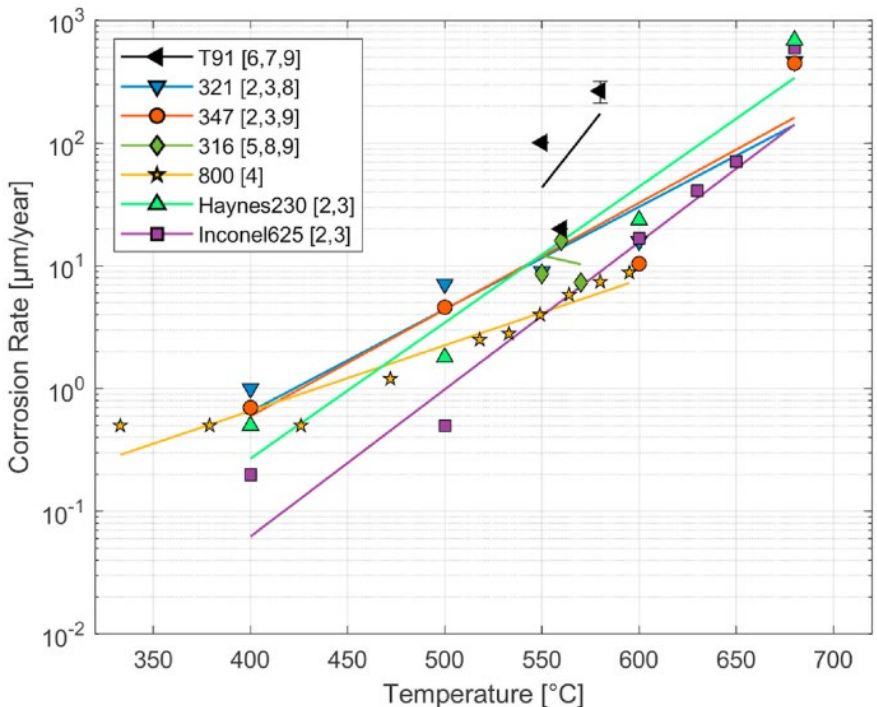
<https://doi.org/10.34637/2zg1-ht96>



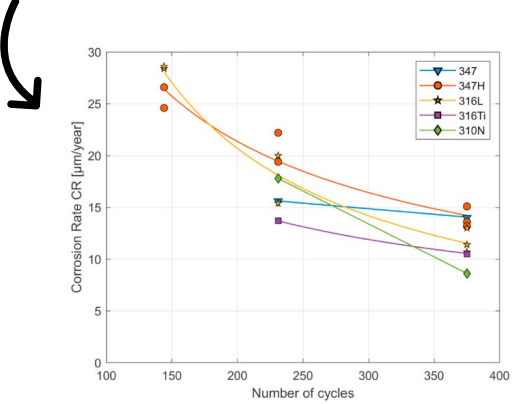
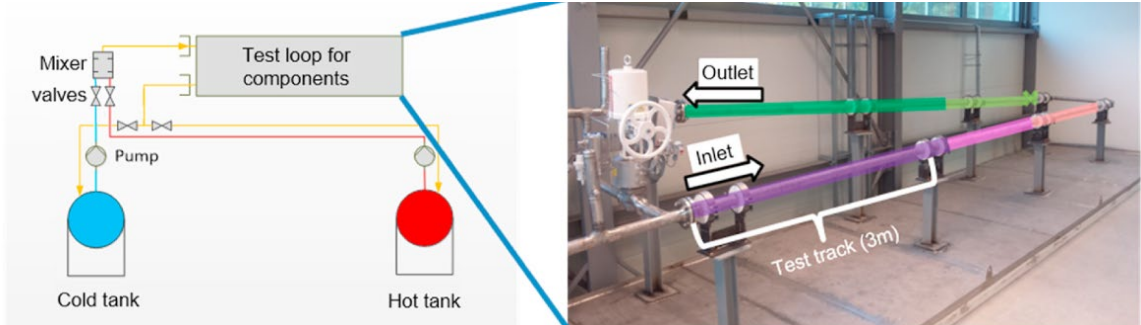
5. CONCENTRATED SOLAR POWER (CSP) : THERMAL ENERGY STORAGE (TES)

Dynamic conditions

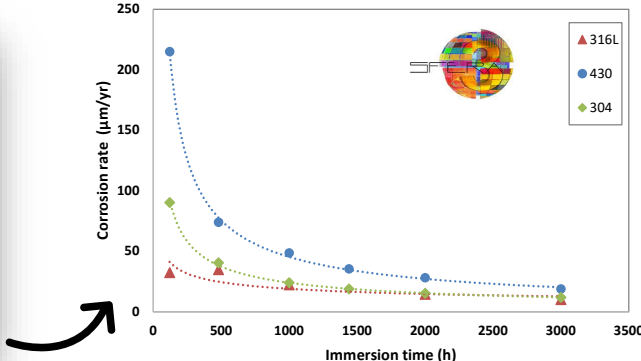
Static conditions



<https://doi.org/10.1016/j.solmat.2021.111331>



<https://doi.org/10.1016/j.solmat.2021.111331>



NEW MATERIALS APPROACHES FOR CONCENTRATING SOLAR POWER (CSP): MOLTEN SALTS AND CORROSION PROTECTION (2023-2026)



1. New LiNaK carbonate molten salts mixtures (doped with micro/nanoparticles) with enhanced thermophysical properties, compatibility with metallic materials and low corrosivity.
2. New coatings to increase the anticorrosive protection of structural materials.
3. Clarify the influence of cyclic thermal condition, dynamic conditions and atmosphere in the corrosion behaviour and corrosion rate of stainless-steel materials.
4. Understand the impact of these new materials (new molten salt mixtures and coatings) on the energetic and economic performance of a solar tower power plant.



