The EU Project MATChING: Materials & technologies for performance improvement of cooling systems in power plants

11th PICWS Meeting

Chatou, 28-29 January 2016

MATChING

MATERIALS & TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT OF COOLING SYSTEMS IN POWER PLANTS

Enel

ENERGIA ALLA TUA VITA

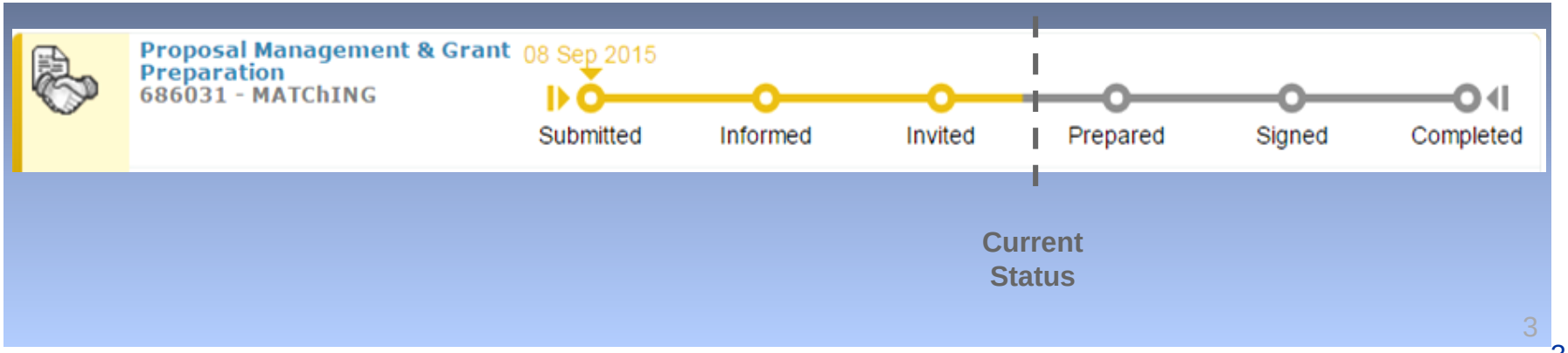
Content

Introduction

MATChING is the acronym of a project titled: *"Materials & technologies for performance improvement of cooling systems in power plants"* which has been submitted for the **call NMP-15 of H2020 EU funding** program.

CALL NMP 15 – 2015 is on "***Materials innovations for the optimisation of cooling in power plants***"
The CALL is within Section 5 of HORIZON 2020 – WORK PROGRAMME 2014-2015 : ***Leadership in enabling and industrial technologies. Nanotechnologies, Advanced Material, Biotechnology and Advanced Manufacturing and Processing***

MATChING has been selected for funding and it is now in the phase of ***Grant Agreement Preparation***



3

Background

Background

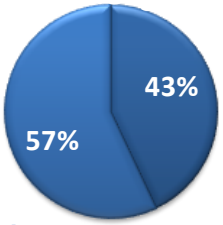
European Commission's Resource Efficient Europe Roadmap 2050, indicates that by 2020 "**Water abstraction should stay below 20% of available renewable water resources**"(1).

Power generation is a sector requiring great amounts of water: cooling water for energy production accounts in fact, for 43-45% of total water abstraction in European Union second behind agriculture (2,4).

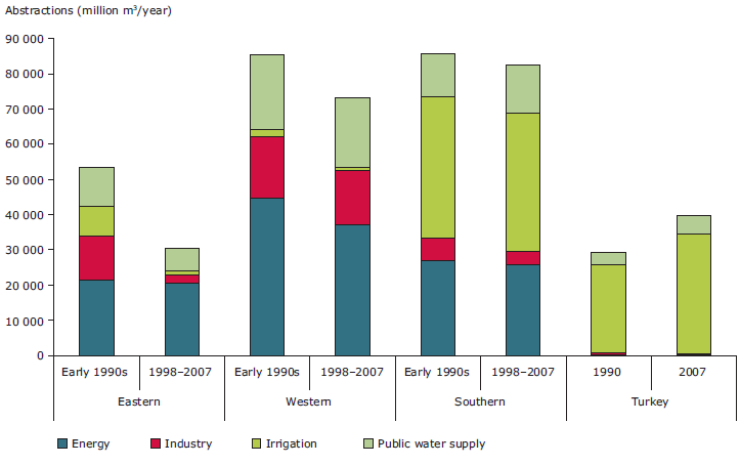
There is currently a gap between water demand and water availability. Following the business as usual approach this gap is expected to increase in the upcoming years (3): to meet EU requirements, **Additional innovation actions are needed.**

