Case Study: Monitoring in CSP molten salt tanks and modules

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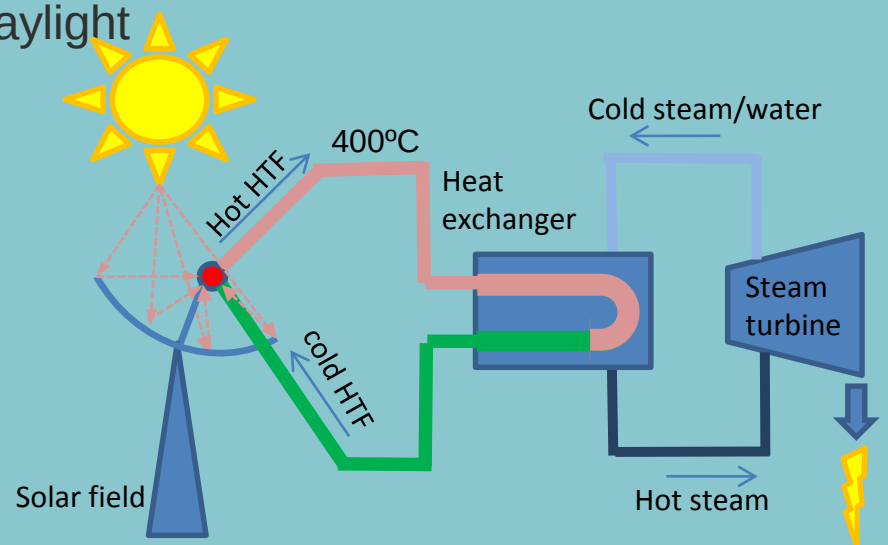
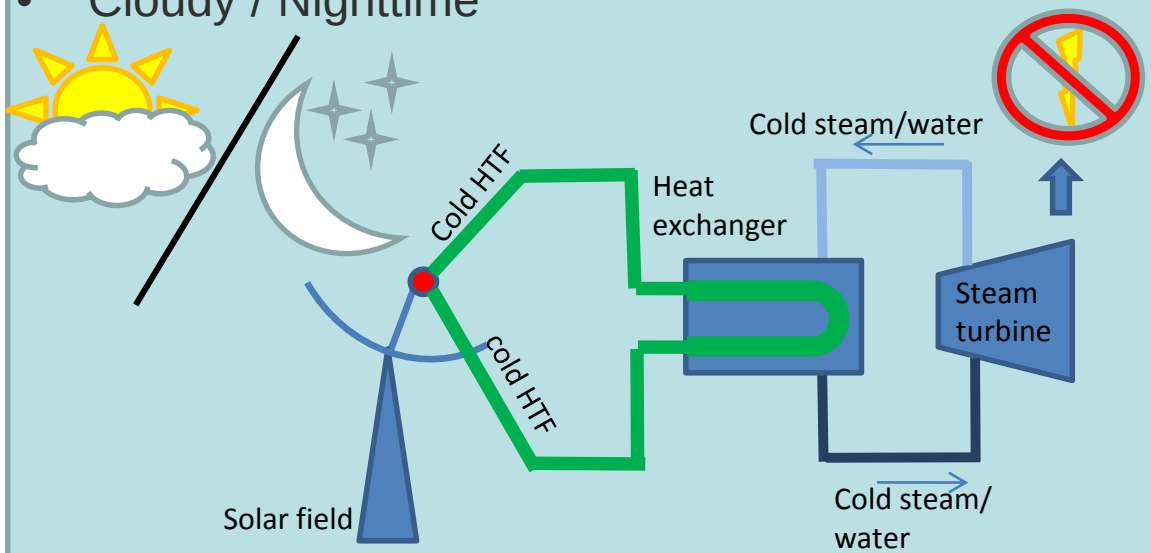
Dublin , May 2017