Some publications/communications

Solar Energy 177 (2019) 406–419

Contents lists available at ScienceDirect

Solar Energy

journal homepage: www.elsevier.com/locate/solener

High-temperature corrosion performance of austenitic stainless steels type AISI 316L and AISI 321H, in molten Solar Salt

A. Gomes^{a,*}, M. Navas^b, N. Uranga^c, T. Paiva^d, I. Figueira^e, T.C. Diamantino^f

^a Laboratório Nacional de Energia e Geologia, I.P. (LNEG), Estrada do Paço do Lumiar, 22, 1649-018 Lisboa, Portugal

^b Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), Avenida Complutense 40, Madrid 28040, Spain

^c ICAE TECNOLÓGICO Research Center, 28002 Alcorcón, Spain

XVII Congreso Ibérico y XIII Congreso Iberoamericano de Energía Solar

ESTUDIO DE LA RESISTENCIA FRENTE A LA CORROSIÓN POR MITRATORIOS FUNDIDOS DE RECUBRIMIENTOS BASADOS EN ALUMINOS EN CONDICIONES DINÁMICAS

Rodríguez S.C., Audigier P., Agüero A., Pedrosa F., Paiva T., Diamantino T.C.**

XVII Congreso Ibérico y XIII Congreso Iberoamericano de Energía Solar

CORROSIÓN DE ACOS INOXIDABLES AUSTENÍTICOS EN SAIS FUNDIDOS TERNARIOS DE

Diamantino T.C., Gomes A., Paiva T., Figueira I., Pedrosa F., Nogueira C., Gouveia L., Calheiros Pereira M.**

* Laboratorio Nacional de Energia e Geologia (LNEG), Estrada do Paço do Lumiar, 22, Ed.F. 1649-018 Lisboa

Solar Energy Materials & Solar Cells 232 (2021) 111331

Contents lists available at ScienceDirect

Solar Energy Materials and Solar Cells

journal homepage: www.elsevier.com/locate/solmat

Dynamic corrosion testing of metals in solar salt for concentrated solar power

Florian Sutter^a, Ceyhan Oskay^b, Mathias Christian Galetz^b, Teresa Diamantino^c, Fátima Pedrosa^d, Isabel Figueira^e, Stefan Glumac^f, Alexander Bonk^g, Alina Agüero^h, Sergio Rodríguezⁱ, Tomás Jesús Reche-Navarro^j, Simon Caron^k

XVII Congreso Ibérico y XIII Congreso Iberoamericano de Energía Solar

ESTABILIDADE DE UMA MISTURA DE SAIS FUNDIDOS CONTENDO LÍTIO PARA O ARMAZENAMENTO DE ENERGIA SOLAR TÉRMICA

Pedrosa F., Nogueira C., Marcelo L., Diamantino T.C., Figueira I., Bonk A., Baser T.**

* Laboratório Nacional de Energia e Geologia (LNEG), Estrada do Paço do Lumiar, 1649-018 Lisboa, Portugal

** Institute of Engineering Thermodynamics, German Aerospace Center (DLR), Cologne, Germany

<https://doi.org/10.1016/j.cies.2020.1.5095>

RESUMIO

Para o desenvolvimento das tecnologias de concentração solar térmica têm sido desenvolvidas misturas de sais, compostas principalmente por metais alcalinos alcalino-terrosos, a serem utilizadas como meio de armazenamento de energia. A introdução de átomos de lítio na mistura de sais de Na e K, permite a diminuição do ponto de fusão

Corrosion Science 209 (2022) 110786

Contents lists available at ScienceDirect

Corrosion Science

journal homepage: www.elsevier.com/locate/corsci

Comparison of descaling methods to study the corrosion kinetics of ferritic steels after dynamic exposure to molten carbonates

Pauline Audigier^a, Sergio Rodríguez^b, Alina Agüero^c, Fátima Pedrosa^d, Teresa Paiva^e, Teresa C. Diamantino^f

COAT4SOL COC

Hot Corrosion Behavior of Slurry Sprayed Aluminide Coatings in a Simulated Dynamic Molten Carbonate Environment

Pauline Audigier^a, Sergio Rodríguez^b, Alina Agüero^c, Fátima Pedrosa^d, Teresa Paiva^e, Teresa C. Diamantino^f

^a INTA, Madrid, Spain

^b LNEG, Lisbon, Portugal

Eurocorr 2022, 28th August, 1st Sept., Berlin/Germany



6. THE IMPORTANCE OF CORROSION: FINAL CONSIDERATIONS

- Durability issues and corrosion behaviour of key materials in the different technologies have to be known before commercial application;
 - Selection of materials should be criteria considering the environment and operating conditions;
 - When selecting materials, it is important to consider their technical performance and their durability and corrosion behaviour to avoid failures and high operating/maintenance costs;
 - Corrosion should be extensively studied and monitored to enable prevention/protection;
 - Importance of pre-normative research, namely the development of new test methods;
 - Relevance to test materials in real environments and in laboratory tests and the correlation between them.
-
- The energy transition requires reliable, functional and low-cost technologies, components and materials;
 - The success of the energy transition is heavily dependent on the materials, their application, functioning, reliability and corrosion protection/durability.

THANK YOU



Teresa Diamantino
teresa.diamantino@lneg.pt

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- Project INIESC - Research Infrastructure on Solar Energy Concentration (Ref. LISBOA-01-0145-FEDER-022113) supported by National Funds through FCT/MCTES (PIDDAC) and co-financed by European Regional Development Fund of Lisbon Regional Operational Programme.
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