MATChING aims to **reduce the water demand and improve energy efficiency for cooling systems in the energy sector** through the use of **advanced and nano-technology based materials and innovative configurations**

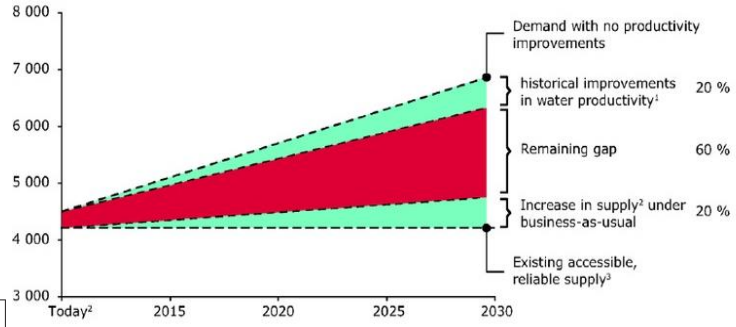
Average EU Water withdrawal 4)



EU Water abstraction per sector – EEA 90's vs 2007



World water demand and supply gap (3)



(1)Roadmap to a Resource Efficient Europe, EC COM (2011) 571 Final (2) The European Environment State and outlook (2010) EEA (3) Charting Out Water Future, 2030 Water Resource Group (2009);(4)Rübbelke and Vögele, 2011

The Objectives of MATChING

Two areas of the energy sector have been taken into account: Geothermal and Fossil fuelled plants

OBJECTIVES

Geothermal Power Plant

- Reduce evaporative losses and plume visibility in geothermal power plants to increment the geo-fluid re-injected fraction;

Thermal Power Plant

- Increase the robustness of cooling equipments to allow the use of non-traditional waters;
  Increase the heat exchange efficiency of condenser and cooling equipments;
- Promote the use of alternative water sources (low quality waters, blow down waters, municipal waters)

TARGET

- Overall reduction of geothermal steam emitted into the atmosphere up to 15% and extension of production wells life up to 10% using hybrid solutions for cooling towers and advanced materials and coatings for dry modules

- Overall plant efficiency increase up to 0.4-0.5%, enhancing the heat transfer efficiency in the condenser both on the steam side and water side via the use of advanced nano-engineered coatings and surfaces..
- Overall reduction of fresh water abstraction in fossil fuelled power plants of about 30% validating a set of solutions (6) for the recovery and treatment of cooling water in CT equipped plants.

The Consortium

Consortium is made of 4 Utilities, 5 Technology Providers, 6 Research institute and 1Service provider.

Partners are from 6 EU Counties: 4 from Italy, 4 from Belgium,3 from Spain,3 from Netherland and 1 from Denmark

MATChING approach and methodology

EVAPORATION

RECOVER EVAPORATION

Water recovery from plume through **membrane condenser** (MC)

REDUCE EVAPORATION

Advanced Hybrid Systems

CONDENSER

ENHANCE HEAT TRANSFER AND EQUIPMENT ROBUSTNESS

Coating to promote drop-wise condensation

Special materials/coatings to handle “dirty” fluids

INTAKE WATER

ALTERNATIVE WATER SOURCES

Novel membrane based technologies for intake water pretreatment

Special materials/coatings to handle “dirty” fluids

Recirculating water

BLOWDOWN WATER

RECOVER BLOWDOWN

Novel membrane based technologies for blowdown recovery

REDUCE BLOWDOWN

Special materials/coatings to handle “dirty” fluids in CT and condenser

Novel membrane based technologies to enhance intake water quality

Novel Circulating water conditioning systems

MATChING approach and methodology

Water saving options for CT systems	Percentage of water saving achievable [%]	Current practice
Intake water pre-treatment	**~14%:** COC increase from 4 to 8 by means of softening process. **~24%:** blowdown elimination (COC of 4) through intake water demineralization.	**Not applied** *Unless too bad quality of intake water.*
Reuse of other available waste water streams, as make up water.	**Up to 100% fresh water reduction** is possible depending on the amount of available waste water sources.	**Not applied** *Unless site specific conditions are met, i.e. a dry region or huge amount of (municipal) waste water available.*
Reduce blowdown through operation at high COC.	**~ 9%** assuming to increase COC from 4 to 6.	**Commonly applied** *Adoption of cooling water treatment programs; implying use of chemicals to avoid scaling and corrosion problems.*
Recovery of blowdown.	**~24%** assuming to completely recover the blowdown water (starting from a COC of 4.)	**Not applied** unless site specific conditions (dry climates and/or restrictions on waste water discharge).
Reduce the evaporation.	**~15%** assuming to reduce the evaporative losses of 15% (without changing COC) through the installation of dry modules.	**Sometimes adopted:** this option reduce also considerably the plume visibility.
Recover the evaporated water.	**~ 60% - 65%** assuming to recover the 80% of evaporated water.	**Not applied** Dry cooling is adopted alternatively