Concentrated solar power (CSP) plant operation work without storage

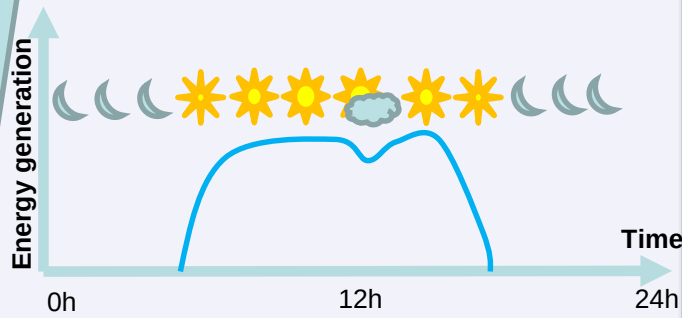
- Daylight



- Cloudy / Nighttime



- Solar thermal energy is converted into electric energy
- Max HTF temperature near **400ºC**
- Energy generation through the day without storage

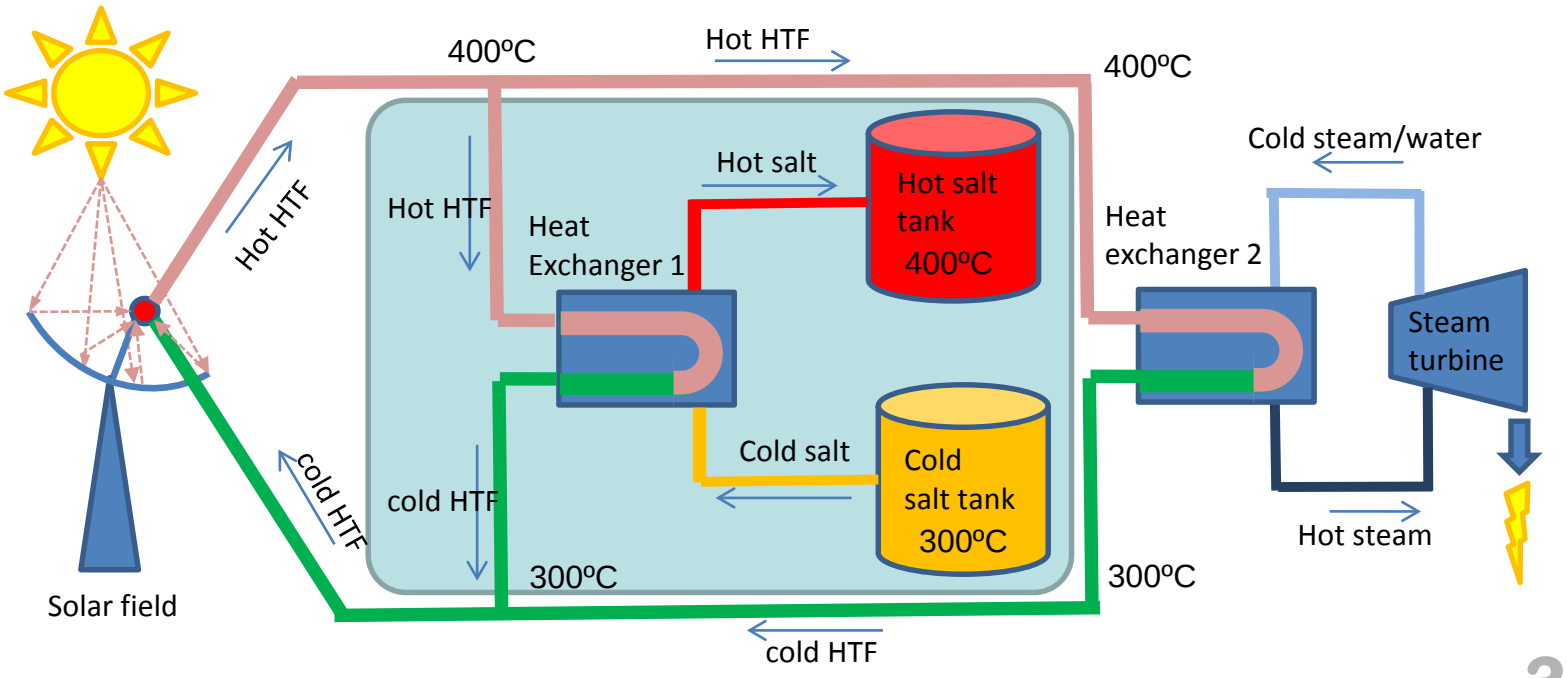


No sunlight, no power

CSP with thermal storage

