Industrial Scale cTES Cold Thermal Energy Storage: Demonstrator in La Africana CSP Power Plant And Evaluation Of Benefits - SOLWARIS Project

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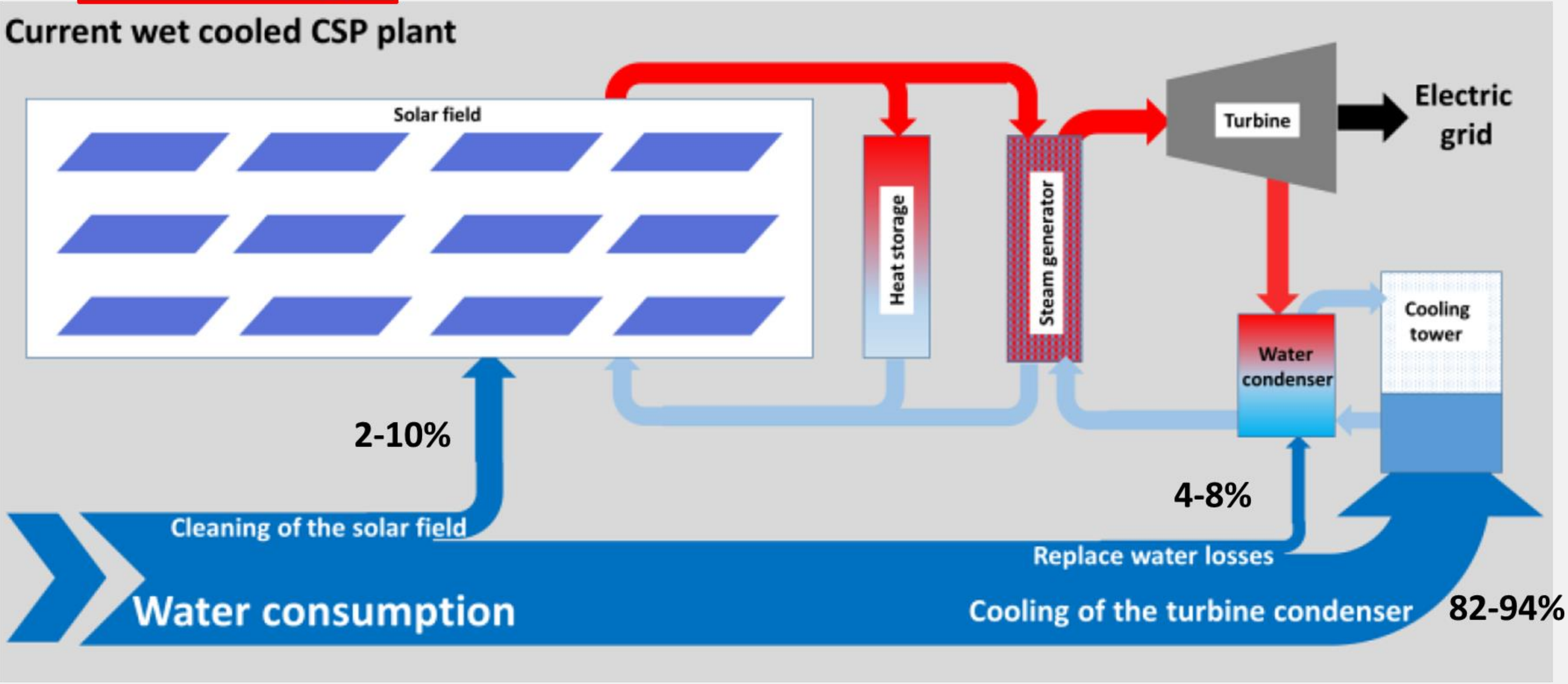
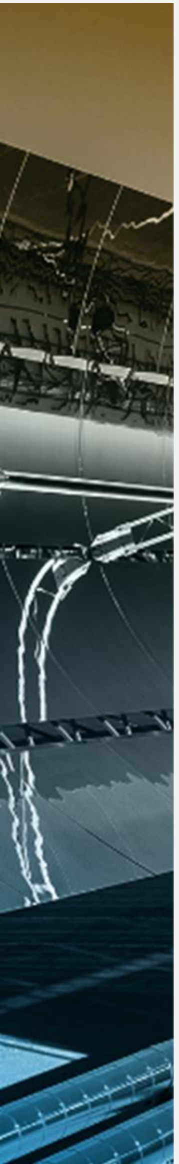
Water consumption in CSP power plant

$3 \rightarrow 6\ m^3/MWh_e$



Water consumption values from Turchi, Water Use in Concentrating Solar Power (CSP), NREL, 2009

Overview of WASCOP and SOLWARIS



WASCOP (2015-2019)

TRL<5

COOLING

- Water/rock thermocline
- Air/rock thermocline
- Hybrid cooling (wet/dry)
- Versatile cooling (dry with spray)

CLEANING

- Dust barrier
- Anti-soiling/self cleaning coating for abosrber
- Anti-soiling/self cleaning coating for reflector
- Soiling characterization devices
- Innovative cleaning systems

Upscale and test in La Africana

SOLWARIS (2018-2022)