MATChING approach and methodology

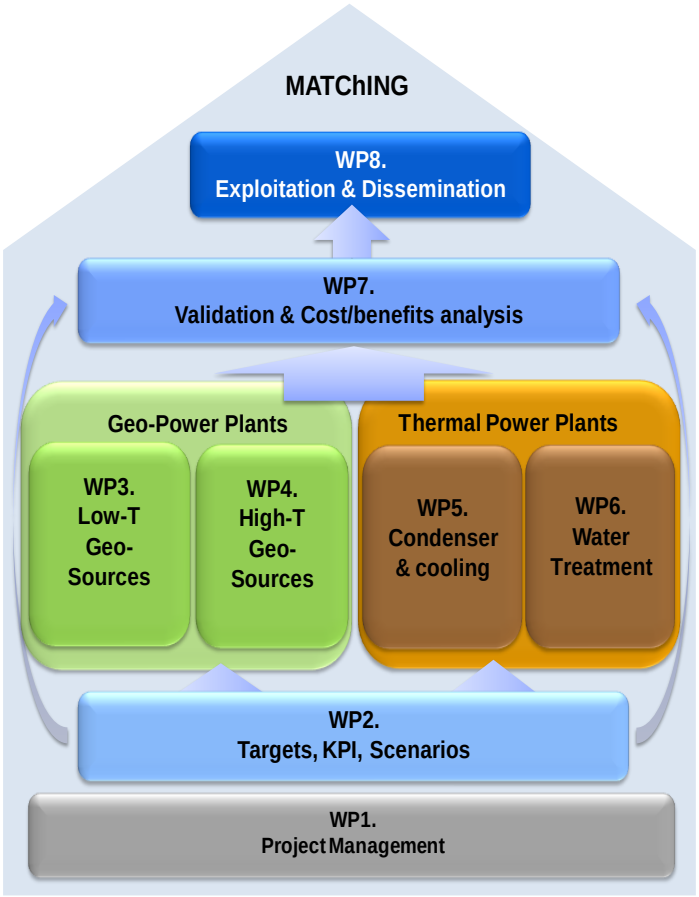
Geothermal Power Plant

Low-T geothermal Source

- Development and testing (BALMATT IN MOL- Belgium) of **coatings for geothermal pipes** with:
  - Anti-scaling properties;
  - Anti-corrosion properties:
- Conceptual design of a **hybryd cooling system coupling a ORC binary cycle with ground water cooling (GWC)** and Air Cooled Condensers (ACC)

High –T geothermal Source

- **New Filling media for Wet Cooling Towers** (advanced geometries for PVC film filling and 3D splash plastic fillings) to be tested in Nuova Radicondoli (ITALY) geothermal site
- **Coatings for dry section modules of hybrid geothermal cooling Towers** to be tested in Nuova Radicondoli (ITALY)



Thermal Power Plant

Steam Condenser &Cooling water circuit

- **Coatings and surface texturing** on steam side of condenser tubes **to promote drop-wise condensation.** Up to five technological approaches wil be tested ;
- **Antifouling and fouling release coatings and alloys with biocide properties on cooling water side of condenser** tube bundles to contrast biofouling. Up to six technologies will be developped and tested.

Water treatment and recovery

- Pretreatment of intake water through **membrane capacitive deionization (MCDi);**
- Combination of pressure driven membranes **(MF/UF/NF/RO) and MD to recover and reuse waste water streams** available at power plants (CT blowdown,FGD waste water ecc..);
- **Novel circulating water conditioning systems** to allow higher COC
- **Membrane condenser (MC)** for the recovery of water vapour from CT

MATChING approach and methodology

ENERGIA ALLA TUA VITA

PROJECT LEVEL

First step

Identification of **technical and economical real success indicators (KPI);**

Definition of the scenarios (present and future).

KPI

Second step:

Strong demonstration program with **9 test sites**.

Laboratory scale investigation ,new pilot plants /existing facilities, AND Full SCALE DEMO

DEMONSTRATION

Third Step

Assessment of results coming from second step allowing the **techno economical validation of solutions** applied in selected European power plants in consideration of the present and future scenarios

COST BENEFIT AN.

TECHNOLOGY LEVEL

First step

Pre-testing activities in Laboratory. Aim is to do a first screening of candidate materials/coatings or even membrane and pretreatment process to select most promising ones for further demonstration

LAB.

Second step:

Characterization and test of the technologies selected in in the first step in pilot scale facilities mimicking full scale operating conditions.

