FINAL PROJECT FACT SHEET
EUROPEAN UNION CO-FUNDED PROJECT

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Project acronym:

MinWaterCSP

Minimizing Water Consumption in CSP Plants

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done in *Bochum* *on:*

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1. SUMMARY

MinWaterCSP consortium will address the challenge of significantly reducing the water consumption of CSP plants while maintaining their overall cycle efficiency. Our objective is to reduce evaporation losses and mirror cleaning water usage for small- and large-scale CSP plants through a holistic combination of next generation technologies. Also, comprehensive water management plans for CSP plants in various locations will be developed. The MinWaterCSP consortium aims to make CSP more attractive for investment purposes in order to drive growth in the CSP plant business as well as job creation at European companies.

MinWaterCSP will significantly reduce the water consumption of CSP plants through a holistic combination of next generation technologies in the fields of:

- hybrid dry/wet cooling systems
- wire structure heat transfer surfaces
- axial flow fans
- mirror cleaning techniques and
- optimized water management

The project has commenced in January 2016 and is scheduled for completion in December 2018.

The MinWaterCSP project is coordinated by Kelvion Holding GmbH (Germany) and consists out of 13 partners in an international consortium of 6 different EU- and Non-EU Countries. Further partners of the consortium are: Kelvion Thermal Solutions Pty Ltd. (South Africa), Fraunhofer ISE (Germany), Sapienza - Università di Roma (Italy), ECILIMP Termosolar SL (Spain), Stellenbosch University (South Africa), Notus Fan Engineering, (South Africa), Laterizi Gambettola SRL – SOLTIGUA (Italy), ENEXIO Germany GmbH (Germany), ENEXIO Management GmbH (Germany), Institut de Recherches en Energie solaire et Energy Nouvelles - IRESEN (Morocco), Steinbeis 2i GmbH (Germany), Waterleau Group NV (Belgium).

2. PROJECT SCOPE

MinWaterCSP aims to develop advanced cooling and mirror cleaning technologies as well as integrated water management plans to reduce cooling system water consumption by up to 95% relative to wet only cooling systems and mirror cleaning water consumption by up to 25%, while maintaining overall cycle efficiency.

3. PROJECT TECHNICAL DESCRIPTION & IMPLEMENTATION

<u>Air-cooled condenser with integrated deluge cooling: Dry/wet cooling system</u>

Air-cooled condensers used in the power industry typically consist of a primary and secondary stage. The primary stage condenses approximately 80% of the steam, while the secondary stage, which is connected on the steam-side in series downstream of the primary stage, condenses the balance. The secondary stage is often referred to as a dephlegmator. One of the functions of the dephlegmator is to concentrate non-condensable gases from where they can be removed from the cycle via a vacuum system such as steam driven ejectors or water-ring pumps. The first technical solution introduced as part of this project is the use of dry and wet cooling in a single direct condensing steam cycle to reduce cooling water consumption while maintaining cooling system condensation capacity.

Combined dry cooling and wet cooling systems to date split the steam into separate and parallel condensing systems. The hybrid dry/wet system introduced here employs both dry and evaporative cooling in a single direct condensing system. In current dry/wet parallel systems the wet part is a traditional indirect condensing system where water cooled in a wet cooling tower is circulated through a shell and tube type condenser. Through the use of a hybrid direct condensing system where the wet part relies on deluge cooling, the cooling tower and condenser of existing parallel dry and wet cooling systems are eliminated and the deluge cooling part is introduced at one or more fan modules.

Wire structure heat transfer surfaces

The next solution relates to the introduction of the wire structure heat transfer surface concept. Conventional direct dry-cooled or air-cooled condensers make use of finned tubes to compensate for the relatively low air-side convection heat transfer coefficient. The MinWaterCSP project proposes to increase the air-side heat transfer areas even further through the use of wire structure heat transfer surfaces. Such wire structures have been demonstrated to exhibit higher specific heat transfer surfaces compared to conventional fins. They further achieve high heat transfer coefficients at relatively low air velocities. In addition a large variety of wire structure surfaces exists which can be exploited for the use in industrial heat exchangers. So far, extensive Computational Fluid Dynamics (CFD) evaluation and experimental work has been carried out by Fraunhofer to develop and characterise wire structure heat transfer surfaces on a very small capacity scale (<1kW). These activities have shown the potential for reduction of heat transfer surface mass by two thirds compared to a reference finned-tube heat exchanger. The findings show that the fan power consumption could be reduced by more than 50% if the amount of heat transfer surface material is kept constant.