TRL→7

COOLING

- Water thermocline 1000 m^3

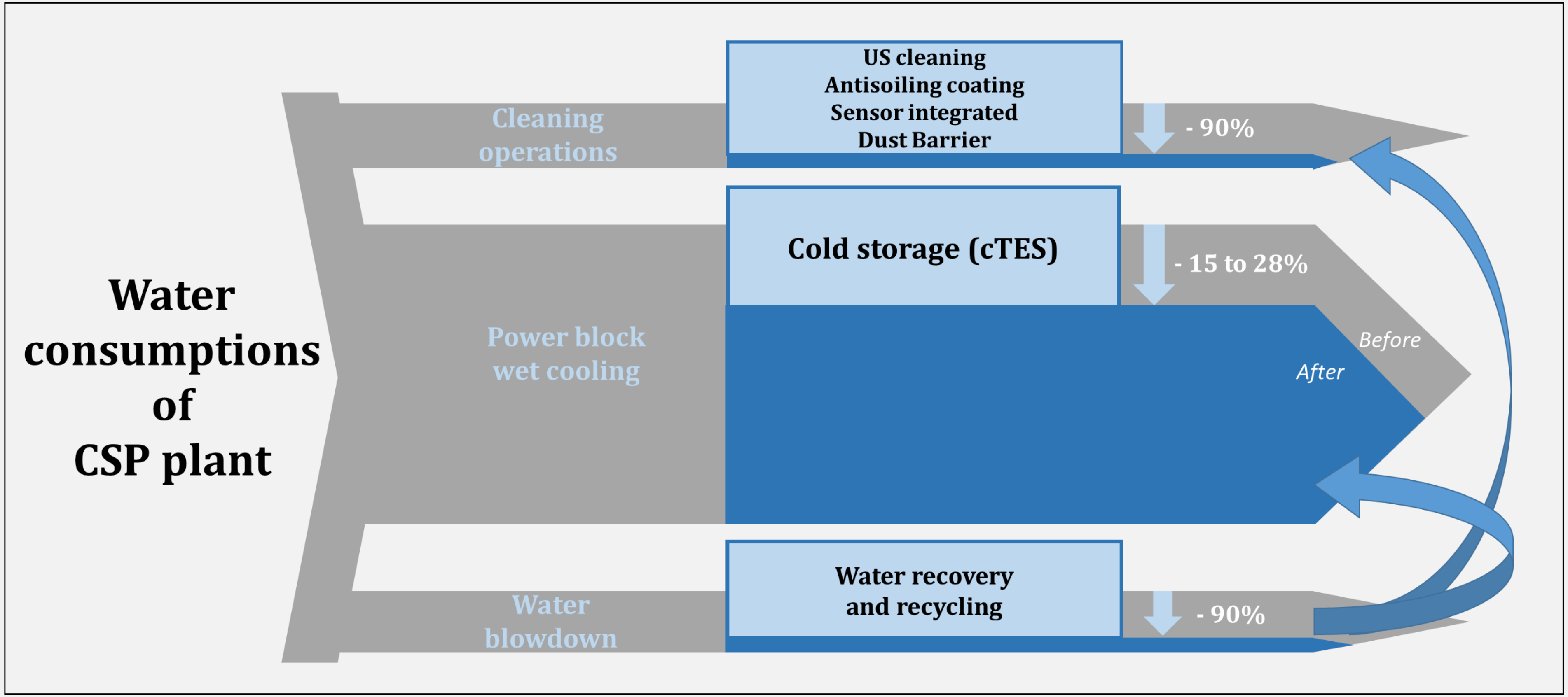
CLEANING

- Dust barrier
- Anti-soiling/self cleaning coating for abosrber
- Anti-soiling/self cleaning coating for reflector
- Ultrasonic cleaner
- Soiling sensor

WATER RECOVERY

SOLWARIS: validation at high TRL of concepts developed in WASCOP

SOLWARIS main objectives

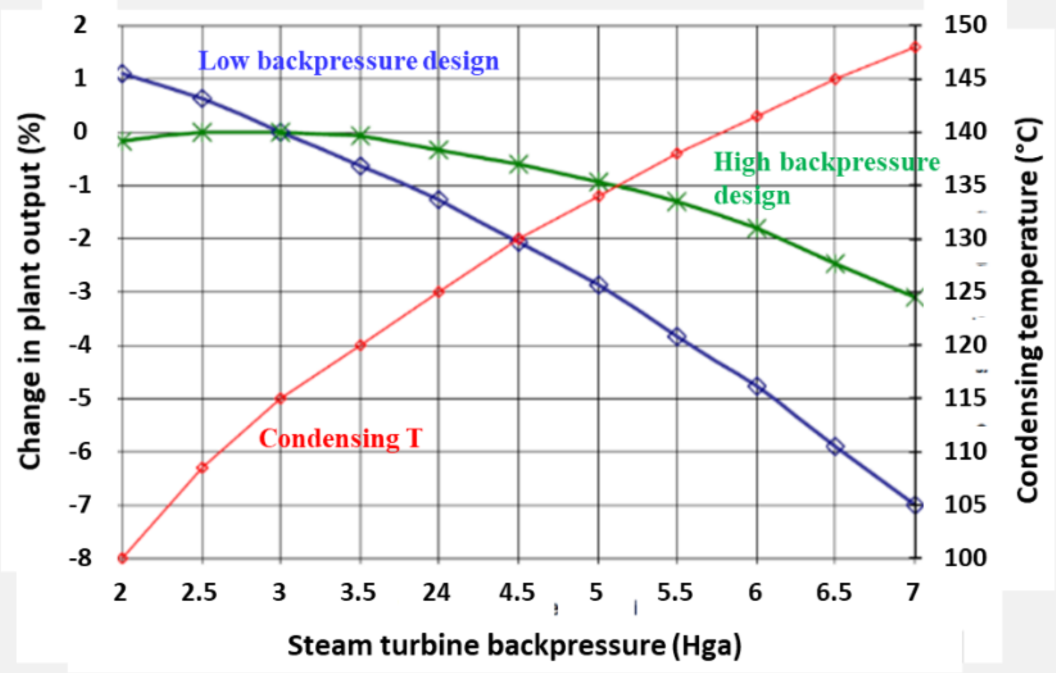


SOLWARIS's objectives for reduction of water consumption:

- 90% for cleaning
- 15% to 28% for condenser cooling
- 90% for recovery and recycling water

- **- 35 % for wet cooling**
- **- 90 % for dry cooling**

Context of condenser cooling



DOE, 2009

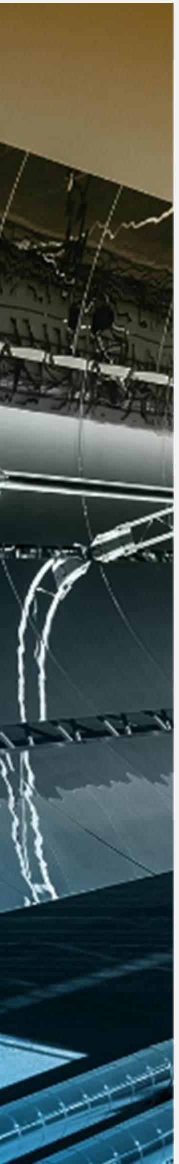
Design parameter	Wet-cooled baseline	Dry-cooled with large ACC
Design point net power output	1	1
Design point steam turbine efficiency	1	-5%
Turbine size (gross output)	1	+2%
Solar field size	1	+8%
Design point parasitic loads	1	+17%
Total installed cost	1	+8%
O&M cost	1	-3%
Annual net energy output	1	+3%
Annual Revenue	1	+3% ?
Levelized Cost of Energy (LCOE)	1	+3% to +10%

