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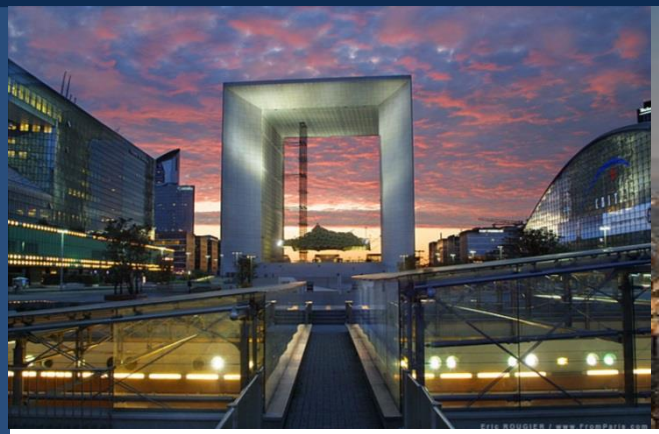

ETN AGM & WORKSHOP

2-3 April, Paris La Defense, France

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Gas-Turbine Hybridisation for Controllable Solar Power

A Horizon 2020 Initiative

James D. Spelling

IMDEA Energy Institute

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Hybrid Power Generation

Hybrid power generation is a promising solution to the challenges of rising fuel prices and the growing policy focus on renewables

Fuel input is supplemented with a **low-carbon energy source**

- Emissions from the power plant are reduced
- Controllable electricity generation is maintained
- Hedges against volatility in fossil-fuel prices

Hydrogen


Biofuels


Solar Thermal

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Solar Hybridisation

Concentrated solar energy is an ideal carbon-free energy source with which to hybridise gas-turbine power systems

- Solar energy can be harnessed at **high temperatures**
- **Large resource** in Sun-belt areas (e.g. MENA-region) which are already heavily dependant on gas-based electricity generation
- Direct integration of solar heat into the gas-turbine circuit allows a fast and **flexible response** to be maintained

Hybrid Gas-Turbine Systems

In a hybrid solar gas-turbine, solar energy is used to preheat the compressor air, reducing fuel burn as well as CO_2 emissions

Combustor can be **controlled** to supply the desired power

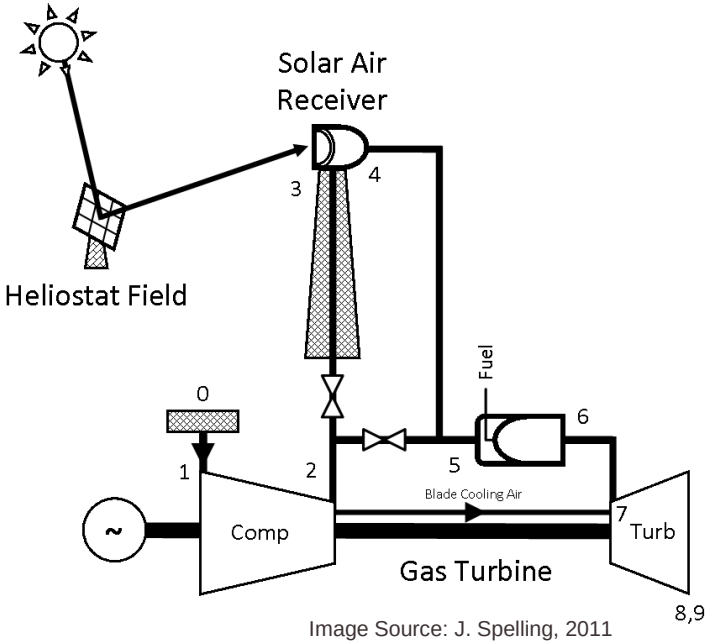

Image Source: J. Spelling, 2011

The **solar share** measures the degree of solar heat utilisation:

$$f_{sol,nom} \approx \frac{T_{rec} - T_c}{T_{fire} - T_c}$$

Higher temperatures are key!