Selection of the two/three most promising options

PILOT

Third Step

Real Environment test in Power Plant and long run test (i.e.through by-pass of existing components, or even by replacement of full scale modules)

REAL ENVIRONMENT

Demonstration Program - Overview

Cooling tower pilot (Merades facility)
Demo Site: Knippergroen PP (Electrabel)
Demo Size: 4 m3/h water flow rate
Demonstration of cooling water treatments (MCDI, CT treatment, MD, Vortex)

Coating pipings pilot – Geo Application
Demo Site: Balmatt site – Belgium
Demo Size: 1 m3/h geothermal fluid
Demonstration of base materials + nanocoatings

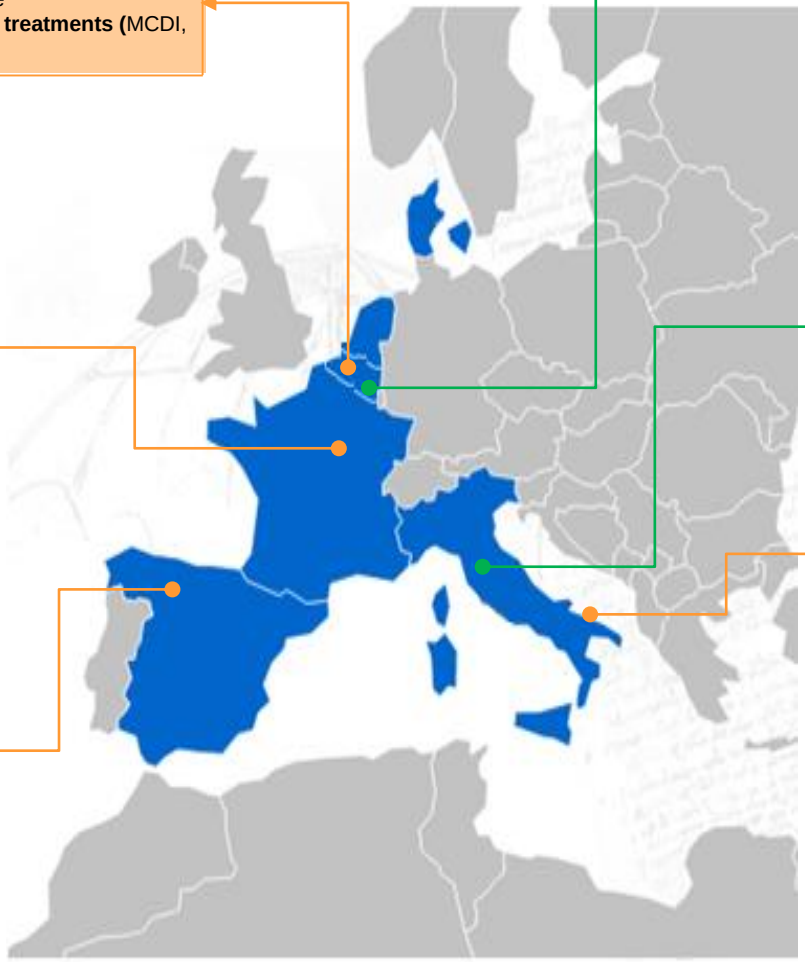
Cooling Tower Pilot (Mistral facility)
Demo Site: EDF Montpellier Power plant
Demo Size: 25 MW thermal
Demonstration of membranes condenser to evaluate water recovery from plume

Hybrid cooling tower
Demo Site: Monterotondo Geothermal Plant
Demo size: 1 full scale cell of hybrid cooling tower (~ 7MW)
Dry section and innovative packing demonstration on geothermal fluid

Condenser circuit pilot (THRyCo/PERICLES facility)
Demo Site: Chatou-EDF Laboratories
Demo Site: 100kg/h steam flow rate
Demonstration of: **Condenser materials and coatings**

Wastewater Membrane Test facility
Demo Site: Brindisi PP
Demo size: 1 m^3/h flow rate
Wastestreams to be treated: FGD WW, CT blowdown

Pilot Condenser and Cooling water treatment (Vortex and MD)
Demo Site: As Pontes – Spain
Demo Size: TBD
Long run test of :
✓**Condenser materials and coatings**
✓**Cooling water treatments (**MD, Vortex)



Conventional Power Plants

Geothermal Power Plants (EGP)

Demonstration Program (1/5)

ENERGIA ALLA TUA VITA

DEMO SITE

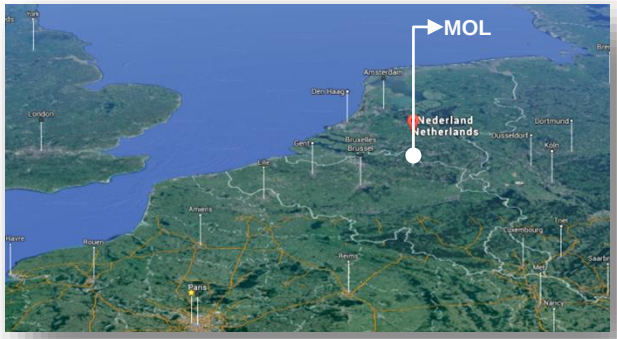
BALMATT -GEOTHERMAL SITE

The first drilling at Balmatt site was done in September 2015.Geothermal fluid will be used to to heat the disctrict area nearby and if steam properties are good enough to produce electricity via an ORC cycle.

