Proposal

Solar Updraft Tower Power Plant

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SOLARWALL TURKEY

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EXECUTIVE SUMMARY

The information contained in this proposal describes the social and economic benefits and the basic cost of a 50 MW solar power plant for **Sikasso in MALI**. A hybrid solar photovoltaic/thermal updraft system has been designed for the purpose of producing renewable energy from sun.

Hybrid Solar Updraft Towers will have a share already in the near future in solving one of today's dominant challenges: The global, sustainable, inexhaustible and affordable supply of energy.

The principle of this technology is rather simple: under a large solar photovoltaic/thermal panel roof the sun warms up the air which is sucked in by the central vertical cylindrical tube (chimney effect). The updraft wind, thus created, drives turbines/generators and so generates electricity with photovoltaic panels

Due to the soil under the collector working as a natural heat storage system, Solar Updraft Towers can operate 24 h on pure solar energy, at reduced output at night time. Simple water tubes, placed on the ground, increase the storage capacity and can yield a uniform 24 h electricity generation, if desired.

Hybrid Solar Updraft Towers, mainly suitable for large-scale energy production in units of 100 MW or more, can be erected by local labor force and to a high degree with locally available materials.

Solar Updraft Towers can be built in desert countries either to cover regional demand resp. to save oil reserves, or to contribute to the energy supply of e.g. Europe, since the electricity produced by Solar Updraft Towers in the sunny countries can be transported and sold to any place either by transmission lines or – as liquid hydrogen – by ships without substantial losses.

Solar Updraft Towers are particularly reliable. Turbines and generators are the plant's only moving parts. This simple and robust structure guarantees operation that needs little maintenance and of course no combustible fuel.

Electricity from Solar Updraft Towers is the cheapest when compared with other solar power plants. Nevertheless its energy production costs are still somewhat higher than those of "conventional" coal or gas-fired power plants.

1 INTRODUCTION

Current electricity production from coal, oil and natural gas is damaging the environment, is non sustainable and many developing countries cannot afford these energy sources. Nuclear power stations are an unacceptable risk in most locations. But inadequate energy supply leads to or maintains poverty, which commonly is accompanied by population explosion: a vicious circle.

Sensible technology for the wide use of renewable energy must be simple and reliable, accessible to the technologically less developed countries that are sunny and often have limited raw material resources, it should not need cooling water or produce waste and should be based on environmentally sound production from renewable or recyclable materials.

The solar updraft tower meets these conditions and makes it possible to take the crucial step towards a global solar energy economy. Economic appraisals based on experience and knowledge gathered so far have shown that large scale solar updraft towers (≥ 100 MW) are capable of generating energy at costs close to those of conventional power plants. This is reason enough to further develop this form of solar energy utilization, up to large, economically viable units. In a future energy economy, solar updraft towers could thus help assure the economic and environ– mentally benign provision of energy in sunny regions.