Turchi, Water Use in Concentrating Solar Power (CSP), NREL, 2009

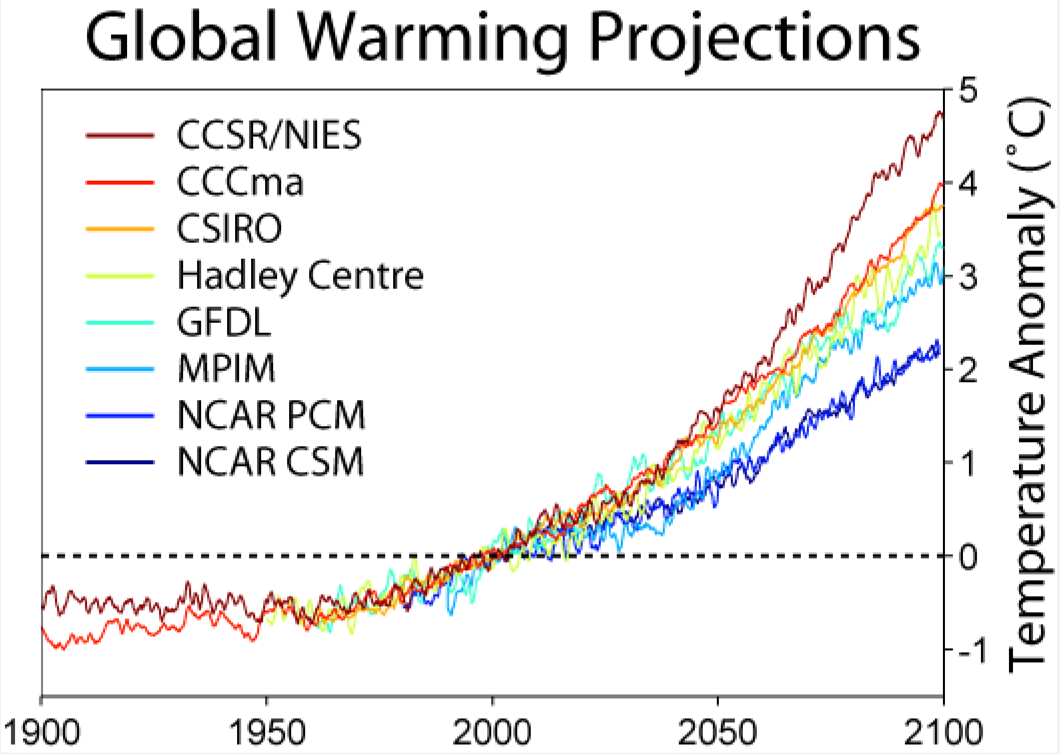
- Wet cooling is the most efficient turbine cooling system
- Dry cooling drops water consumption by 90% at cost to turbine size and efficiency

- Performances of cooling system directly impacts the turbine back pressure and performances

Context of condenser cooling



- All projections lead to global increase of ambient temperature
- Increase of T_{amb} implies increase of turbine backpressure and reduction of turbine efficiency
- For wet cooled turbine, additional water consumption is expected
- For dry cooled turbine, additional reduction of turbine efficiency is expected



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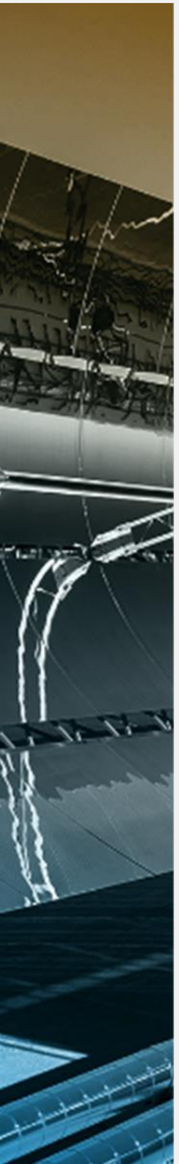
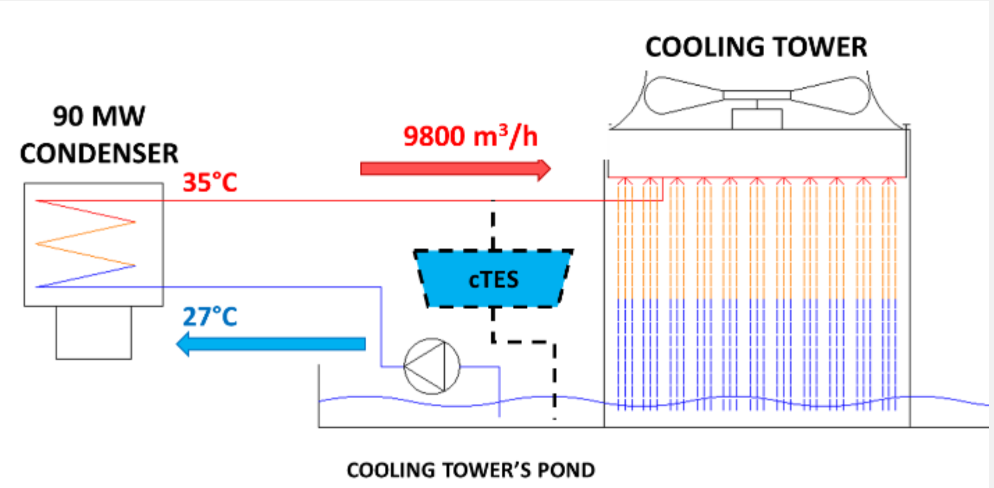
Relevancy of additional cooling system that can
- **reduce the water consumption**
- **increase the turbine efficiency**
- **be installed on existing power plants and cooling systems**

