Predictable & Flexible Molten Salts Solar Power Plant

First EC Review, 2nd February 2017 at Brussels

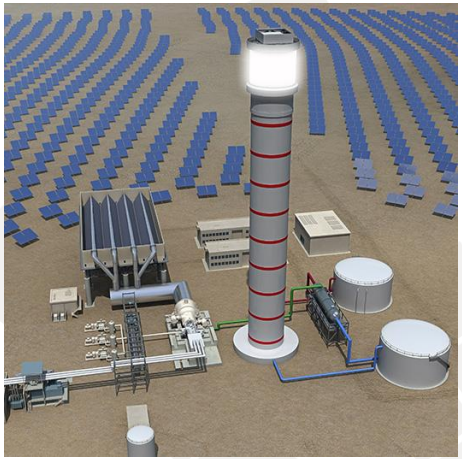
Vipluv Aga

WP 1 – Coordination and project management

PreFlexMS

PREDICTABLE&FLEXIBLE SOLAR POWER WITH MOLTEN SALT ENERGY STORAGE

Project Objectives



- Improve flexibility by designing and demonstrating a molten salt **Once-through-steam generator (OTSG)** for CSP tower plants
- Reliable **DNI and weather forecasts** to enhance the use of **optimised dispatch algorithms**
- **Demonstrate** hardware (OTSG) with software elements (dispatch optimiser, virtual power plant and improved day ahead weather forecasts) in real-environment conditions

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Project Objectives

Why is it important?

- **Why state-of-the-art technology needs to evolve – Trends we see in the market**
  - **Regulators** are reducing flat tariff incentives and promoting incentive/penalty schemes for CSP plants to match electricity demand (E.g. Peak consumption after sunset)

    → Improve "*timing*" of production – Forecast and shift production to high priority hours
  - **Grid operators** want stable, responsive, reliable, committed power supply

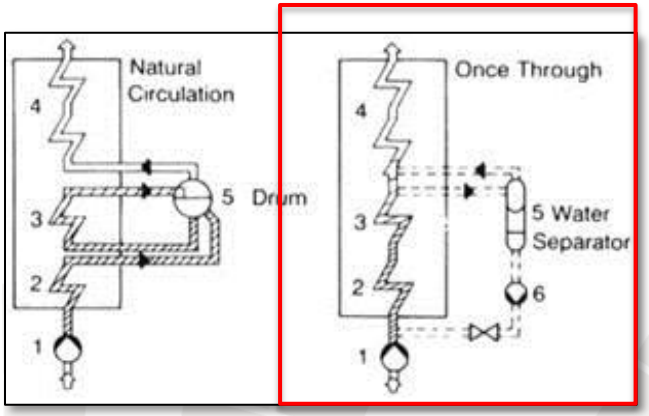
    → Increase "*quality*" of production – Forecast reserves and provide fast response to grid
  - **Plant operators** want flexibility to diversify revenue streams in mature (liberalized) markets

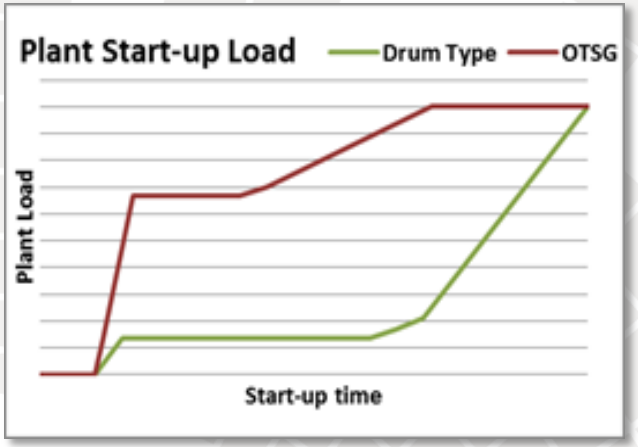
    → Improve "*effectiveness*" of production – Participate in electricity trading; Forecast and dispatch when most economical
- **The plant of tomorrow**
  - Shall be economically viable with no incentives and no niche operating regime (e.g baseload)
  - Shall provide flexible, predictable and dependable power to the grid