MAP

MOL- BELGIUM

The Balmatt site is located in Mol, in the north part of Belgium.



Technology to be tested

- ✓ **Coatings with nanometer-thin surface layers** - obtained through optimization of already commercial coatings or specifically developed within the Project- will be first selected in lab and then tested in real scale.
- ✓ Within MATChING **a bypass will be installed onto the georthermal brine circuit** for the evaluation of different coated materials in contact with the brine (at extraction temperature):
- ✓ Performance of coatings will be demonstrated trhough: periodic examination/in situ measurements of corrosion rates/post exposure lab analysis

Partners

vito

DANISH TECHNOLOGICAL INSTITUTE

aimen CENTRO TECNOLÓGICO

Aquastill

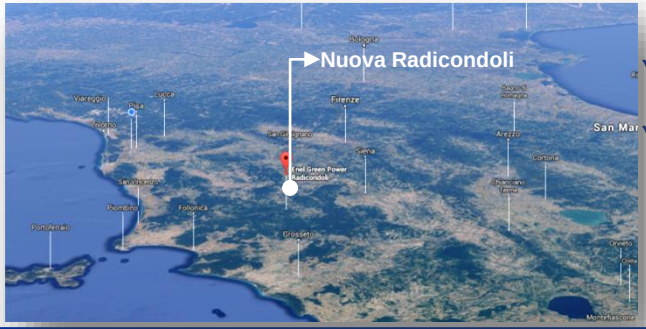
Enel Green Power

NUOVA RADICONDOLI -GEOTHERMAL SITE

The Nuova Radicondoli Gr1 Power Plant was build in 2002 in Radicondoli Geothermal Area in Siena. The plant hs an installed capacity of 40MW with 1 generating unit, and include 6 forced cooling towers

SIENA – ITALY

Nuova Radocondoli is located near SIENA, Tuscany, in the central part of ITALY



Technology to be tested

- ✓ The **Hybrid cooling tower** will be integrated in Nuova Radicondoli Power Plant.
- ✓ It will include an innovative dry section, designed with new materials and coatings
- ✓ An optimized wet section through the use of advanced packing.
- ✓ The Hybrid demo module will enable different operating configurations (traditional Wet and Hybrid operation) with the finail aim to evaluate the robustenss of dry section and the overall system thermal efficiency in the cooling tower in several configurations.

Partners

Enel Green Power

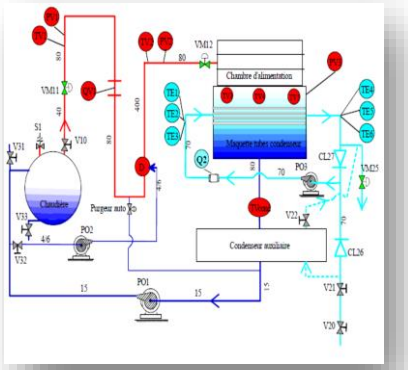
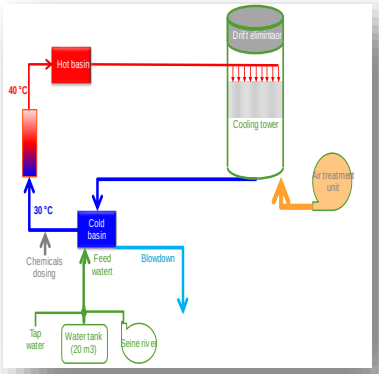
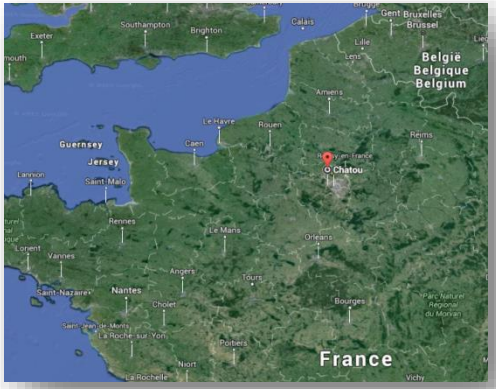
SPIG

Enel

aimen CENTRO TECNOLÓGICO

Demonstration Program (2/5)