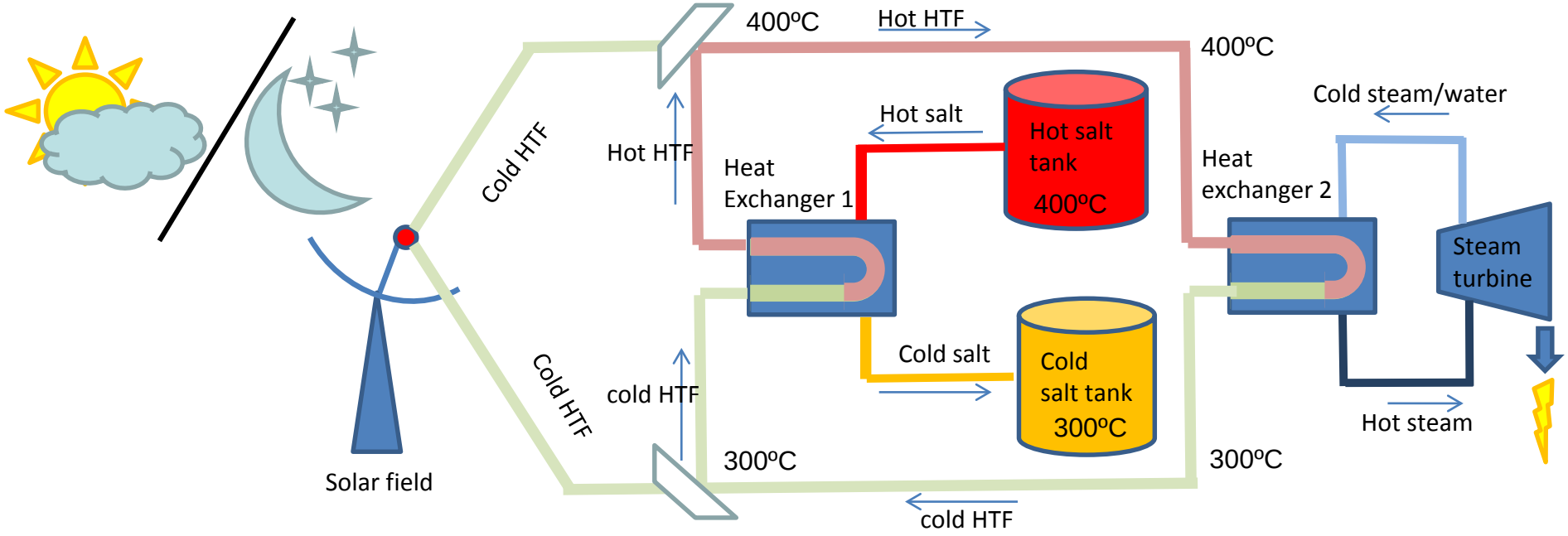
- **Thermal energy (heat) is stored by heating molten salt**
- Molten salt composition: **KNO_3+$NaNO_3$**
- A **new heat exchanger** (between HTF and Molten salt) and two Molten salt tanks are needed
- Molten salt can store temperature but it is **highly corrosive and cannot solidify** (melting temperature 280ºC)

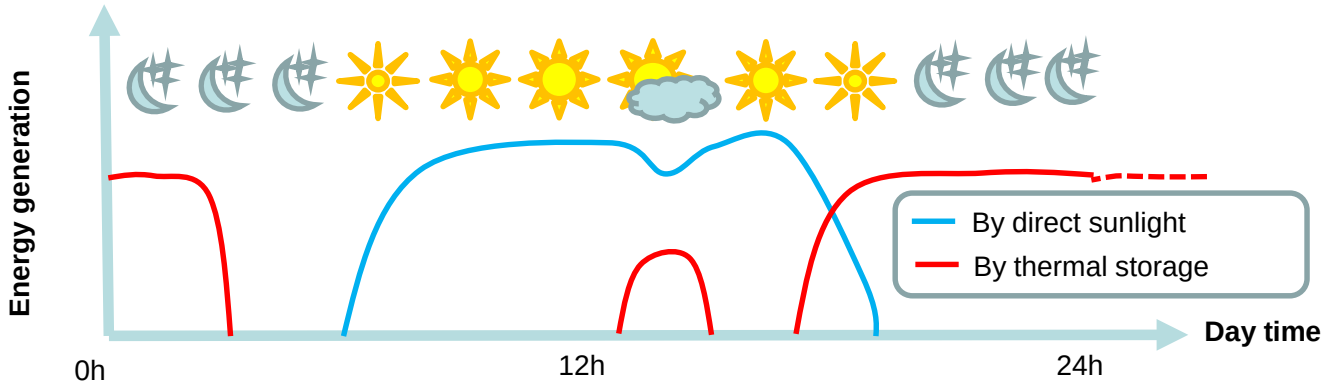
Daylight operation:



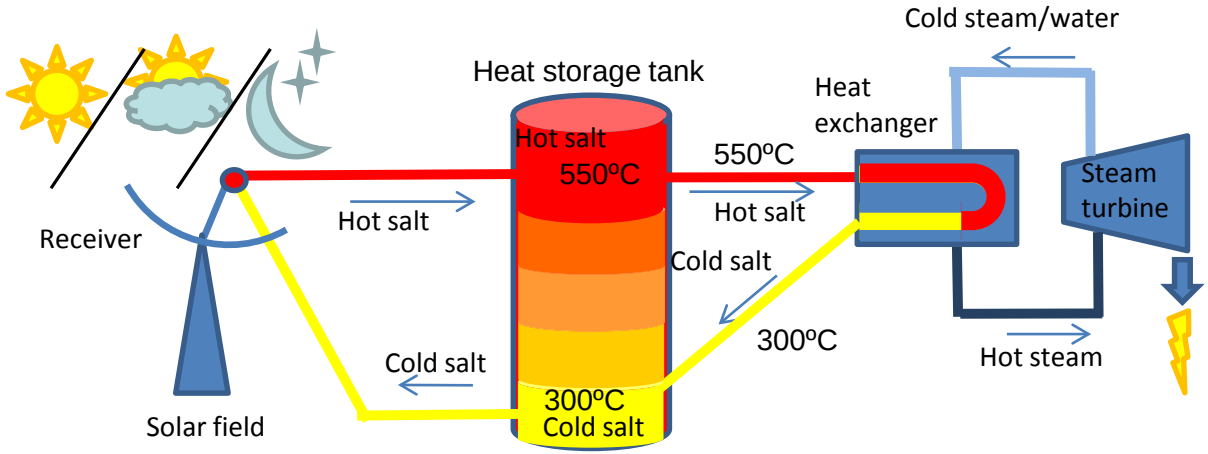
CSP with thermal storage

- When there is no sunlight

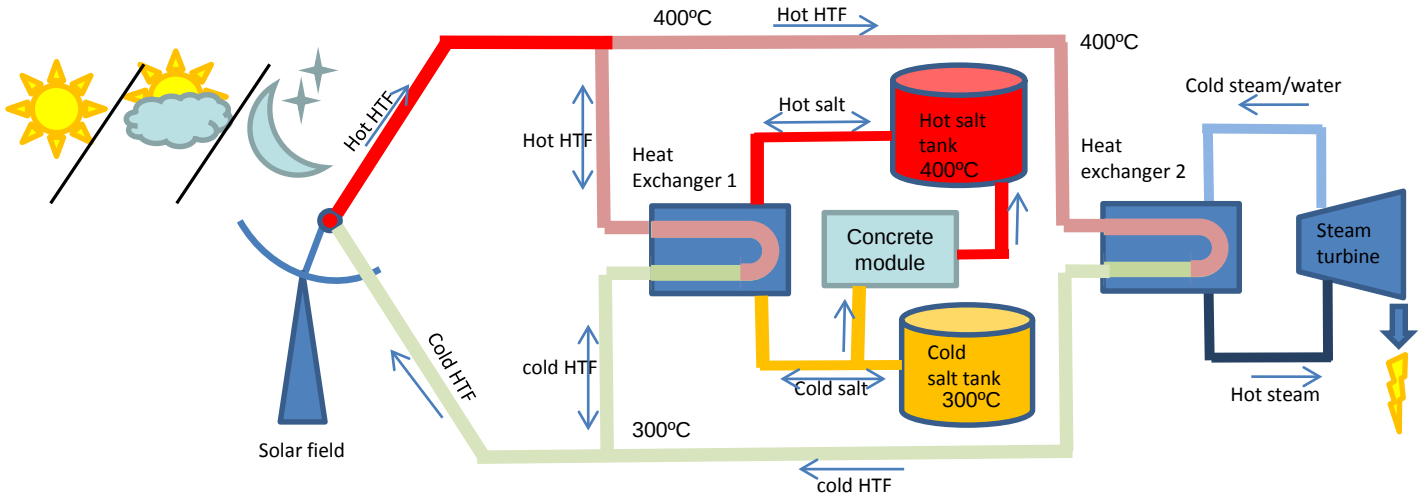