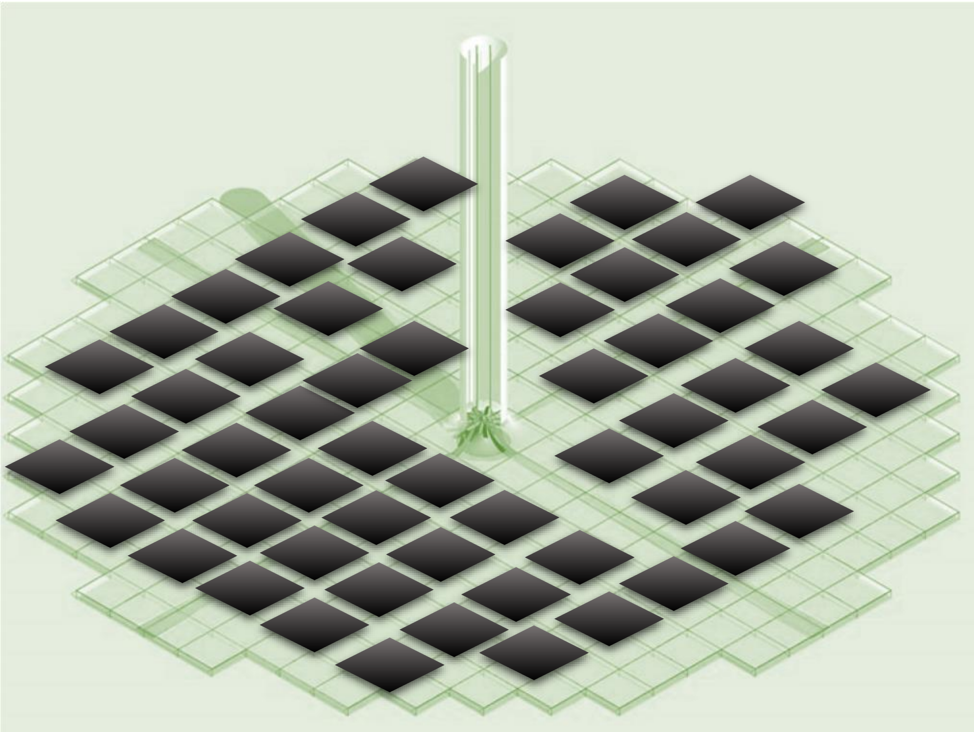


Figure 1. Hybrid Solar Updraft Tower Principle

2 THE HYBRID SOLAR UPDRAFT TOWER TECHNICAL CONCEPT

2.1 Principle

The hybrid solar updraft tower is based on SolarWall PV/thermal technology and its essential elements – transpired solar air collector, photovoltaic panels, chimney/tower, and wind turbines – have thus been familiar for decades, but are combined now in a novel way.

Figure 2. Hybrid Solar Updraft Tower Test Unit

Hybrid solar updraft tower provides up to 300% more energy (in the form of solar electricity and solar heat) than a conventional solar PV system. The heat energy captured from the PV modules is used to produce electricity in the chimney unit. The new solar power technology works as a hybrid system and produces electricity by using two different methods: solar updraft tower and photovoltaics. The secondary benefit is to provide PV cooling by reducing the operating temperature of PV modules, which improves the electrical performance.

PV module efficiency is typically between 8-15%. In a PV module, most of solar energy is converted into heat energy, which normally is lost and provides no value to the system owner.

As well, the heat build-up behind PV modules reduces the electrical output by 0.4-0.5% for every 1°C above its rated output temperature (which is 25°). Given that panels can reach temperatures as high as 90°C, the actual operating efficiency of PV system is often significantly less than the rated output.

For standalone PV systems, high capital costs and low energy production result in very long paybacks. The hybrid solar updraft technology offers a solution that actually makes solar power systems financially feasible in standard industrial and solar power applications.

The principle is shown in Figure 1: Air is heated by solar radiation under a SolarWall PV/Thermal panels; in the middle of the roof is a vertical tower with large air inlets at its base. The joint between the roof and the tower base is airtight. As hot air is lighter than cold air it rises up the tower. Suction from the tower then draws in more hot air from the collector, and cold air comes in from the outside.

2.2 Power Output

Hybrid solar updraft tower provides up to 300% more energy (in the form of solar electricity and solar heat) than a conventional solar PV system. The heat energy captured from the PV modules is used to produce electricity in the chimney unit. The new solar power technology works as a hybrid system and produces electricity by using two different methods: solar updraft tower and photovoltaics. The secondary benefit is to provide PV cooling by reducing the operating temperature of PV modules, which improves the electrical performance.

