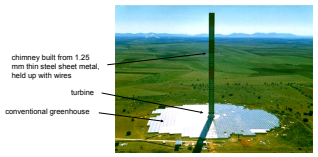
Scaled Demonstrator of Solar Tower Plant

Hermann F Fasel and Andreas Gross

Scope

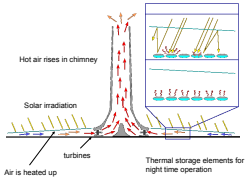
We propose to employ commercial fluid dynamics and structural analysis software for designing a solar tower plant with 44m tower height that will allow for scaled investigations of the characteristics of MW-class full size plants. The proposed demonstrator will be instrumented for scientific analysis and also permit studies of the environmental properties and agricultural potential of the collector greenhouse.
Federal funding is mainly being channeled into photovoltaic (PV) research and development. Simpler and more robust technologies such as solar tower plants attract little support. Our proposed research will proof that solar tower plants can be a viable alternative to PV arrays.
Areas of Challenge Theme are Resources, Energy, and Environment

Prototype of solar updraft tower in Manzanares, Spain
(Total cost approximately 1 Million USD)



Chimney: height: 195 m
diameter: 10 m
Collector (greenhouse) diameter: 244 m
area: ~11 acres
Maximum power output: 50 kW

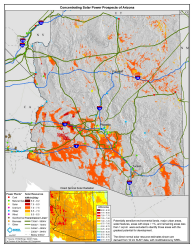
Operating principle



Farming under the collector

- simple design (conventional construction materials and techniques)
- scalable (total output is proportional to collector area times tower height)
- low maintenance (due to its simplicity)
- no system degradation as for PV

100 MW plant would require a 1000 m tower and a 20 km² greenhouse
costs lie mainly in construction and not in operation (free 'fuel', little maintenance and only 7 personnel)
⇨ cost per energy is largely determined by interest rates and years of operation (5¢/kWh for 4% and 20 years to 15¢/kWh for 12% and 40 years)



The Southwest has tremendous potential for solar power generation

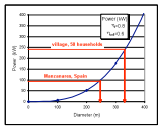
Large areas with less than 1% slope

Many sites near transmission lines that would be appropriate for solar tower plants

power output is directly related to collector size, A_{coll}, and tower height, h,

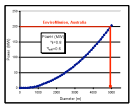
$$P = \frac{2}{3}\eta_{th}\eta_{col}\frac{g}{c_p T_a}hA_{coll}G$$

g=9.81m/s², c_p=1005J/(kgK), T_a is ambient air temperature, and G=1000W/m² is solar irradiation
Typically: turbine and collector efficiency, η_t=0.8 and η_{coll}=0.6
and (for an average Tucson day) inflow temperature of about T_a=90°F



Solar tower plants are **scalable**:

Largest solar tower plant proposed so far is by EnviroMission, Australia
Power 200 MW (200,000 homes)
Diameter approx. 6,000 m - 7,000 m
Height 1,000 m
Collector area max. approx. 9400 acres
will result in 830,000 tons/year greenhouse gas reduction



Focus of proposed research

- In the US focus has been on solar trough and PV technology for solar power harvesting
- Currently available photovoltaic (PV) power conversion units are not competitive when compared with conventional power plants in terms of cent/kWh (the unit production cost is very high and system performance typically degrades considerably over life span)
- Solar-thermal power conversion technologies, such as the solar tower concept, promise to be more cost effective for large power plants than PV systems
- Solar tower plants do not require high-tech production facilities and can be operated and maintained by relatively untrained personnel
- Solar tower plant technology is investigated in Europe and Australia but not in the US
- Solar tower plants are ideally suited for Arizona and the Southwest of the US

- Proposed research program will
  - allow the country to catch up with competition from abroad
  - benefit the nation and Arizona as it will provide a solar power generation alternative that is both, inexpensive and low maintenance
- If technology can be brought to full scale application it will provide jobs and considerably cut back on greenhouse gas emissions and reduce dependence on fossil fuels

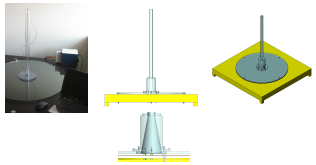
Knowledge/expertise gaps

- Solar tower plants have the potential to provide a lost-cost and low-tech alternative to PV based solar power generation. Issues related to the fluid- and thermodynamics of the collector and the structural design of the tower have to be addressed to provide the confidence level necessary for the construction of MW-class plants.
- In addition, the collector area can potentially be used for greenhouse farming which may create jobs in agriculture. Research regarding the environmental conditions under the collector is needed to determine the agriculture suitability for more arid climates such as Southern Arizona.

Previous work

- We designed and built a scaled demonstrator of the Manzanares power plant for laboratory experiments
- The demonstrator is equipped with instrumentation for obtaining temperature and velocity measurements
- We also carried out a preliminary computational fluid dynamics (CFD) analysis of the plant

3×3ft solar tower laboratory model



The model is equipped with sensors and allows for controlled energy addition

Proposed research

- We propose to employ Computational Fluid Dynamics (CFD) and structural analysis software (FEM) for designing solar tower plants with tower heights of up to 100m that will allow for scaled investigations of the characteristics of up to 200 MW full size plants.
- Explore novel ideas for substantially decreasing the tower height (tower constitutes major cost of plant)
- The proposed demonstrator will be instrumented for scientific analysis and also permit studies of the environmental conditions under the collector. This will determine the agricultural potential of the collector greenhouse.

We propose to build several solar tower demonstrator plants with scientific instrumentation

Power output [kW]	Tower height [m]	Collector (greenhouse) diameter [m]	Collector area [m²]	Tower diameter [m]
0.1	19.8	24.8	483	1
1	42.8	53.5	2,250	2.2
10	92.2	115.3	10,400	4.7
100	198.6	248.2	48,400	10.2

We have established a business contact with
Schlaich Bergermann Solar GmbH, Stuttgart, Germany
who designed and and built the solar tower prototype plant in Spain.

Funding opportunities

The proposed work has high potential for obtaining funding from DOE or NSF and industry

Participants

The main part of the proposed research will be carried out by researchers at the Aerospace and Mechanical Engineering Department at the University of Arizona.
The proposed research will also include researchers from the College of Engineering and the College of Agriculture and Life Sciences.
The PI has close contact with R. Bergermann who was the program manager for the solar tower prototype in Manzanares, Spain, who is currently co-owner of Schlaich Bergermann Solar. The PI has written confirmation that Schlaich Bergermann Solar is willing to cooperate with him on this project.

Hermann F Fasel
Aerospace and Mechanical Engineering Department
University of Arizona
Tucson, AZ 85721
(520) 621-2771
faselh@email.arizona.edu

Andreas Gross
agross@email.arizona.edu

azengineering

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