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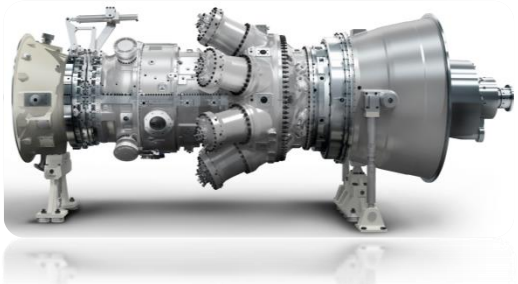
Gas-Turbine Modifications

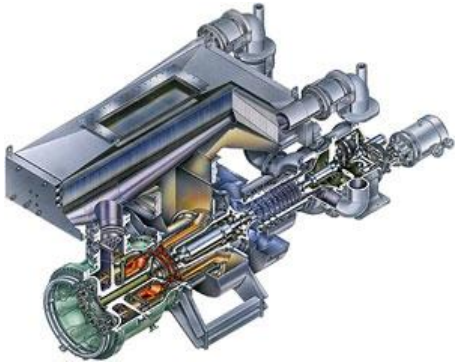
The central section of the gas-turbine must be modified to allow **extraction of the main airflow** leaving the compressor

- Silo/can combustors and recuperated designs simplify this process

Silo Combustor



Can Combustors



Recuperation

The gas-turbine control strategy must also be updated to take into account the added thermal inertia and gas volumes

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Key Market Opportunities

Two key initial markets for hybrid solar gas-turbine technology

- Gas pipeline **compressor stations** in high insolation areas
- Combined-cycle **power generation** in gas-exporting countries

The business cases for these markets are not reliant on subsidies

- High gas import prices in Europe and Asia are the driver

Pipeline Compressor Stations

Numerous gas pipelines run through high solar resource areas

Gas-turbines in pipeline compressor stations burn a portion of the transported gas, which could otherwise be sold for profit

Opportunity for medium-scale hybridisation to limit risks

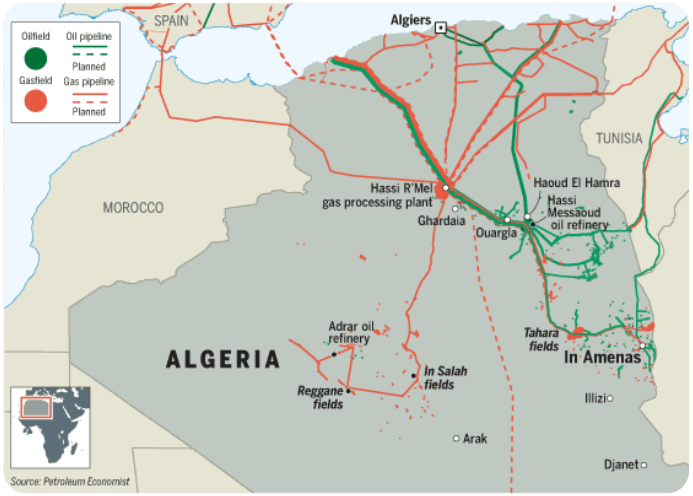


Image Source: Petroleum Economist, 2013

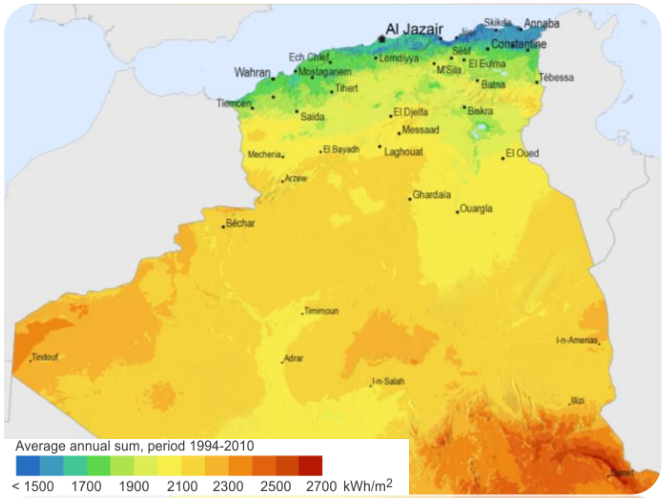
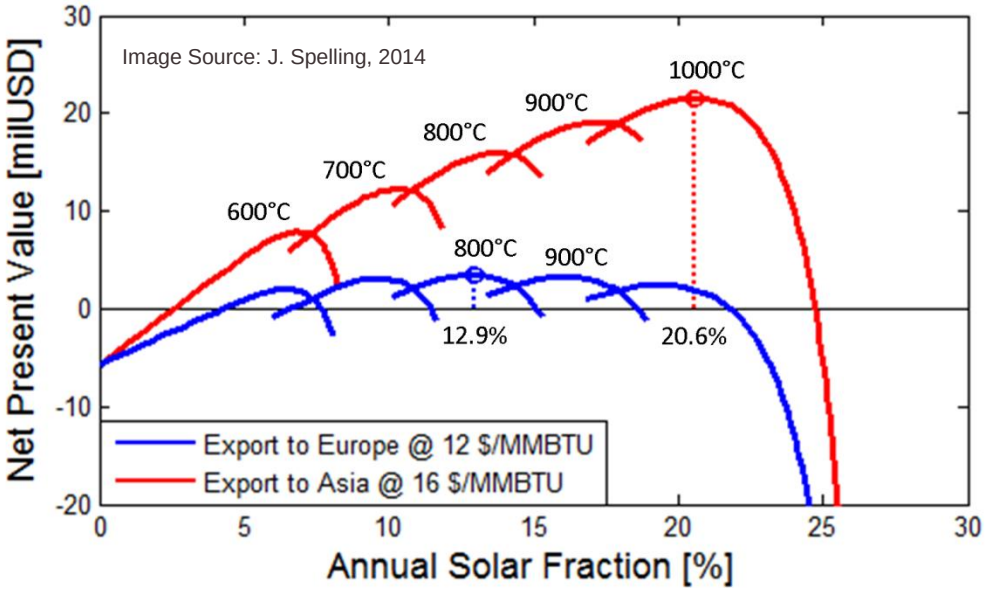