PreFlexMS – Flexibility

Once-through steam generator

- **Why Once-Through Steam Generator (OTSG)**
  - Best for frequent on/off, fast load changes
  - Potential for cost reduction
- **Where technology stands**
  - Drum-type standard in solar but no flexibility
  - OTSG never applied in solar but proven for Gas Turbine Combined Cycle
- **PreFlexMS**
  - Design & integration for solar application
  - Innovative design process with dynamic modeling and optimum control feedback





Innovation in technology & methodology

PreFlexMS – Predictability

Weather forecasting + Dispatch optimization

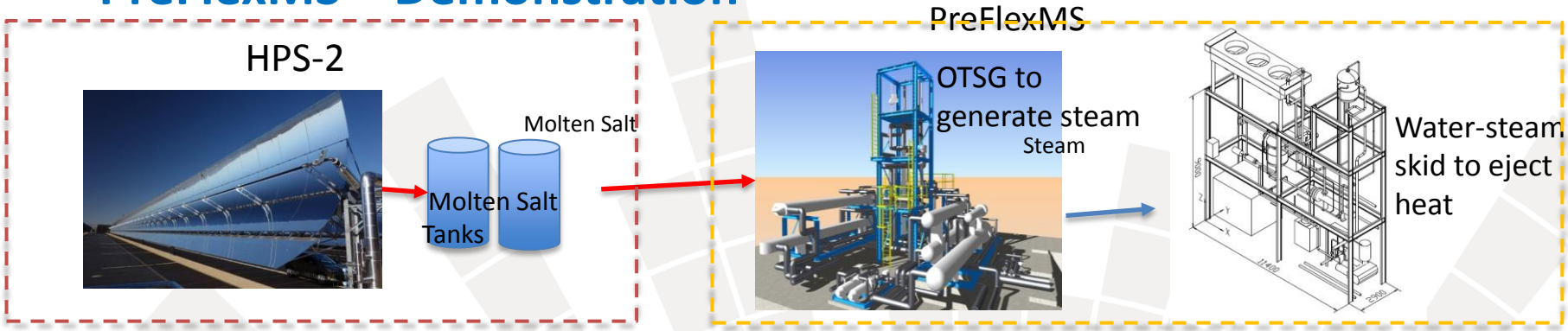
- **Where technology stands**
  - Limited geographical availability (EU; NA)
  - No reliable direct irradiation forecast technology
- **PreFlexMS**
  - Improve DNI forecasting, satellite based
  - Quantification of probabilistic and deterministic forecasts
  - Specification of data and equipment set-up for CSP

Real-time forecasting for integration in dispatch optimization

Real-time optimization under forecast uncertainty

- **Where technology stands**
  - Demonstrated for seasonal scheduling of hydro plants
  - Only proof of concept for CSP
- **PreFlexMS**
  - Max. revenues irrespective of uncertainties and perturbations
  - Continuously re-map plant performance by machine learning algorithms, to reflect real behavior and capabilities

PreFlexMS – Demonstration



- Pilot design derived from concept-level design of full scale
- HPS-2 (main funds from German ministry of Economics) – construct a molten salt trough – which provides hot molten salt and valuable infrastructure (molten salt tanks) that can be used by PreFlexMS

Expected Impacts

- A CSP plant to have similar/better economic attractiveness as a combined cycle gas turbine (CCGT) power plant
  - Access multiple revenue streams as CCGT including grid services, fluctuating price profiles or demand matching, lower cost of electricity with CAPEX savings
- Dependable production
  - Weather forecasting tools should be coupled with smart dispatch planning to provide similar levels of production reliability as any CCGT - extend to countries (MENA, Asia, Africa) with worse forecast reliability compared to Europe
- Flexible production
  - Start-up times, load change rate, turn-down and part load efficiency similar to CCGT
- Superior match between model and operation
  - High resolution modeling and machine learning to allow plant dispatch software to match better predicted against actual production plan