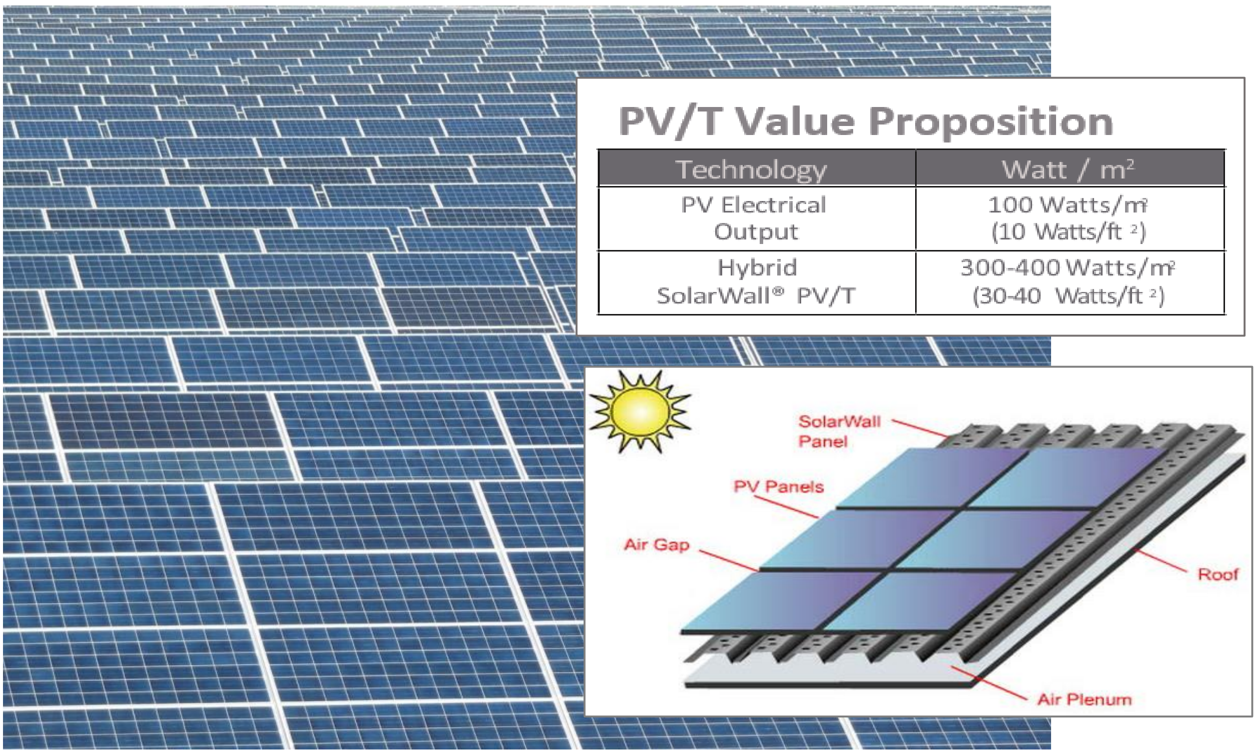
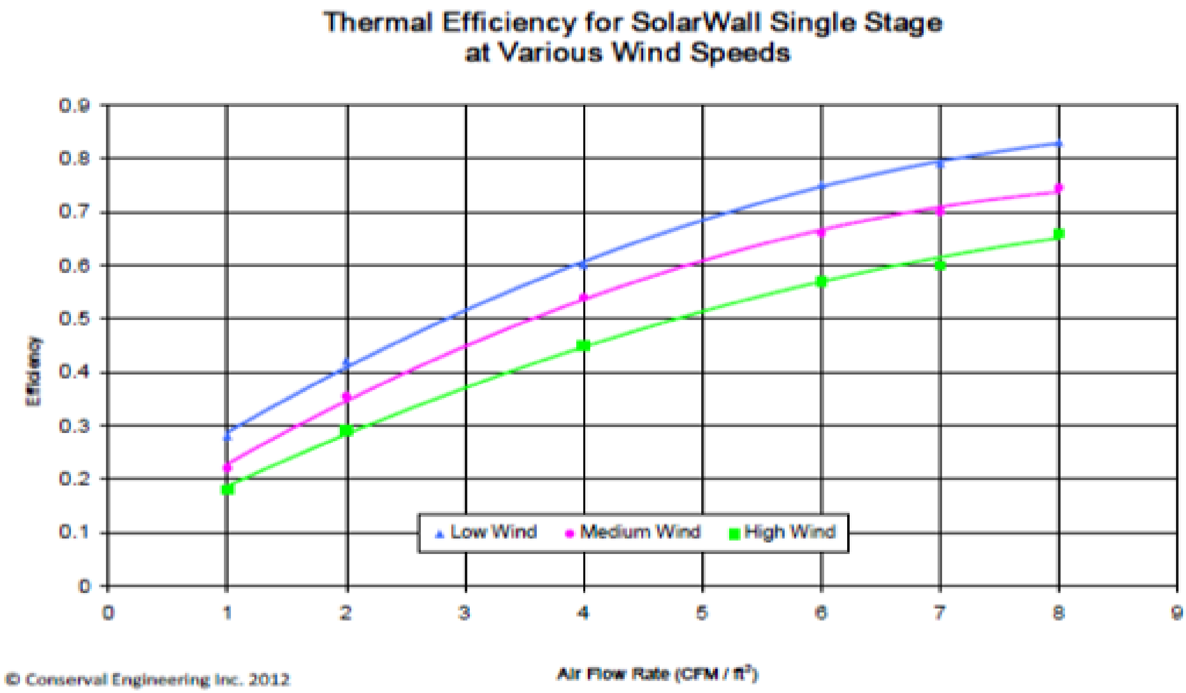