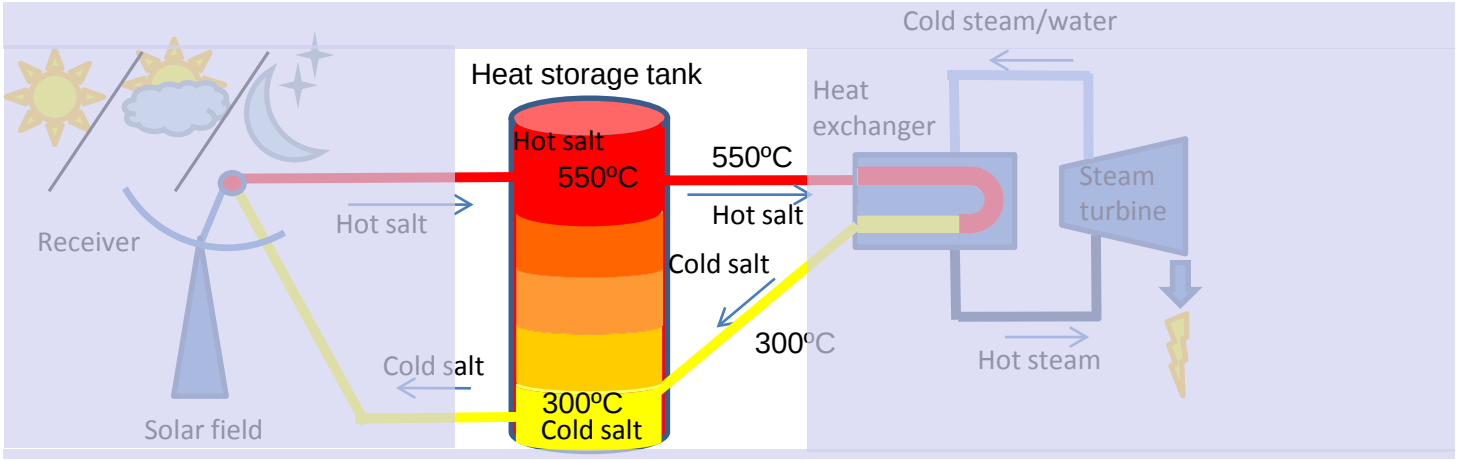
New Plant concept



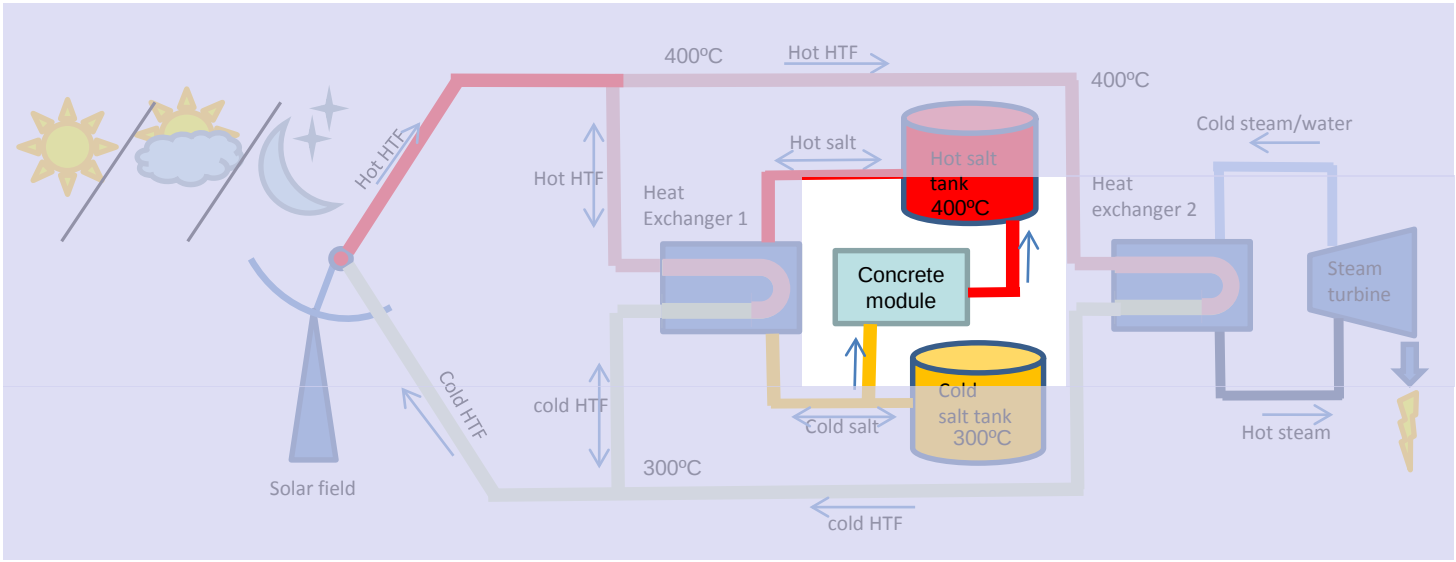