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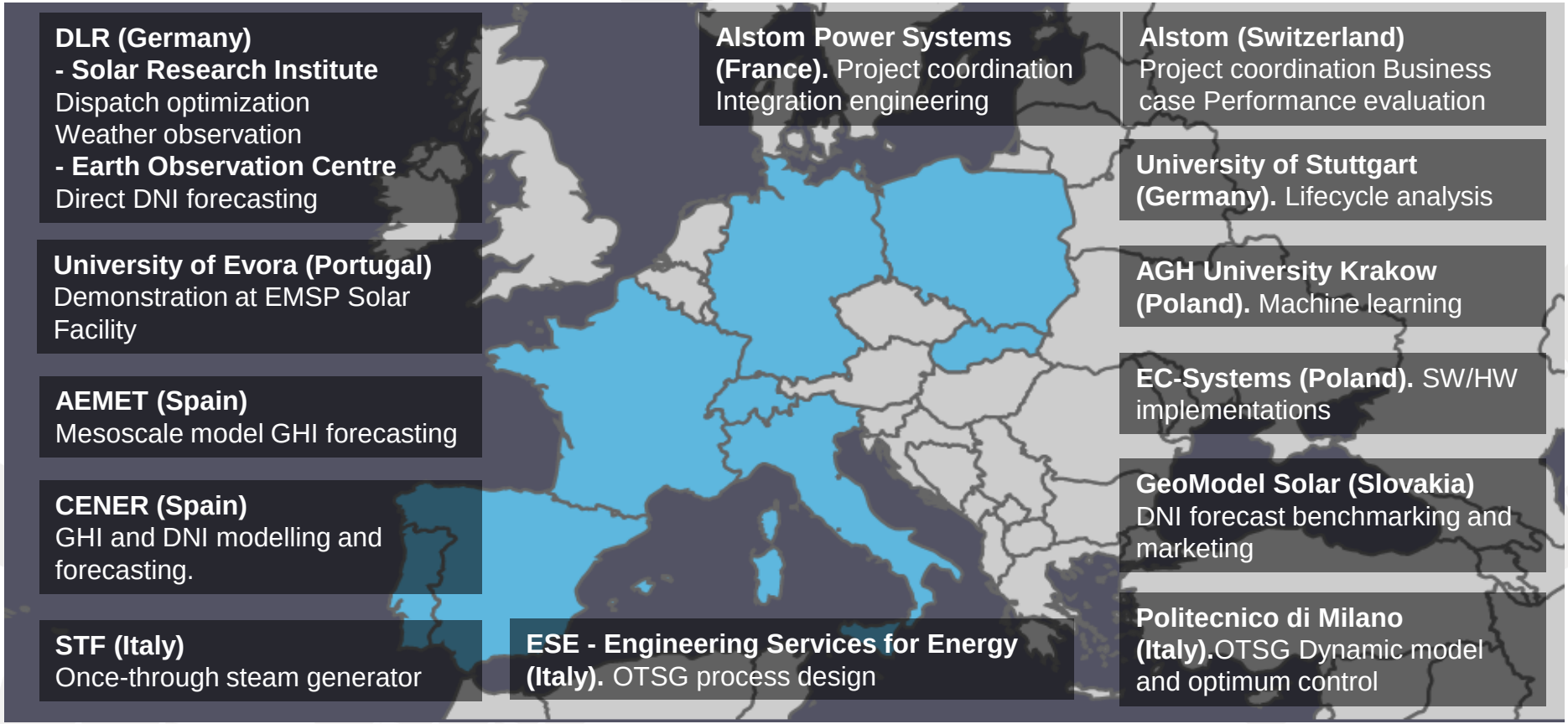
Project Partners



DLR (Germany)
- Solar Research Institute
Dispatch optimization
Weather observation
- Earth Observation Centre
Direct DNI forecasting

University of Evora (Portugal)
Demonstration at EMSP Solar Facility

AEMET (Spain)
Mesoscale model GHI forecasting

CENER (Spain)
GHI and DNI modelling and forecasting.

STF (Italy)
Once-through steam generator

Alstom Power Systems (France). Project coordination Integration engineering

ESE - Engineering Services for Energy (Italy). OTSG process design

Alstom (Switzerland)
Project coordination Business case Performance evaluation

University of Stuttgart (Germany). Lifecycle analysis

AGH University Krakow (Poland). Machine learning

EC-Systems (Poland). SW/HW implementations

GeoModel Solar (Slovakia)
DNI forecast benchmarking and marketing

Politecnico di Milano (Italy).OTSG Dynamic model and optimum control