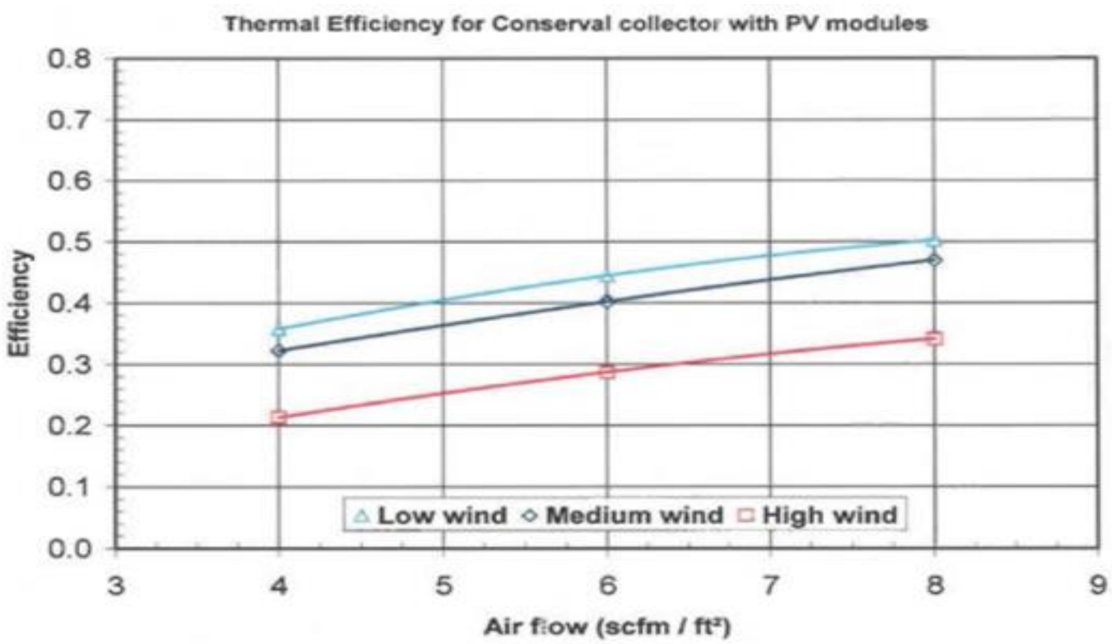