Image Source: Solar GIS, 2014

Pipeline Compressor Stations

The business case for a typical compressor station on the Trans-Saharan gas pipeline has been analysed

The added hybridisation costs are borne by the added gas sales



Location: Hassi R'Mel (32.9°N, 3.3°W)

Turbine Size: 25 MW

Solar Resource: 2643 kWh/m^{2}yr

NPV over 20 yrs, discounted at 6 %

Pipeline Compressor Stations

For a 25 MW gas-turbine compressor station, with 20.6 % solar hybridisation, the plant layout ressembles the schematic below

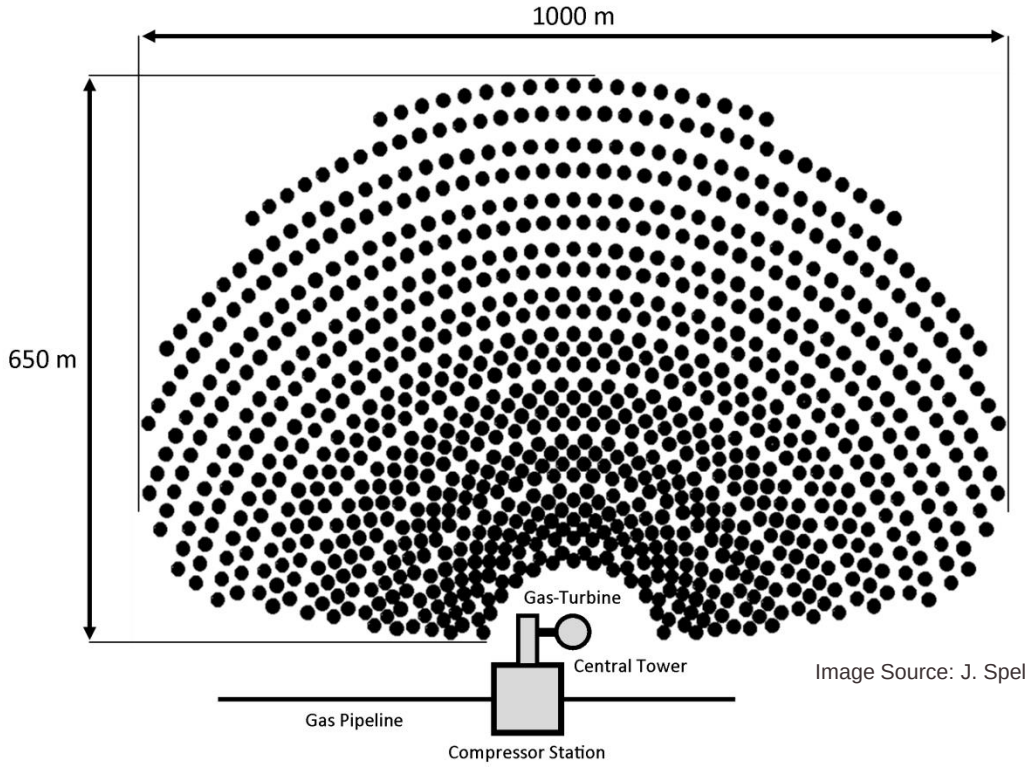


Image Source: J. Spelling, 2014

Design

Total Heliostats: 982

Central Tower: 100 m

Receiver Power: 52 MW_{th}