Existing Plant concept



New Plant concept

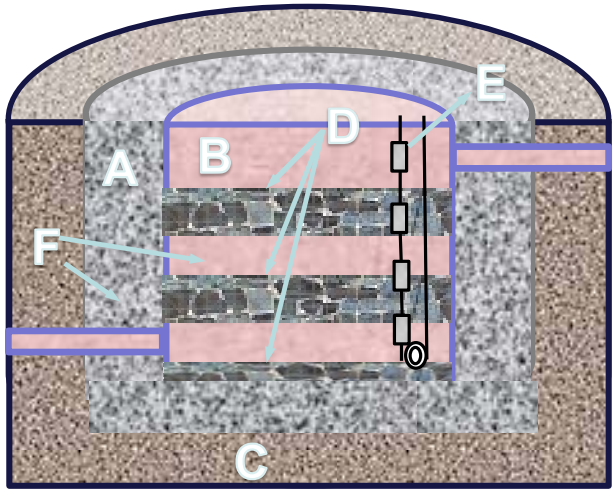
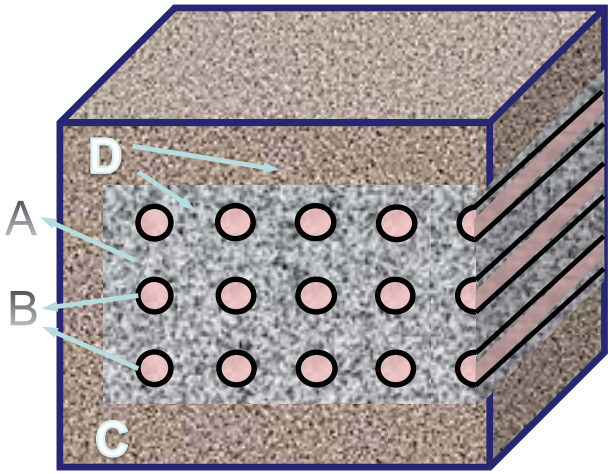