ENERGIA ALLA TUA VITA

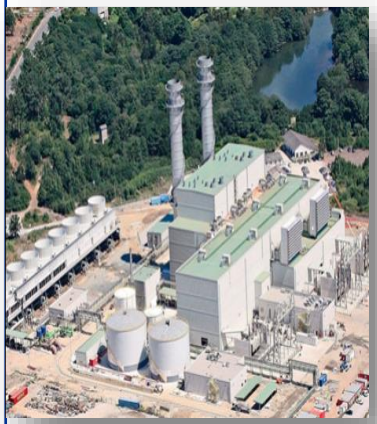
DEMO SITE	MAP	Technology to be tested	Partners
THRyCo – EDF LABORATORIES	**CHATOU- France**	✓ TRHyCo will be used to characterise qualitatively and quantitatively the heat transfer coefficients of steam condenser tube bundles	
 The TRHyCo Facility is used to investigate the thermal performances of the surface steam condensers at low pressure. The Volume of test section can host around 30-40 tubes of 1.5 m length		✓ The tubes will be coated **using lab selected hydrophobic surface** (special coatings, nano structuration,…) and **special surface texturing**, with the final aim to promote drop wise condensation and consequentially increase the overall heat transfer coefficient.	
PERICLES– EDF LABORATORIES	**CHATOU- France**	✓ PERICLES will be used to evaluate **stainless steel with biocide properties** and **antifouling coatings** simulating the internal tube side of condenser with the final aim to explore alternative water sources usages without treatment (re-use) and/or after treatments (re-cycled)..	
 PERICLES is a facility equipped with: 1) Full on-line water quality instrumentation 2) Full-length steam condenser tubes to duplicate flow velocities, heat flux, inlet/outlet cooling water temperatures 3) Pilot cooling towers			

Demonstration Program (3/5)

ENERGIA ALLA TUA VITA

DEMO SITE

AS PONTES – PP-ENDESA



The As Pontes power plant has an installed capacity of 2421 MW and it is composed by 4x350 MW Coal groups and a 2x1 Combined Cycle with 2x258,5 MW gas turbines and a 253 MW steam turbine.

MERADES II Facility

The MERADES Facility, fully automated and remotely controlled, simulates semi-open cooling circuits, made of 2 parallel and independent circuits allowing parallel treatment evaluation. It includes one shelter of a residential caravan size hosting the simulated heat exchangers equipped with a Cleaning System, the analyzers, the sampling devices and the control and data acquisition system.

MAP

AS –PONTES-SPAIN

As Pontes power plant, part of Endesa Generation fleet, is located in the municipality of Puentes de García Rodríguez, Northwest of Spain.

KNIPPERGROEN – BELGIUM

The Knippegroen Gas Power Plant, part of the Electrabel fleet, and located at Arcelor-Mittal, East Flanders - Belgium, has an installed capacity of 350

Technology to be tested

- ✓A **new condenser pilot plant** will be integrated in As Pontes Power Plant to perform long run test on:
- ✓Steam-side nano-coating/laser based structured materials to increase the overall power plant efficiency;
- ✓Water side stainless steel with biocide properties
- ✓Water side antifouling coatings for testing the use of alternative water sources

Three different technologies will be tested:

- ✓Membrane Deionization (MCDI) provided by VITO for CT feed pre-treatment;
- ✓Vortex (VPT) Module provided by PATHEMA for chemical free CT circulation water treatment;
- ✓Distillation (MD) unit provided from VITO for CT blowdown reuse.

Partners

ionics surface technologies
DANISH TECHNOLOGICAL INSTITUTE
EDF
endesa
aimen CENTRO TECNOLÓGICO
MateriaNova MATERIALS R&D CENTRE
INTEGASA INTERCAMBIADORES DE CALOR
Enel
LABORELEC GDF SUEZ
Aquastill
Pathema Innovatief met Water
vito
endesa
DNV·GL

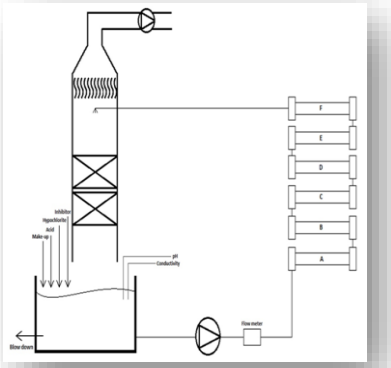
Demonstration Program (4/5)

ENERGIA ALLA TUA VITA

DEMO SITE	MAP	Technology to be tested	Partners

DNV GL TEST RIG

.