Performance

Field Efficiency: 63 %

Receiver Efficiency: 78 %

Hybrid CCGT Power Plants

Many MENA countries are dependent on gas-based generation

Subsidied gas prices in these countries make it difficult for renewable energy technologies to compete directly

Opportunitiy costs for export of unused gas need to be considered

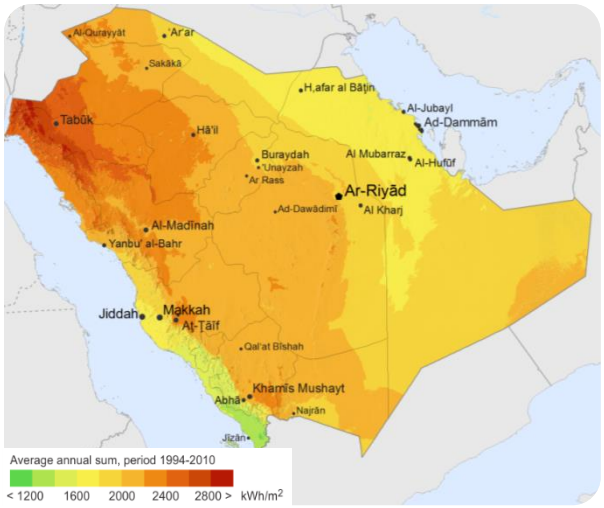
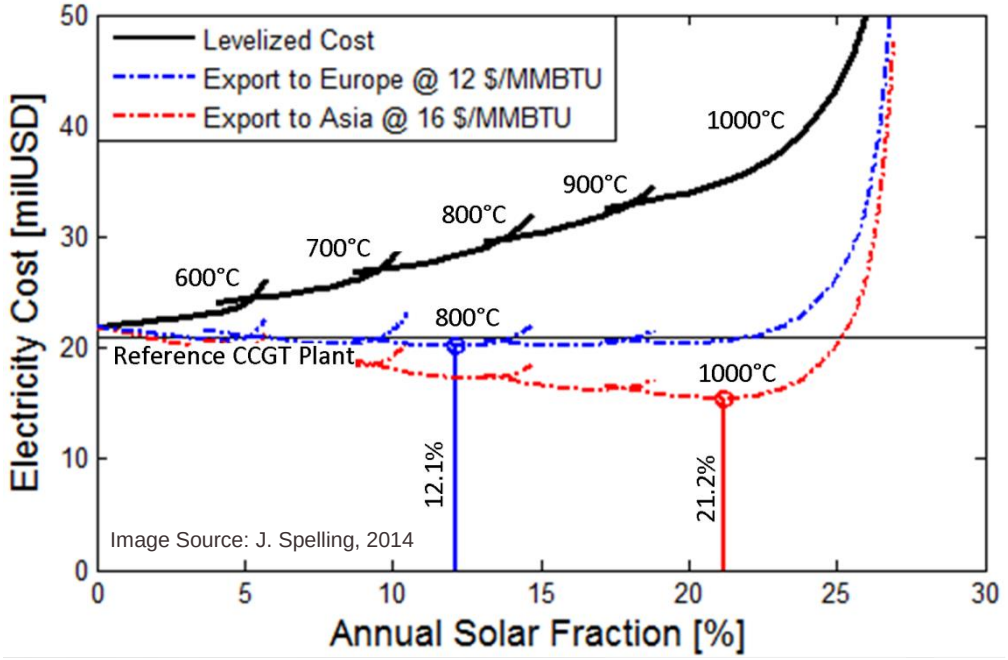


Image Source: Solar GIS, 2014

Hybrid CCGT Power Plants

The business case for a typical combined-cycle power plant in western Saudi Arabia has been considered

Electricity costs are evaluated with and without extra gas sales



Location: Riyadh
(24.7°N, 46.8°E)