Existing Plant concept



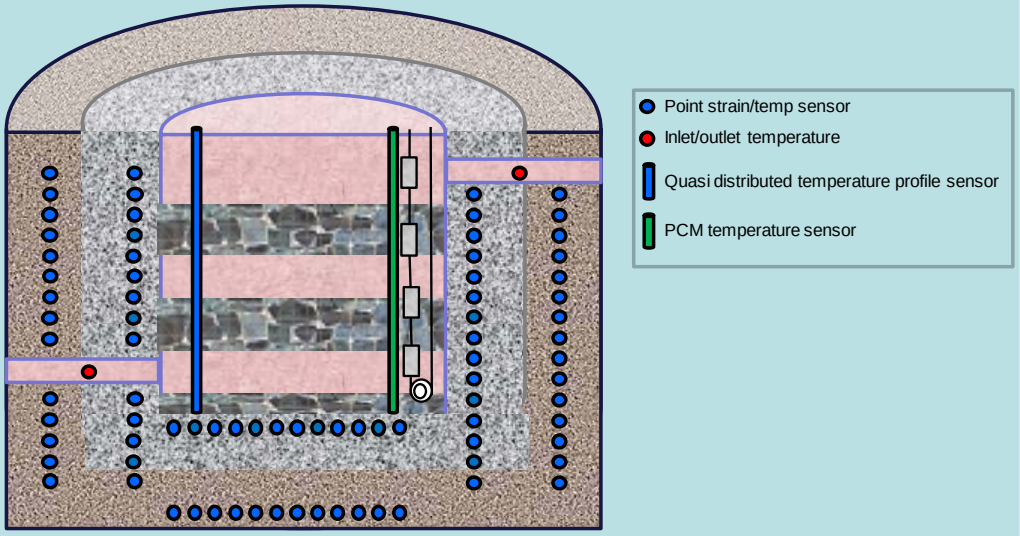
New heat storage system concept

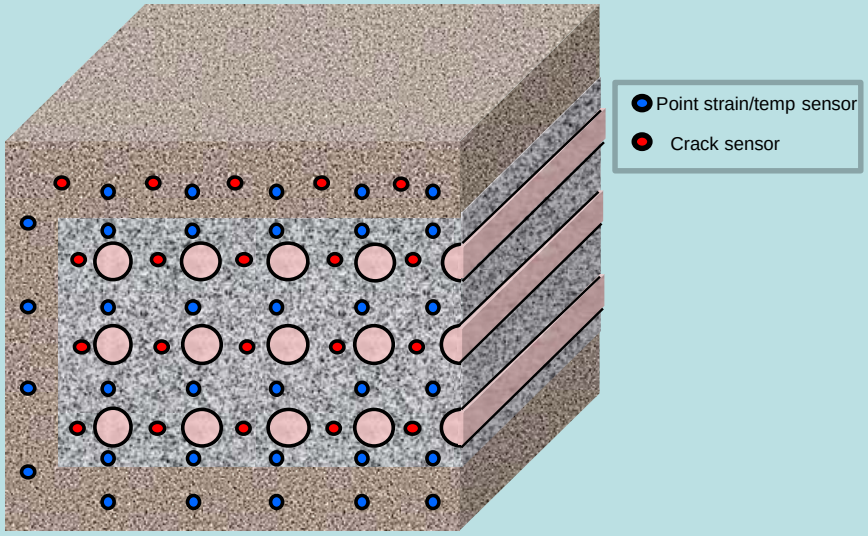
New SOL

	Novel Hybrid Energy Storage System for New Plants	Novel Thermal Energy Storage System for Existing Plants
New storage system architectures		
Novel functional/ advanced materials	A) Ultra High thermal performance concrete B) Advanced Ca-ternary molten salts (incorporating also nanoparticles) C) Insulating foam concrete with aerogels D) Low cost thermocline filler rock material E) Encapsulated PCM´s **F) Embedded monitoring system**	A) High thermal performance concrete B) Advanced Ca-ternary molten salts C) Insulating lightweight aggregates concrete **D) Embedded monitoring system**

Objective

- Assessment of thermal performance of materials
  - Increase energy efficiency of the system
- Structural health monitoring of the tank and concrete module
  - Increase safety of the structure