SOLWATT

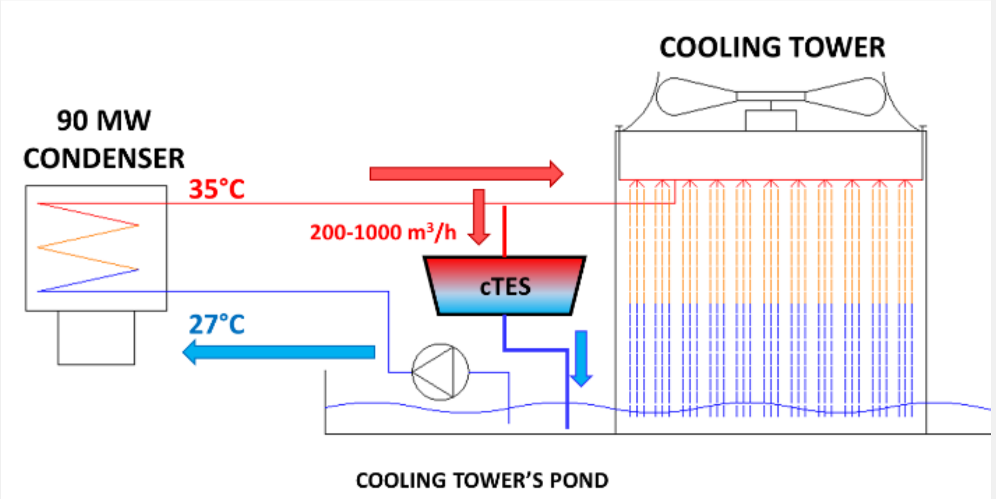
cTES concept



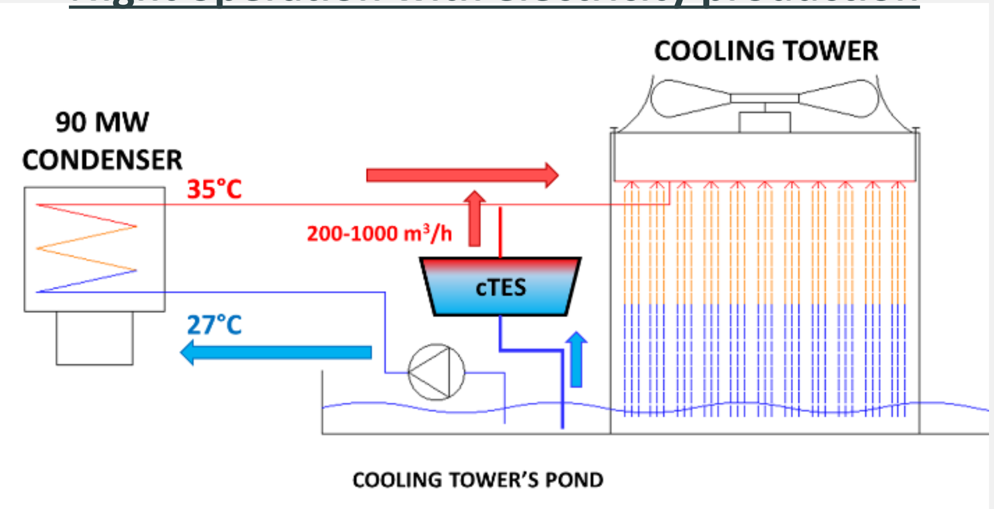
Day operation, moderate T_{amb}



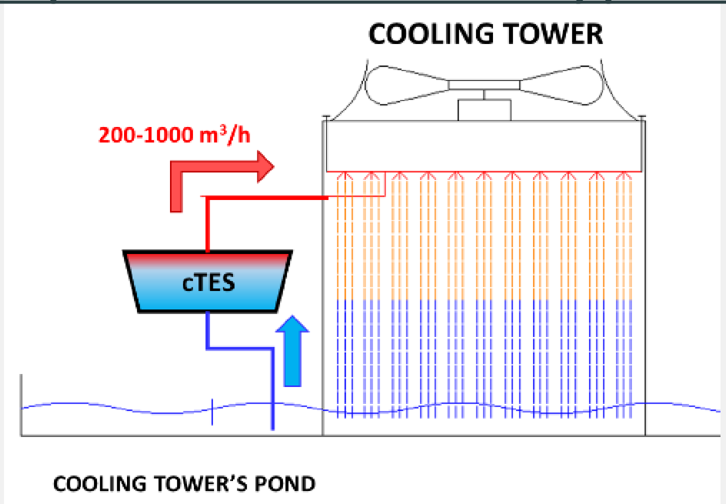
Day operation, high T_{amb}



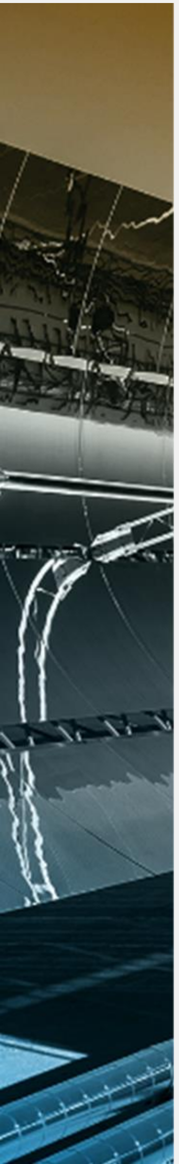
Night operation with electricity production



Night operation without electricity production



cTES: SOLWARIS OBJECTIVES

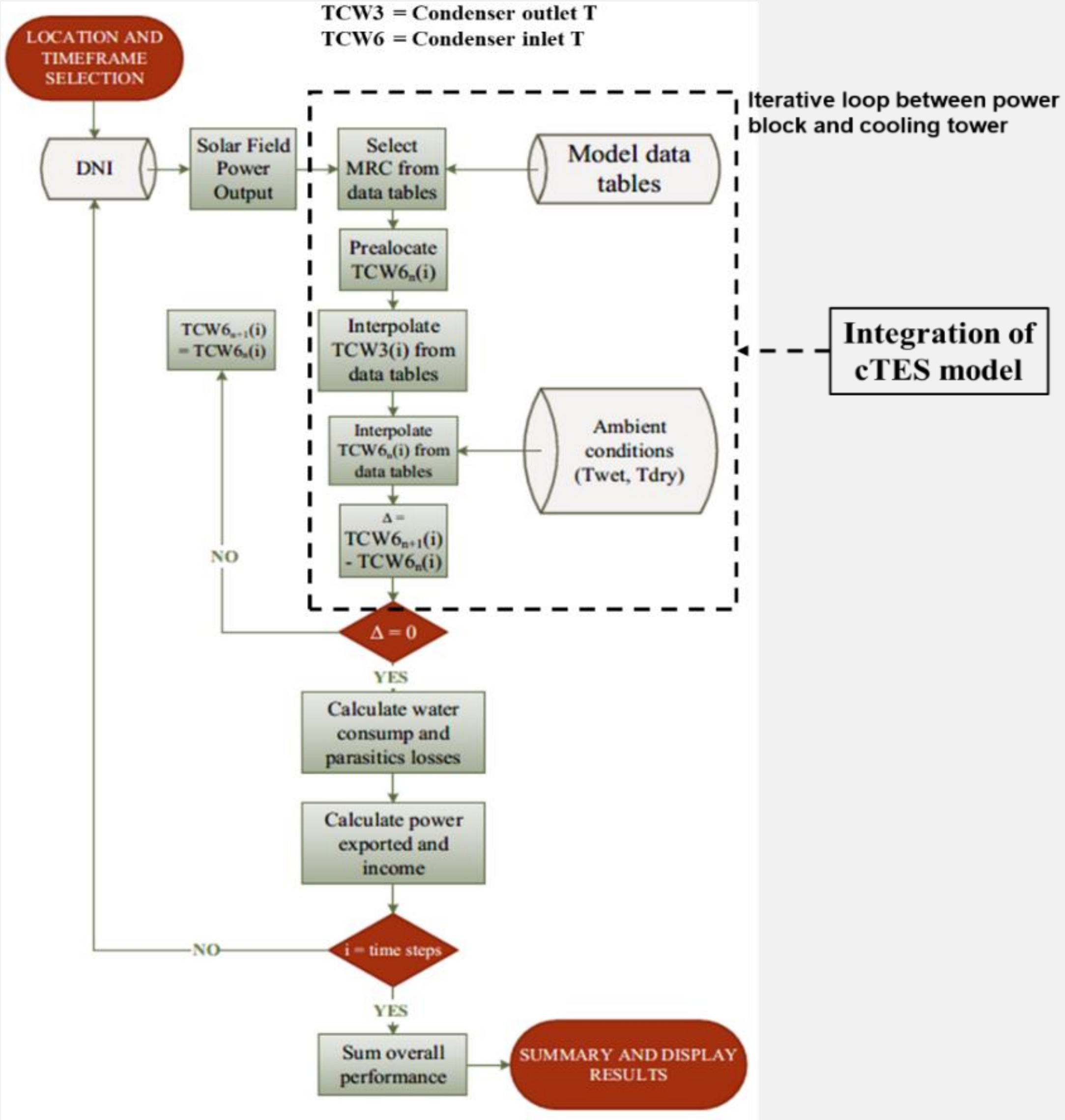


- **<u>DEMONSTRATION at TRL 7 of cTES concept</u>**
  - **Representative volume: 1000 m^3**
  - **Real environment: La Africana CSP power plant**
  - **Real operation and automation**
  - **Real design and construction**