PlantSize: 250 MW_e

Solar Resource: 2431 kWh/m^2yr

Domestic Gas Price: 0.75 $/MMBTU

Plant lifetime: 25 yrs

Interest Rate: 7 %

Hybrid CCGT Power Plants

For a 250 MW combined-cycle power plant, with 21.2% solar hybridisation, the plant layout ressembles the schematic below

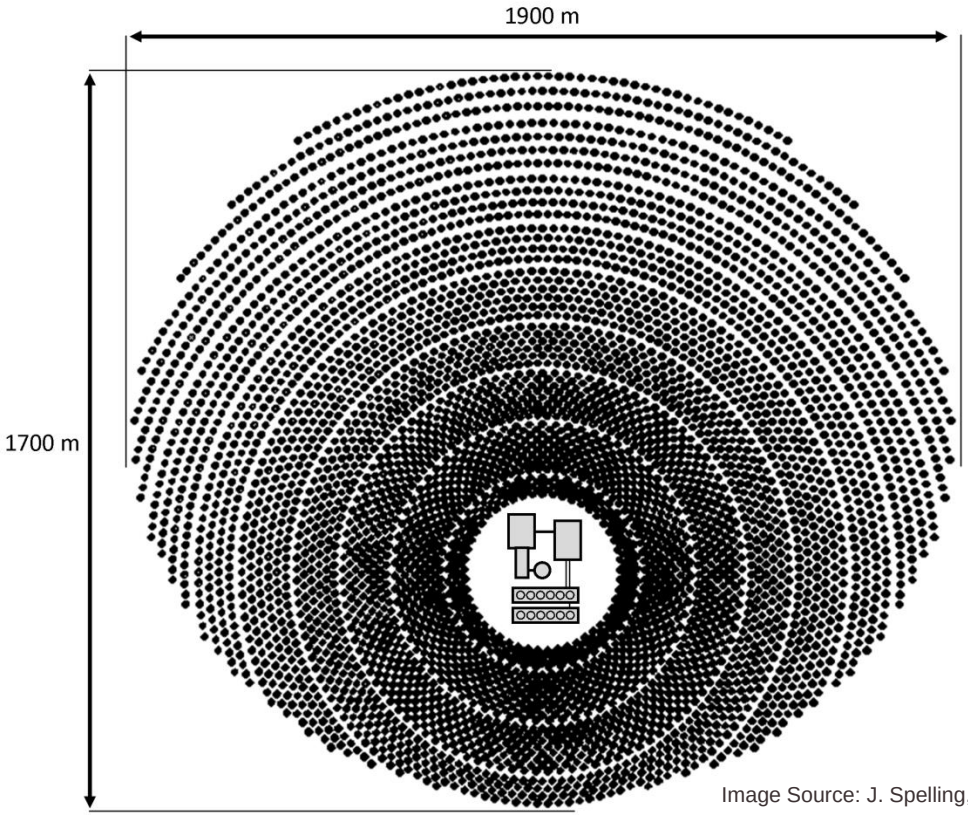


Image Source: J. Spelling, 2014

Design

Total Heliostats: 4844

Central Tower: 165 m

Receiver Power: 255 MW_{th}

Performance

Field Efficiency: 61 %

Receiver Efficiency 78 %

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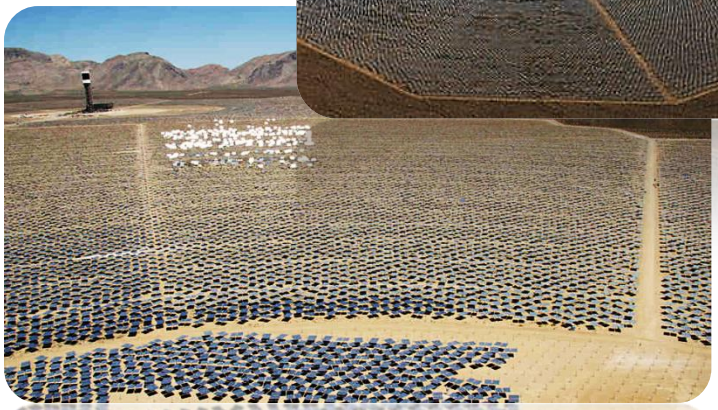
Hybrid CCGT Power Plants

Hybrid CCGT power plant designs are well within the current state of the art in solar thermal power technology