Customised axial flow fan blade design

The third proposed solution is the introduction of a new axial flow fan blade design and manufacturing methodology for large-scale fans used in air-cooled condensing systems of CSP plants. The new methodology is based on cooling system or fan duty point specific optimization and a low-cost blade mould manufacturing approach, which allows the use of new/different moulds for each cooling system specific optimized solution. The goal is to increase the static efficiency of fans from currently 55-60% to 65-70% through design iterations aimed at optimising the electrical fan drive system and the aerodynamic design. In addition, passive flow control solutions will be considered in an attempt to reduce the sensitivity of the fan performance to atmospheric conditions (especially wind). All these measures are expected to substantially reduce the power consumption of the fans which reduces the overall performance of the CSP plant and the reachable turbine output. Alternatively, more cooling air could move through the system for same power consumption and therefore allow a reduction in the overall size of the cooling system.

Improved mirror cleaning process

The fourth solution of the MinWaterCSP project is an improved mirror cleaning system which increases water resource efficiency. Mirror cleaning is essential to maintain high CSP plant performance. Currently, most cleaning systems use cleaning vehicles with water from a mobile tank, not retaining the used cleaning water for reuse and therefore consuming significant amounts of water. The water demand for mirror cleaning generally depends very much on the local site conditions and is reported for example by Turchi, Wagner and Kutscher for a CSP plant located in the Mojave Desert to be in the range of 75 m³/GWh. For a CSP plant producing 500 GWh/a that results in a water demand of 37,500 m³/a. The aim of the project is to reduce this water demand by 25% compared to the state of the art by developing new hardware and process solutions. This is achieved by recuperation of cleaning water combined with on board water treatment for reuse and by enhanced reflectance measurements with vehicle-mounted devices to monitor mirror cleanliness and to allow for the optimization of cleaning and maintenance strategies.

While truck-based mirror cleaning solutions are state of the art for parabolic trough mirrors and heliostats in solar power tower plants, there is no cost-effective solution yet for smaller CSP plants employing linear Fresnel mirrors. This is due to the fact that for those CSP plants truck-based solutions cannot be used due to space constraints as Fresnel collectors are usually located close to each other to optimise the use of plot area. As a drawback, no large corridors are available for the passage of cleaning trucks, which makes it necessary to use other systems such as cleaning robots. The proposed MinWaterCSP solutions will solve this bottleneck by realising a cost-effective cleaning robot targeted at system price below 100,000 EUR/system (vs. a current price range of 200,000 to 400,000 EUR).

4. RESULTS ACHIEVED

Due to the project plan, the deluge bundle test facility has been designed, which enables further its constructing. This test facility will be used for investigating the effect of fouling on bare tube heat exchangers subject to intermittent deluge cooling. Thereby the tremendous operational losses on heat exchangers can be prevented.

5. IMPACT

Replicability

Hybrid cooling technology can be deployed in existing non-renewable power plants, leading to higher efficiency and thus reduced carbon-dioxide emissions.

The improved cost-competitiveness and more precise cost calculations will make CSP technologies more attractive for investment purposes, which leads to growth in the CSP plant business sector. This in turn drives job creation at European companies which provide essential and technologically advanced CSP plant components.

Estimated impact:

- Reduction of water evaporation losses by 75 to 95% compared to wet-cooling
- Improving fan performance through increased fan static efficiency
- Increase of the net power cycle efficiency by up to 2%
- Reduction of water consumption due to mirror cleaning by 25% through improved cleaning processes for parabolic trough collectors
- Reduction of cleaning cycles enabled by an enhanced monitoring of mirror reflectance
- Development of a comprehensive water management plan

Market Transformation:

The technological advances generated by MinWaterCSP will strengthen the European industrial technology lead in this sector which in turn can give impetus to further job creation and growth in Europe.

The European industrial technology base is improved by establishing new design know-how for hybrid cooling systems within KELVION/ENEXIO European entities and water efficient mirror cleaning technologies for international CSP markets in desert-like environments. CSP technology can be expanded to locations with limited water supply for plant cooling, where CSP plants cannot be established at the moment with state-of-the-art cooling technology.

Policy:

The deployment of CSP for electricity generation reduces the dependency on fossil fuels and, therefore, improves energy security. One major potential bottleneck for a broader use of CSP can be its significant water consumption, as this may lead to conflict with other water uses, e.g. agriculture and drinking water. The project will reduce this constraint.

MinWaterCSP will inform and communicate the results with legislative, national bodies as well as governmental bodies. The MinWaterCSP results will be compiled and published on the website. As the consortium has got international network contacts, the impact on policy will be in the mainstream of the big players.