The DNV GL Test-Rig has been set up in order to mimic an open recirculating cooling water system and has been built and designed - according to ISO-norm, ISO 16784-2. The test-rig can be brought on site, or tested at DNV GL in Arnhem the Netherlands with site test collected water. The Test-Rig is equipped with the following main sections: 1) Coatings of condensers; 2) 3D filler; 3) Water of site source.

AS –PONTES-SPAIN

As Pontes power plant, part of Endesa Generation fleet, is located in the municipality of Puentes de García Rodríguez, Northwest of Spain.

✓Vortex degasification technology , integrating the Vortex module (VPT) from PATHEMA, for CT circulation water treatment.

✓Membrane Distillation modules, provided from AQUASTILL will be integrated in sidestream to the blowdown of the As Pontes CT to evaluate CT blowdown reuse.

endesa

Enel

DNV·GL

Aquastill

Pathema

vito

LABORELEC

GDF SUEZ

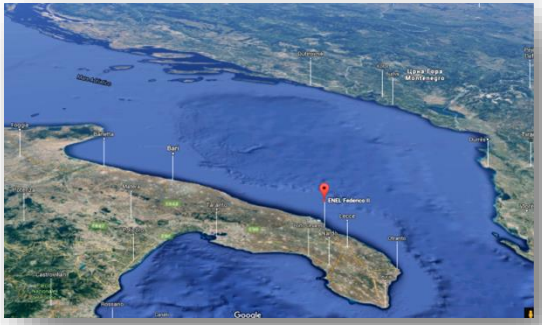
BRINDISI SUD –PP-ENEL

Federico II Power Plant has a nominal capacity of 2640 MWe, and has 4 units running with coal.

The first unit was commissioned in 1991 and the last in 1993. It is operated by ENEL PRODUZIONE SPA.

BRINDISI-ITALY

ENEL Brindisi Sud (Federico II) Coal Power Plant Italy, located at Brindisi, Italy,



A new Membrane Testing facility will be integrated in Brindisi Power Plant:

•It will include pilot units of both MD modules and pressure driven membrane (MF, UF, RO) and will be used to scale and demonstrate the membrane technologies up to a significant industrial size (e.g 10-20 mc/day) for the recovery of water from unconventional water sources like CT blowdown and FGD waste water

Enel

vito

ITM

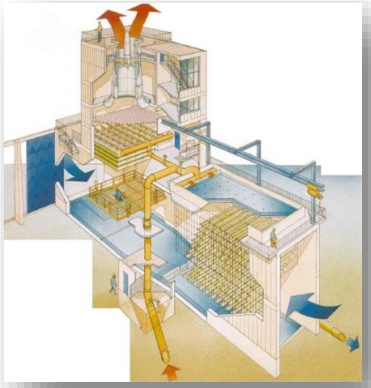
Demonstration Program (5/5)

ENERGIA ALLA TUA VITA

DEMO SITE	MAP	Technology to be tested	Partners

MISTRAL FACILITY EDF NUCLEAR PLANT

.



MISTRAL is a facility equipped with a pilot Cooling Tower including the following components:

1)a comprehensive set of different equipment such as exchanger surfaces (fills, splashing grids, etc.);

2)Water distribution device;

3)drift eliminators.

MISTRAL is fully instrumented with flow meters, temperature probes and differential pressure drop..

Bugey -FRANCE

The Bugey Nuclear Power Station is located in Bugey about 65 km from the Swiss border. It is on the edge of the Rhône River, from where it gets its cooling water, and is about 30 km upstream from Lyon.

- ✓The MISTRAL facility will be used to test membranes condensers (MC) provided by ITM in order to evaluate water recovery from plume.
- ✓The test will allow the evaluation of: 1) the amount water recovery (Liter /day /m2) in winter or summer condition; 2) the quality of collected water; 3) the associated energy consumption.