- **<u>CHARACTERIZATION of « real » cTES</u>**
  - **R&D instrumentation of the cTES**
  - **Hydraulic and thermal characterization**
  - **Validation of cTES numerical model**

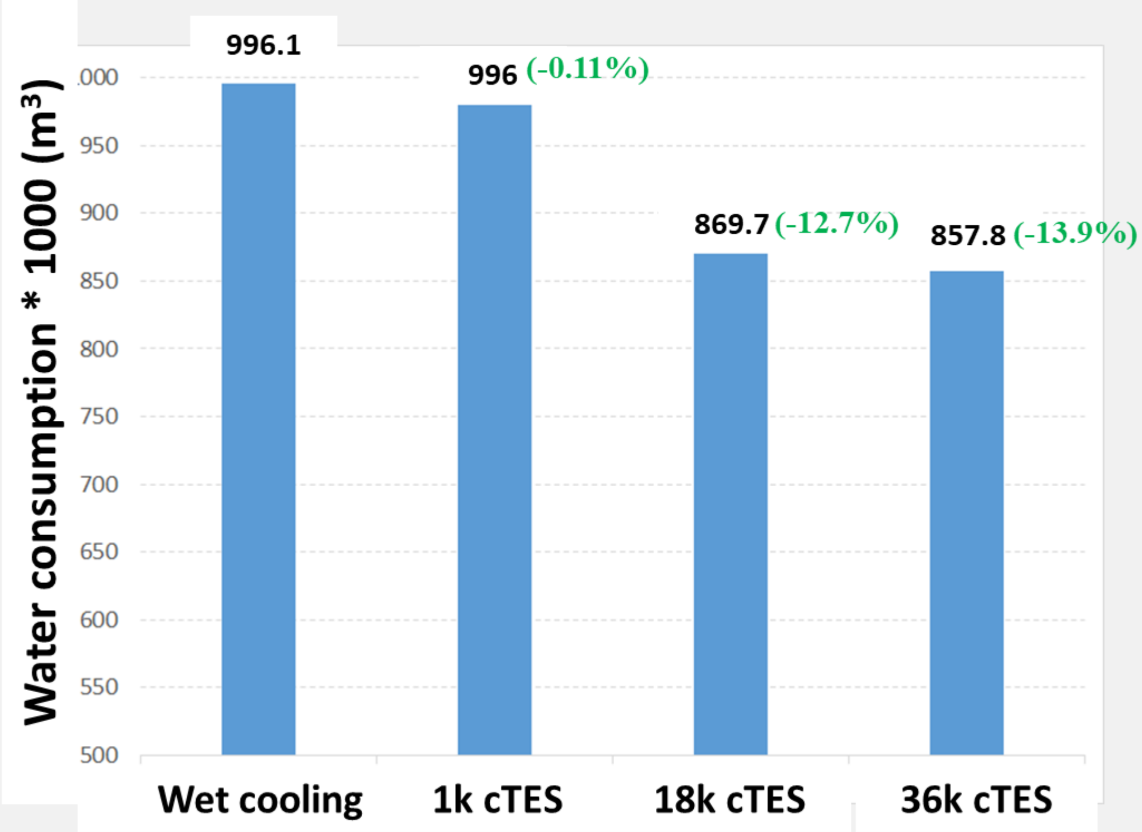
- **<u>EVALUATION of cTES benefits</u>**
  - **Water consumption and electricity production**
  - **CSP power plant with wet and dry cooling, at different locations and ambient conditions**
  - **Technico-economic analysis**

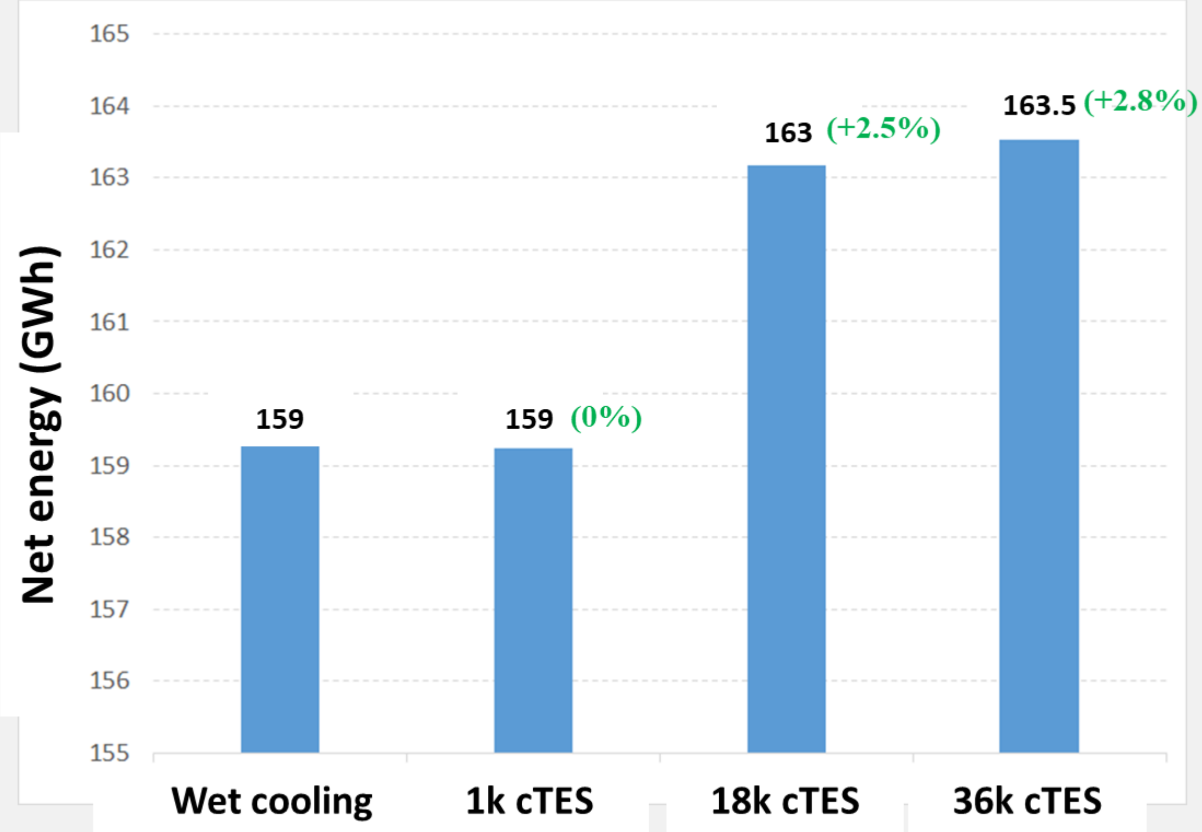
cTES benefits calculations



- Global Plant Model (GPM) developed in WASCOP
- Different cooling systems (wet, dry, hybrid, w/wt cTES …)
- Validation of different components and performances on the specific case of Andasol 1
- Water thermocline cTES model integrated
- Iterative process based on data tables for solar field, power block and cooling system

cTES benefits calculations

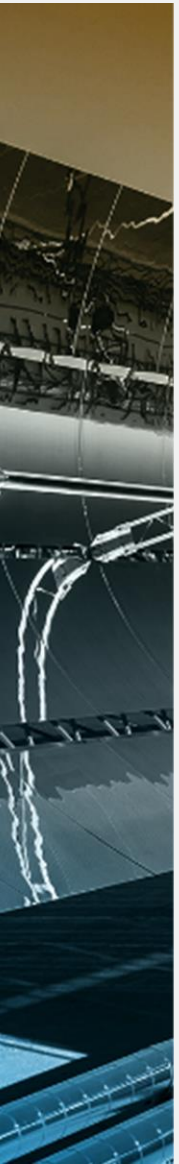




Study case:

- **Andalsol 1 data tables**
- **La Africana TMY meteo data**

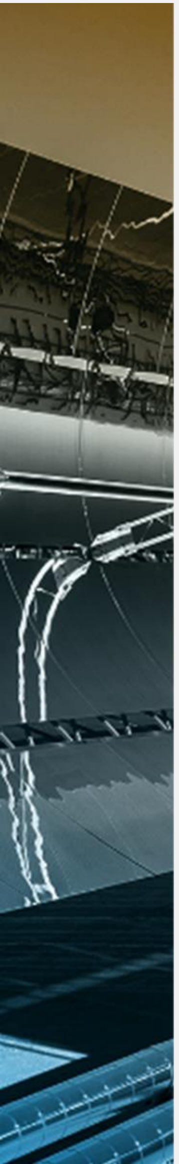
La Africana CSP power plant



Power plant name	La Africana
Country	Spain (Posodas, near Sevilla)
Owners	Ortiz/TSK/Magtel
Technology	Parabolic trough
Turbine capacity	50 MW gross
Cooling system	Open wet cooling tower
Start year	2012

Location of future cTES prototype
in la Africana

cTES sizing and characteristics



Cranfield University

- Global simulation tool for CSP power plant
- Evaluations of benefits of cTES
- Pre-design, design and engineering, ccTES instrumentation

CEA

- cTES numerical model
- Pre-design, design and engineering
- cTES instrumentation
- cTES operation laws

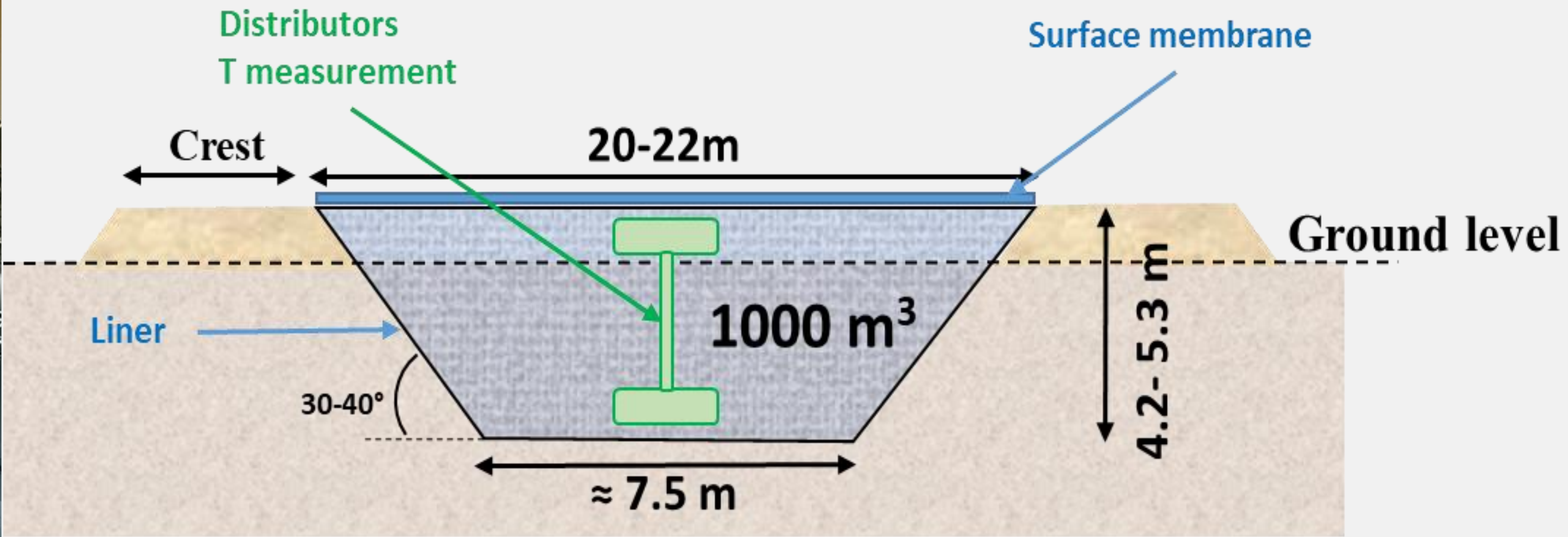
Bertin Technologies

- Pre-design, design
- Engineering and construction

TSK

- La Africana operator
- Pre-design, design and engineering

cTES sizing and characteristics



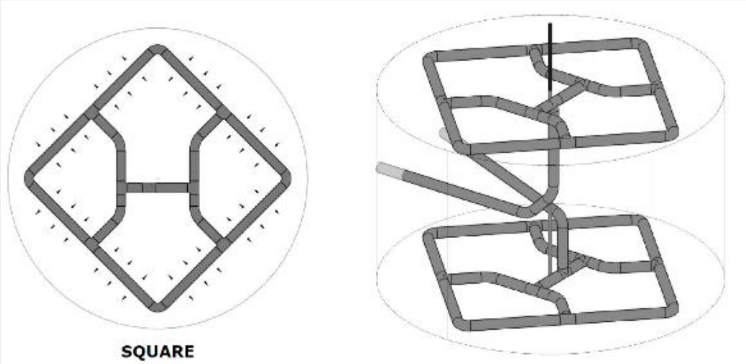
- 1000 m^3
- 10-50°C
- 200-1000 m^3/h ←→ <1/10th cooling circuit nominal flow rate

cTES sizing and characteristics

HYDRAULIC ASPECTS

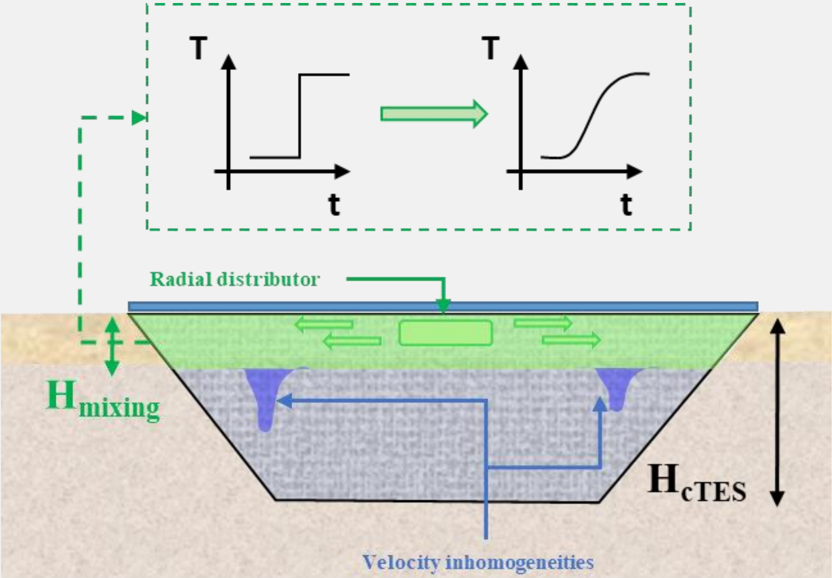
- Type of distributor? Sizing? Supplier?