Figure 3. Solar PV/Thermal Principle





2.3 Components

2.3.1 Collector

Hot air for the solar updraft tower is produced by the greenhouse effect in a SolarWall PV/T air collector horizontally several meters above the ground. The height of the collector increases towards the tower base, finally the air is diverted from horizontal into vertical movement with minimum friction loss.

2.3.2 Tower

The tower itself is the plant's actual thermal engine. It is a pressure tube with low friction loss (like a hydro power station pressure tube or pen stock) because of its favorable surface-volume ratio. The updraft of the air heated in the collector is approximately proportional to the air temperature rise (ΔT) in the collector and to the height of the tower. In a large solar updraft tower the collector raises the air temperature by about 30 to 40 K. This produces an updraft velocity in the tower of about 15m/s at full load. It is thus possible to enter into an operating solar tower power plant for maintenance without danger from high air velocities.

2.3.3 Turbines

Using turbines, mechanical output in the form of rotational energy can be derived from the air current in the tower. Turbines in a solar updraft tower do not work with staged velocity like a free running wind energy converter, but as a shrouded pressure-staged wind turbo generator, in which, similarly to a hydroelectric power station, static pressure is converted to rotational energy using a cased turbine. The specific power output (power per area swept by the rotor) of a shrouded pressure staged turbine in the solar updraft tower is roughly one order of magnitude higher than that of a velocity staged wind turbine. Air speed before and after the turbine is about the same. The output achieved is proportional to the product of volume flow per time unit and the pressure differential over the turbine. With a view to maximum energy yield the aim of the turbine control system is to maximize this product under all operating conditions. To this end, blade pitch is adjusted during operation to regulate power output according to the altering airspeed and airflow. If the flat sides of the blades are perpendicular to the airflow, the turbine does not turn. If the blades are parallel to the air flow and allow the air to flow through undisturbed there is no drop in pressure at the turbine and no electricity is generated. Between these two extremes there is an optimum blade setting: the output is maximized if the pressure drop at the turbine is about 80 % of the total pressure differential available, depending on weather and operating conditions as well as on plant design.

3. General system advantages

Apart from working on a very simple principle, solar updraft towers have a number of special features:

1. The collector can use all solar radiation, both direct and diffuse. This is crucial for tropical countries where the sky is frequently overcast.
2. Due to the soil under the collector working as a natural heat storage system, solar updraft towers will operate 24 h on pure solar energy, at reduced output at night time. If desired, additional water tubes or bags placed under the collector roof absorb part of the radiated energy during the day and release it into the collector at night. Thus solar updraft towers can operate as base load power plants. As the plant's prime mover is the air temperature difference (=air density difference) between the air in the tower and ambient air, lower ambient temperatures at night help to keep the output at an almost constant level even when the temperature of natural and additional thermal storage also decreases without sunshine, as the temperature *difference* remains practically the same.
3. Solar updraft towers are particularly reliable. Turbines and generators - subject to a steady flow of air - are the plant's only moving parts. This simple and robust structure guarantees operation that needs little maintenance and of course no combustible fuel.
4. Unlike conventional power stations (and also some other solar-thermal power station types), solar updraft towers do not need cooling water. This is a key advantage in the many sunny countries that already have major problems with water supply.
5. The building materials needed for solar updraft towers, mainly concrete and glass, are available everywhere in sufficient quantities. In fact, with the energy taken from the solar tower itself and the stone and sand available in the desert, they can be reproduced partly on site.
6. Solar updraft towers can be built now, even in less industrially developed countries. The industry already available in most countries is entirely adequate for solar updraft tower requirements. No investment in high-tech manufacturing plants is needed.
7. Even in less developed countries it is possible to build a large plant without high foreign currency expenditure by using local resources and work-force; this creates large numbers of jobs while significantly reducing the required capital investment and thus the cost of generating electricity.

Nevertheless, solar updraft towers also have some features that make them less suitable for some sites: They require large areas of flat land. This land should be available at low cost, which means that there should be no competing usage, like e.g. intensive agriculture for the land. The siting of the solar updraft tower has to be carefully considered in extremely earthquake prone areas.