EDF

ITM

DNV·GL

Focus on materials and coatings for bio-fouling mitigation

ENERGIA ALLA TUA VITA

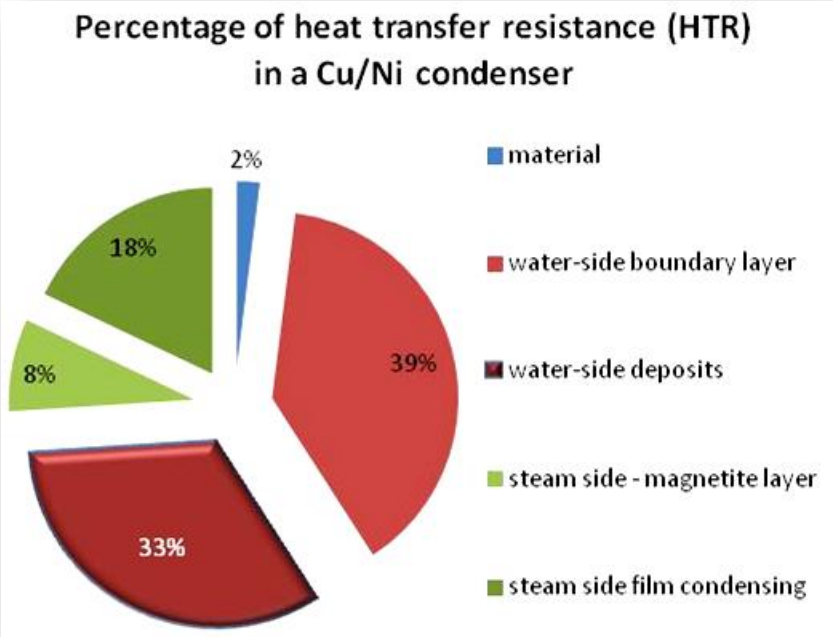
DRIVERS

Heat exchanger fouling is a major economic problem, and maintenance costs are estimated to account for 0.25% of the world GDP.7

Steam side heat transfer improvements are important however **improvements on the cooling water side have the highest potential benefit (33% of the overall heat transfer losses)**

Facility owners face many problems with heat transfer in today's restrictive and regulated discharge environment.

There are significant restrictions on chemical use for once-through cooling water systems which limit common practices of adding chemicals to cooling water systems to control fouling, deposits, and corrosion



Coatings can be an advantageous option to limit water-side fouling in steam condensers and recover MWe however coating durability, stability, thickness and cost effectivness can be and should be further improved

Focus on materials and coatings for bio-fouling mitigation

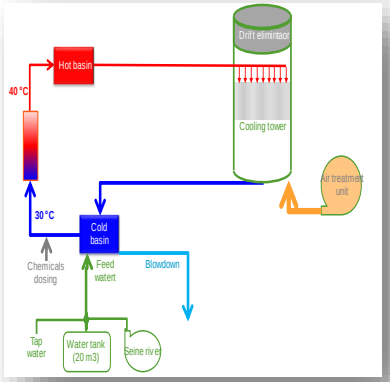
ENERGIA ALLA TUA VITA

SELECTED TECHNOLOGIES >> **LABORATORY** >> **PILOT SCALE** >> **LONG RUN TEST**

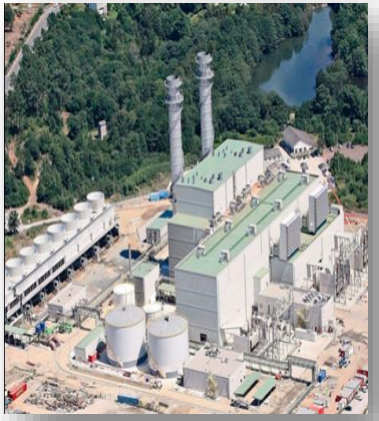
1. **Enzime based** antifouling coatings
2. **Ultra smooth surface** coatings
3. Coatings with **embedded nano-paticles** (like TiO2 ecc..) with antibacterial properies
4. **Optimization of** existing **commercial system** (like those based on silicon rubber or poliethilen glycol) through reduction of their thicknes
5. Surface functionalization of coatings through the **addition of antibatteric peptoids**
6. Tailored **alloys with biocide properties** (introduction of alloying elements to stainless steel)

- Formulation and laboratory scale testing:
- Evaluation of coating parameters (adhesion,hardness,roughness,thickness, surface energy,coating stability);
- Evaluation of weldability and repair methodologies for new SS with biocide alloying materials;
- Quick lab test for fouling adhesion;

- Most promising coatings and SS alloys from lab test wil be tested for three months with two kind of waters in the **EDF PERICLES FACILITY**



- Selected coatings and materials from pilot scale test will be used to coat the internal side of the new condenser tube bundles that will be installed in **Endesa Power Plant in AsPontes.**
- The duration of the test will be around 6 months



Current list of MATChING users' group

No.	Stakeholder	Country / Region	Type
1	EMIRI Energy Materials Industrial Research Initiative.	Europe	Association
2	European membrane House (EMH)	Europe	Association
3	EURELECTRIC	Europe	Association
4	EPRI	USA	Research Institute
5	ESKON	France	Utility
6	Alstom	France	Industry
7	European Water Platform (Wss TP)	Europe	Association
8	VLAKWA - FLAnders Knowledge Center Water	Belgium	Association
9	Plataforma planeta	Spain	Association
10	Plataforma Tecnologica espanola del Agua	Spain	Association
11	ARTES Ingegneria	Italy	Industry
12	FEDERCHIMICA	Italy	Industrial Association
13	Membrane s.r.l.	Europe	Association

Thanks for your attention