Marstal, Sunstore 4



(HEI-TKDA)

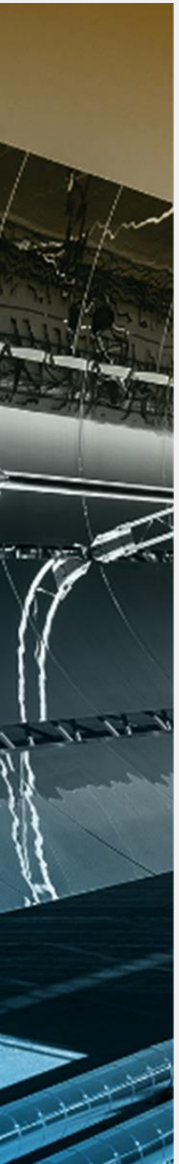
- Contribution of distributor to thermocline's initial thickness?



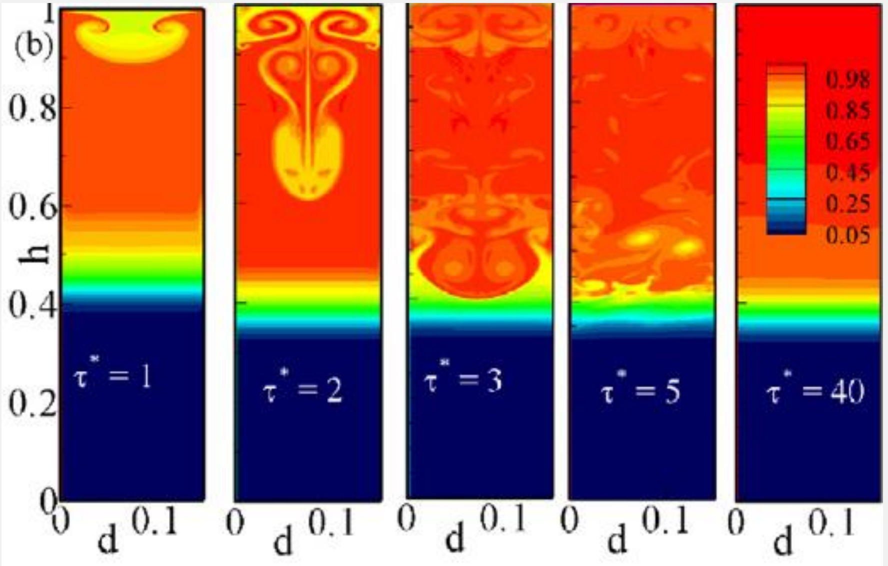
cTES sizing and characteristics

HYDRAULIC ASPECTS

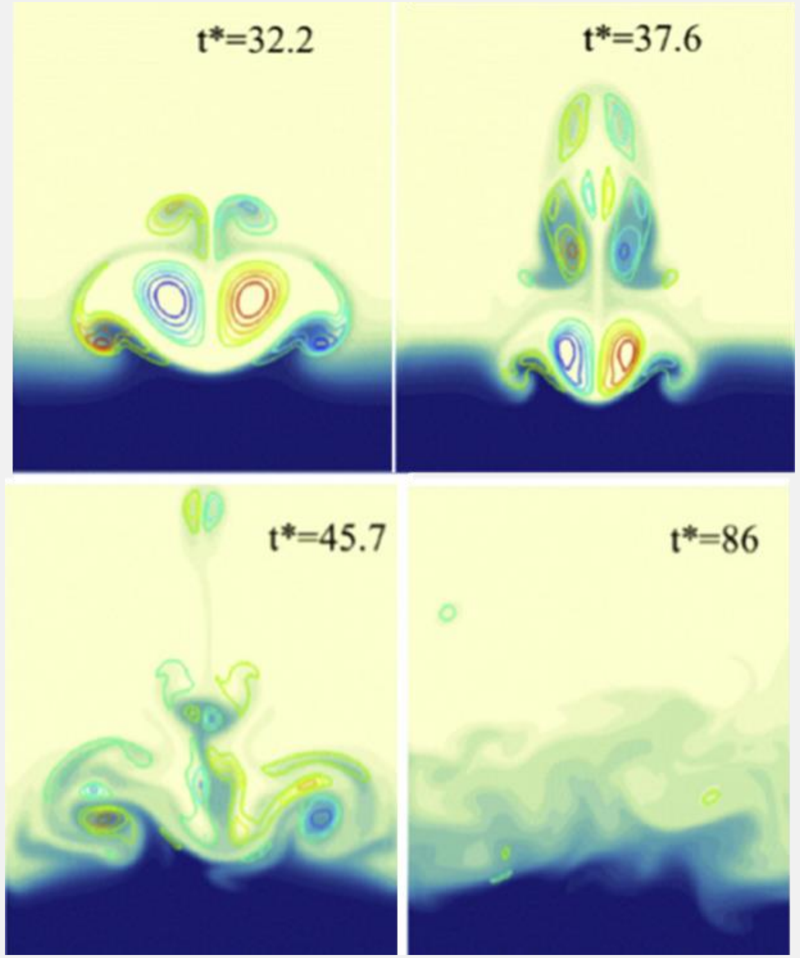
- Contribution of distributor on local mixing effect?
- Fluid velocity and related mixing effect?
- Pressure drop?