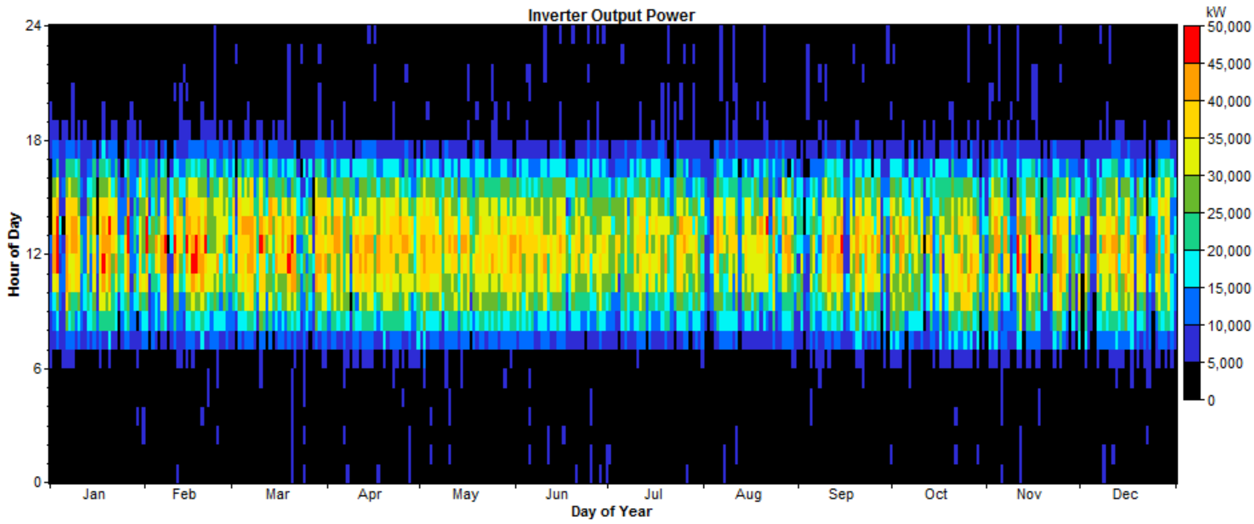
4. Preliminary Energy Yield Protection

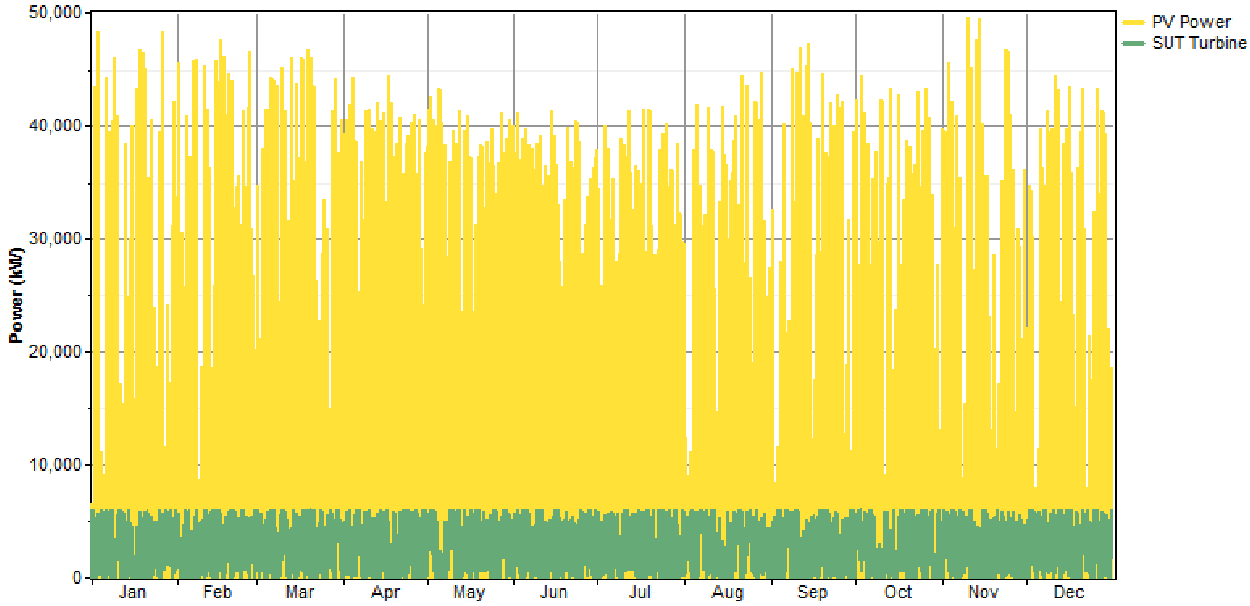
Project location: Sikasso-Weather data

Month	Air temperature	Relative humidity	Daily solar radiation	Atmospheric pressure	Wind speed	Earth temperature
	°C	%	$kWh/m^2/d$	kPa	m/s	°C
January	26.2	20.8%	5.56	97.1	1.8	28.4
February	28.4	21.5%	6.14	97.0	1.8	31.1
March	30.4	31.8%	6.07	96.9	2.5	33.7
April	30.3	47.9%	6.17	96.8	2.4	33.5
May	28.4	62.8%	6.03	97.0	2.8	30.4
June	26.1	75.1%	5.54	97.2	2.6	27.3
July	24.7	81.1%	5.16	97.2	2.4	25.6
August	24.4	81.9%	4.93	97.2	2.1	25.2
September	25.2	76.5%	5.20	97.2	1.7	26.0
October	26.6	64.4%	5.62	97.1	1.5	27.6
November	27.9	38.8%	5.68	97.0	1.7	29.7
December	26.6	22.4%	5.49	97.1	1.9	28.3
Annual	27.1	52.2%	5.63	97.1	2.1	28.9

Estimated Electricity Production	kWh/yr
PV array	85030208
Chimney turbines	26210808
Total	111241016

PV panels		
Quantity	Value	Units
Rated capacity	45,000	kW
Mean output	9,707	kW
Mean output	232,959	kWh/d
Capacity factor	21.6	%
Total production	85,030,208	kWh/yr
Minimum output	0	kW
Maximum output	47,685	kW
PV penetration	19.4	%
Hours of operation	4,368	hr/yr
Turbines		
Total rated capacity	5,000	kW
Mean output	2,992	kW
Capacity factor	59.8	%
Total production	26,210,808	kWh/yr
Quantity	Value	Units
Minimum output	0	kW
Maximum output	6000	kW
Wind penetration	5.98	%
Hours of operation	8,380	hr/yr





5. Detailed breakdown of equipment and installation

Group	Description	Amount	Unit
	Solar Air Heating panels		
1	SolarWall SW200 1000 Watt	450000	Pcs
	Modules		
2	Astrosolar 260 Watt poly crystal or similar	173077	Pcs
	Turbines		
3	Special production – 250 kW	20	Pcs
	Inverter and transformer		
4	AEG 1250 kVA Station incl. transformer	30	Pcs
	Mounting system		

	SolarWall framing system	450000	Pcs
5	PV mounting system	173077	Pcs
	DC components		
6	PV IcX combiner box	250	Pcs
	Monitoring system		
7	Special design	3	Pcs
	Cables & Accessories		
8	DC solarcable AC cable CAN cable MV cable Connectors Earthing cable	50000	kWe
	Mechanical and electrical installation		