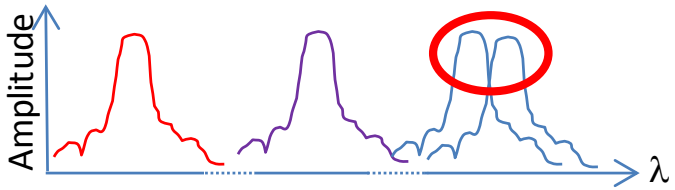


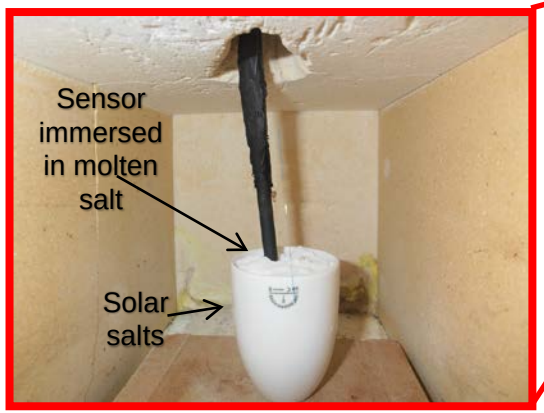
NewSOL solution

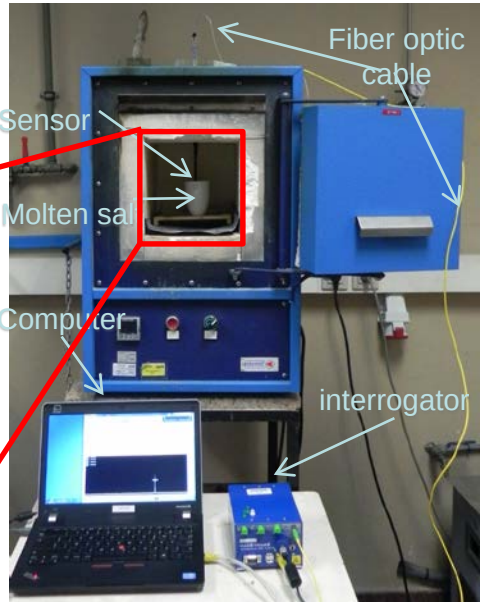
- **High temperatures and high corrosion** → **NEED MONITORING TECHNOLOGY**
- Due to monitoring requirements of CSP plants, need for:
  - **Multiplexing**
  - Good performance at **high temperatures** (550ºC) → **Fiber optic sensors**
  - **Withstand** Molten salt **corrosion**

Monitoring system development for concrete made heat storage systems in CSP

- Molten salt temperature profile in tank depth (packaged FBG arrays and distributed sensors)
- Concrete embedded temperature/strain sensors (FBG and distributed)
- Fiber optic network design
- Interrogator development







A. Zornoza, T. Grandal, and S. fraga, "Solar molten salt temperature monitoring with fiber optic sensors," in Advanced Photonics 2016 (IPR, NOMA, Sensors, Networks, SPPCom, SOF), OSA Technical Digest (online) (Optical Society of America, 2016), paper SeM4D.5.

Approach for implementing formal VoI analysis

- **KPI's defined for monitoring technology are set to help VoI analysis**

KPI	Description	Clarification/Internal comments	Target values
Number of sensors multiplexed	Number of sensors multiplexed by combination of wavelength division and time division multiplexing	To estimate the number of sensors to be multiplexed and interrogated using a single interrogator, to minimize instrumentation cost	500
Temperature and strain sensors reliability	$RF = \frac{NS - US - BQS}{NS} \cdot 100\%$ where: RF = Reliability Factor. NS = Number of Sensors. BQS = Number of sensors providing bad quality measurements. US = unavailable sensor	To estimate the number of sensor operating long term after three month test period of the demonstrator	80%
Savings due to the monitoring system under operation of the demonstrator tank	$S = Structural + Efficiency =$ $= \sum[CNM_S - CWM_s] + \sum[CNM_E - CWM_E]$ where: Structural =Savings related to Structural monitoring Efficiency =Savings related to Energy Efficiency event monitoring CNMS =Cost of Structural event with No Monitoring CWMS =Cost of Structural event With Monitoring CNMEE =Cost of energy generation event with No Monitoring CNMEE =Cost of energy generation event With Monitoring	To calculate the savings due to efficiency improvement and structural health provided by the monitoring system on the demonstrator tank and module during 3 month operation	>0

Current status

- **June 2017 –** framework to start project

- **January 2019 –** Monitoring system developed and tested in lab demonstrator

- **September 2019** – Tank and module operating

- **January 2020** – Evaluation after 3 month of tank operating

Open questions

- VoI is not only related to Structural performance – Energy efficiency and material performance too

Potential to use synergies with other case study proposals

- ?

Acknowledgements

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 720985

H2020 Grant Agreement Nº	**720985**
Start date of project:	**01/01/2017**
Duration of project:	**42 months**

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Gracias por su atención

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