Manu et al., 2015



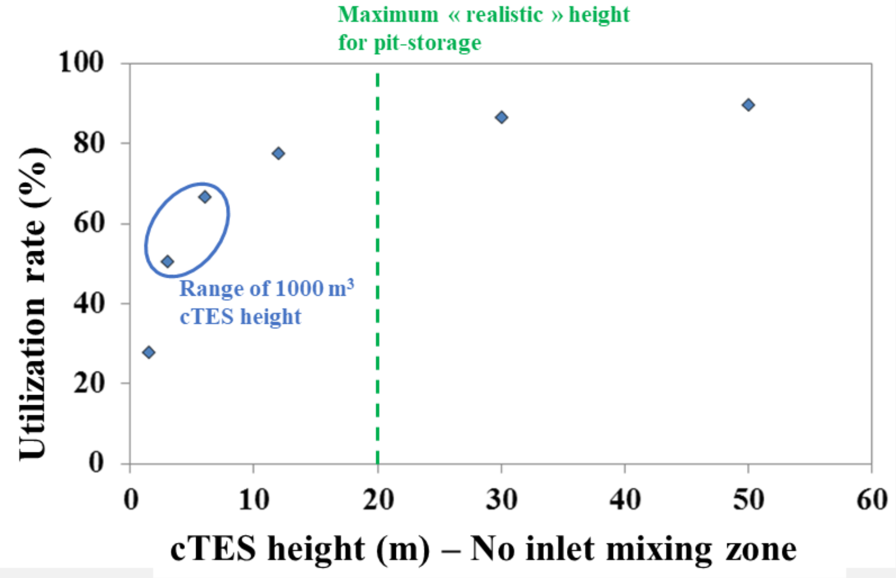
Tinaikar et al., 2016

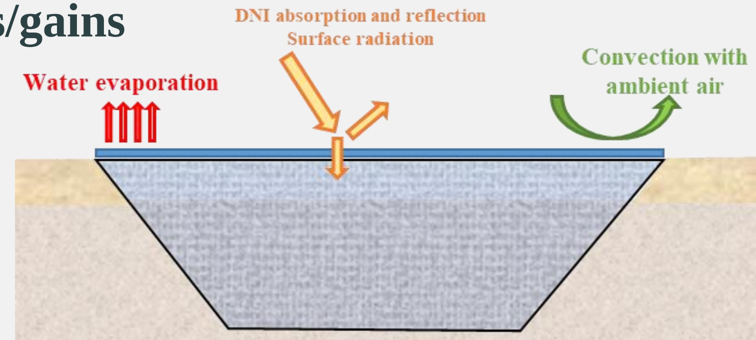


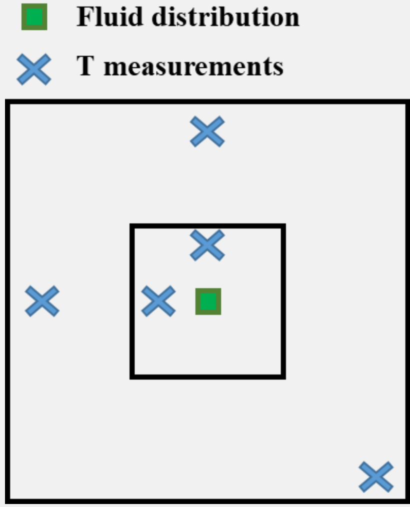
cTES sizing and characteristics

THERMAL ASPECTS

- Thermal stratification
  - Fluid distribution
  - Fluid velocity
  - cTES height
  - Thermal losses/gains
  - …
- Top surface
- Instrumentation for qualification
  - TRL7
  - Research project/qualification/validation

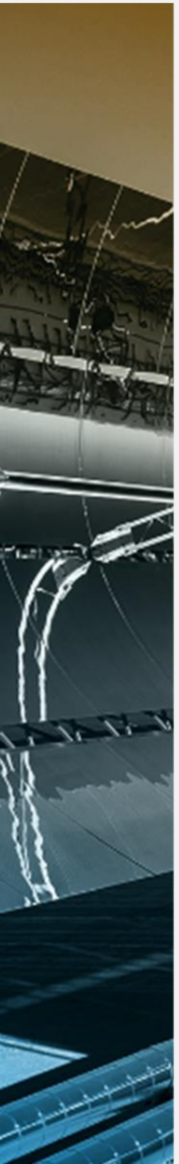






Multi-point TC stick

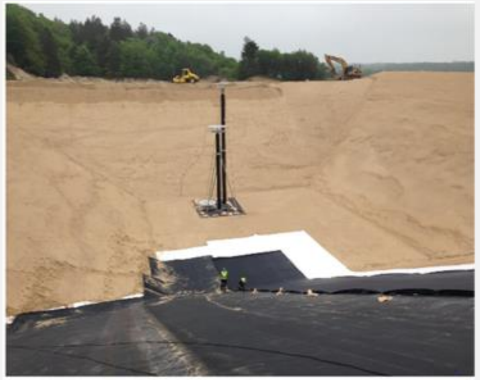
cTES sizing and characteristics

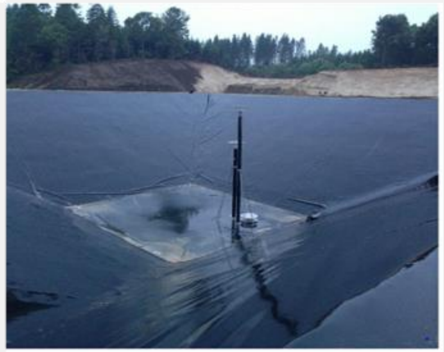


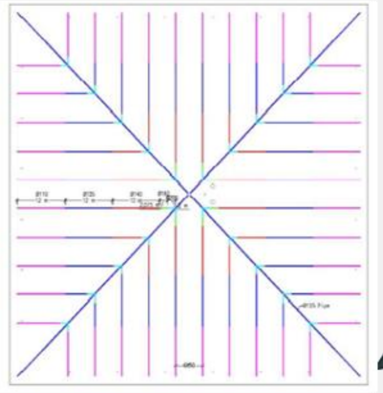
MECHANICAL/CONSTRUCTION ASPECTS

- **Pit angle**
- **Soil characteristics → influence on pit angle and feasability**
- **Liner definition and characteristics**
- **Global cost**

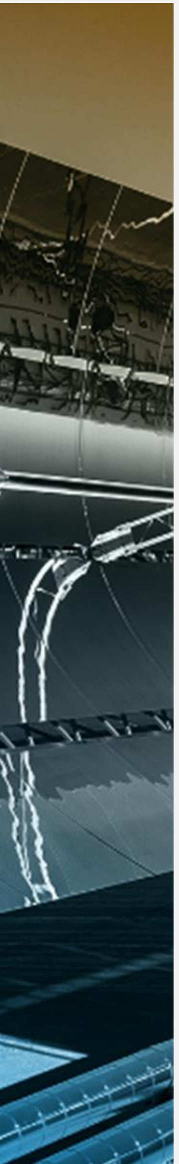
Marstal, Sunstore 4







cTES construction schedule



TO (05/2018) → **TO + 6**

cTES PRE-DESIGN

- La Africana limitations and constraints
- First PI&D and implanattion
- cTES parametric study:
    - Q, H, T, geometry …

TO + 4 → **TO + 12**

cTES DESIGN

- Final PI&D and implantation
- Modes of operation
- Links with La Africana control command
- cTES geometry
- Components and operating ranges

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TO + 9 → **TO + 24**

cTES ENGINEERING

- Components definition, sizing and purchase
- Preparation of cTES construction
- Preparation of piping, electric work etc…

TO → **TO + 30**

CTES CONTROL

- Expert laws
- Mathematically optimised control (MILP)
- 1000 m^3 and real size cTES

February 2020 – December 2020

TO + 20 → **TO + 30**

CONSTRUCTION

- Excavation, liner, distributor …
- Components
- Piping, electricity, automation
- …

TO + 24 → **TO + 30**

CTES INSTALLATION

05/2022

TO + 30 → **TO + 48**

COMMISSIONING/TESTS