9	SolarWall Modules Tower Turbines Inverter and MV DC and AC cable Switchgear Earthing solar system	50000	kWe
	Site management and external services		
10	Surveying Project management Design civil and electrical works H&S coordination Legal and tax advise	1 24 1 24 1	Pc Month Pc Month Pc
	Other contractor costs		
11	Occupational health and safety Generator during construction 24h security guard	60 60 8760	Month Month h/year
	Internal Engineering Services		
12	Technical planning Project Management Commissioning Travel expenses Supervision and Training	incl	incl
	Transportation and Import costs		
13	Transportation to Mali Transportation within Mali Import duties	incl	incl

6. Social and economic benefits

1. Tallest structure of the country and its high tourism potential; a big income from 300 m height tower which is not comparable with any other power plant such as PV or wind
2. Prestigious installation for the country, prestigious facility for development
3. Possibility to use as broadcast-telecom antennas, so double benefit plus no need to build additional tower for the future
4. A very important observation deck
5. High electricity production
6. Agricultural production possibilities
7. An emergency shelter for exigency
8. Huge CO2 reduction
9. Solar tower built in the desert, instigates plant growth
10. Condensation created at night enlivens the soil with moisture
11. Transforms the desert into arable land
12. A local labor power needing and its social and economic benefits
13. Different kinds of crops can be planted depending on the local soil and moisture conditions
14. Possibility to use for crop drying
15. Scientific interest and a significant contribution to development
16. Lifetime continuous job creating potential

7. Basic result of project

Total EPC price	**€**	**101,000,000**
Estimated solar generation income (electricity rate 0.18 €/kW)	**€**	**20,023,383**
Estimated preliminary design period after approval	**month**	**10**
Estimated construction time to build SUT after preliminary design	**month**	**36**
Estimated commissioning time after completing construction	**month**	**3**
Simple payback period	**years**	**5**