Ivanpah Solar Power Plant

Plant Size: 3 x 125 MW_e

Receiver Power: 3 x 445 MW_{th}

Total Heliostats: 170’000

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Project Focus Areas

Considering the overall hybrid gas-turbine system, including storage, a number of key technology gaps can be identified

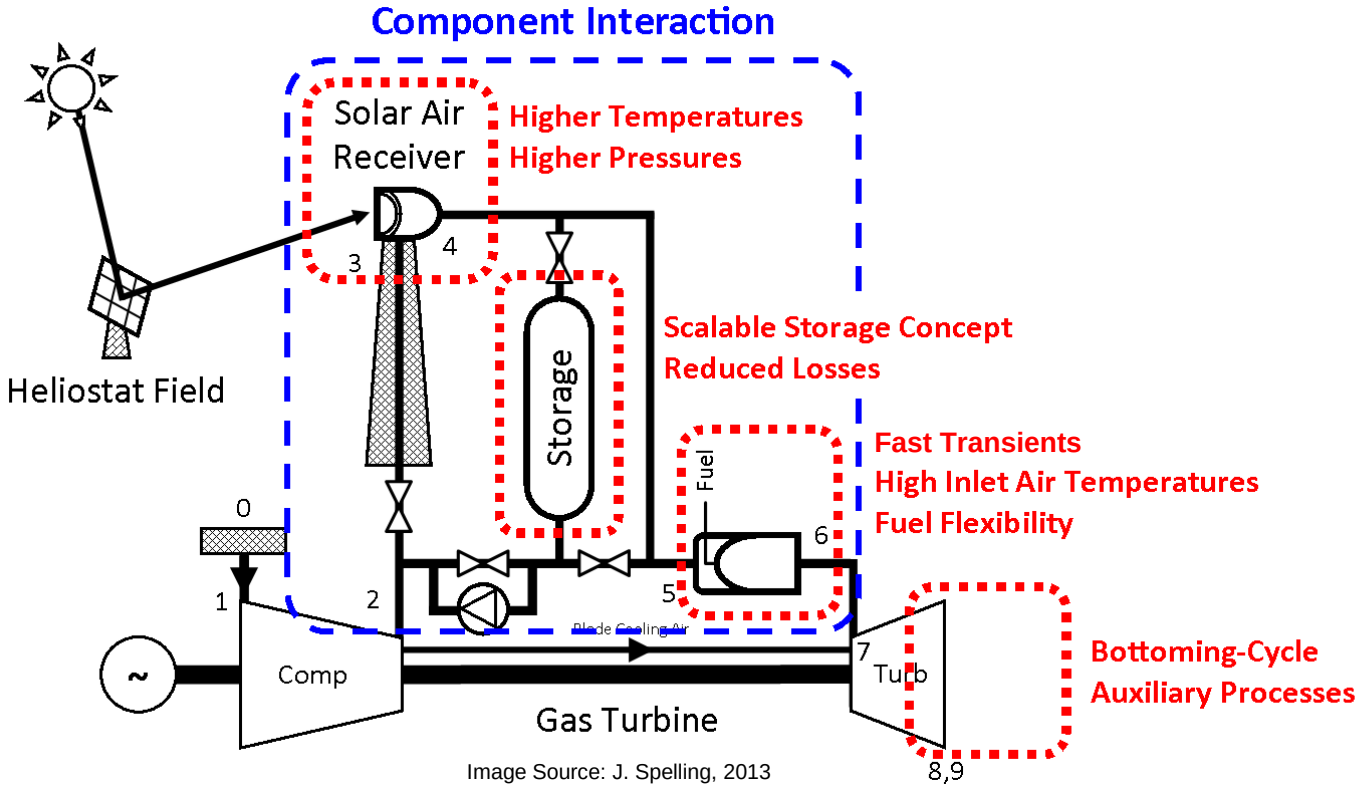

Image Source: J. Spelling, 2013

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Current Proposal Status

The key **markets**, core **technology concept** and main research and **development areas** have all been identified

Current focus is on assembling a world-class consortium

- A **gas-turbine OEM** to anchor the core technology development
- **Utilities and end-users** to analyse markets and plant configurations
- **Research centers** and **universities** to develop the next generation of hybrid solar gas-turbine components and designs

H2020 Application Deadline: 10th September 2014

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Contact

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