GREENTOWER: PERFORMANCE GUARANTEES THROUGH INSURANCE POLICIES

WW Stinnes
MD GreenTower Limited, Pretoria/Haiger, Consultant for the Northern Cape Province

ABSTRACT

This paper shows how the resistance to new solar technologies and distrust in their performance can be overcome by performance guarantees based on insurance policies. As example serves the GreenTower® technology being developed from Prof. Schlaich's Solar Chimney by using two thirds of the collector as a greenhouse. Despite high profits and low cost of power the investment community remained reluctant until Prof. Kröger from ITM [1], Stellenbosch University, was contracted to issue a guaranteed expert opinion on power delivery, based on which insurance policies cover the GreenTower's performance. Seven GreenTowers are at present under negotiation.

1. INTRODUCTION

Market entrance of new sustainable and especially solar power technologies is often hindered by the perception of too high risks regarding the reliability of the specific technology, the surety of power supply and the economic storage of power. In the case of the Solar Chimney/ GreenTower its tall chimney flue of 1 000/1 500m also caused some concern. The greatest risk was seen to be the upgrade from the Spanish pilot plant's generation of 50kW to the 100 to 400MW generation of a commercial plant. This is a specific problem of the Solar Chimney, sown in Figure 1, since efficiency and power production are nearly directly porportional to its height. Hence only tall chimneys with large collectors will produce power at decent cost. The medium size 1, 10 and 30MW plants were regarded too expensive by interested investors to serve as demonstration plants without commercial value.

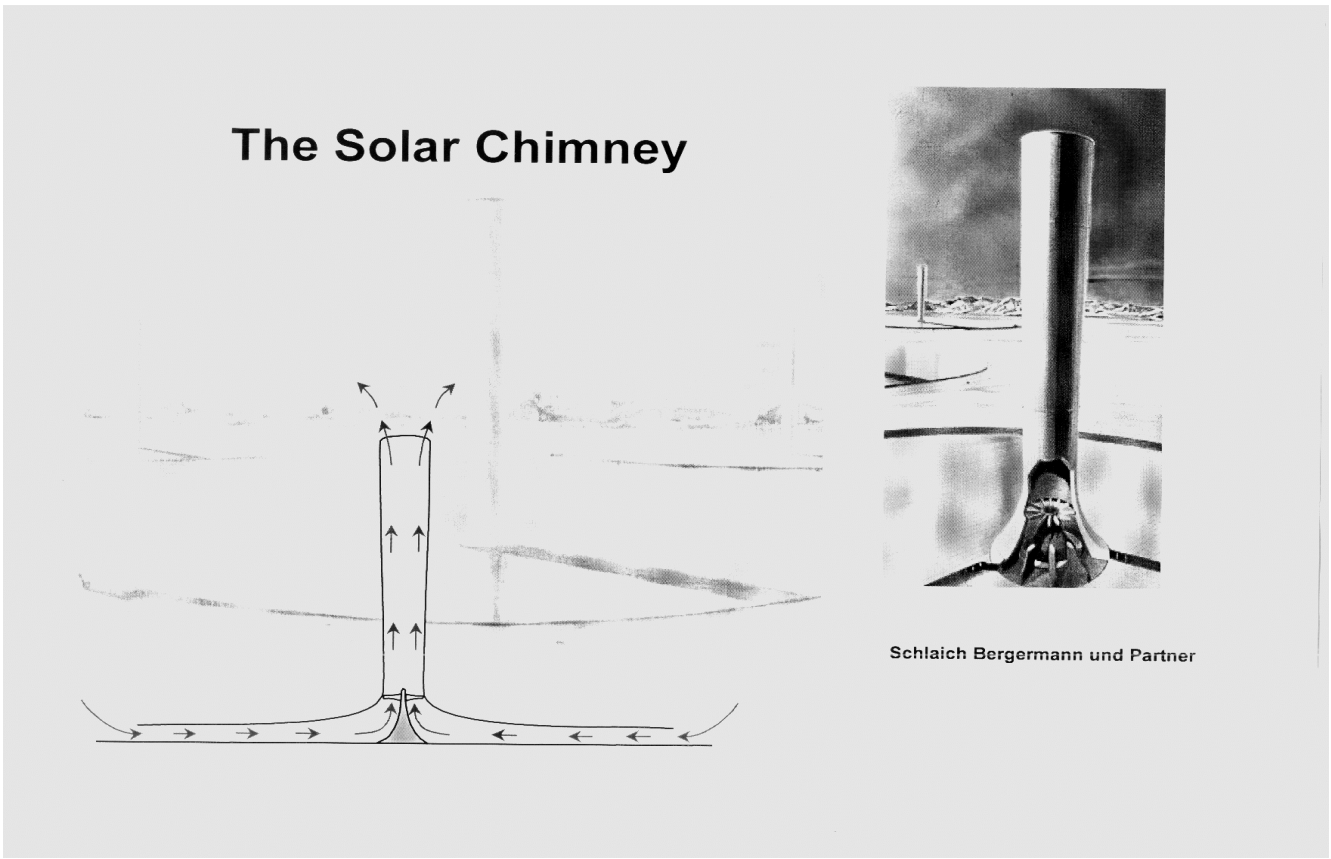


Figure 1: The Solar Chimney – Full Scale Appearance and Working Principle.

A pre-feasibillity study undertaken 1997 in South Africa by the Northern Cape Administration showed Prof. Schlaich's Solar Chimney to produce the cheapest electricity in the Northern Cape due to the lowest life-cycle (160 year design life-span) and lowest running cost of all power technologies including (See Table 1) a new power line from Mpumalanga [2]
:

Table 1 : Comparison of Life Cycle Costs and Cost of Power Generation

Million Rand	Solar Chimney	Phoebus II	Schlaich Dish	SEGS LS3	Coal-fired	Combined Cycle
Investm. quoted	2 371 store,savs.	2 700	1 900	2 600	1 485	1 186
O & M p.a.	3	48	33	50	74	33
Fuel p.a.	-	130	-	130	82	190
Investment 80 y	2 371	9 000	6 333	8 660	4 950	5 930
80 years running	240	14 240	2 640	14 400	12 480	17 840
Interest 80 y	6 160	5 840	4 160	5 600	3 200	2 840
Life cycle cost	8 890	29 080	14 133	28 660	20 630	26 610
Production	5,1	34,4	17,3 – 29,2	33,8	18,5	21,8
Abatement	-	2,5	-	2,5	10,0	2,7
Cost/kWh ZAc	5,1	36,9	17,3 – 29,2	36,3	28,5	24,5

In spite of this no investment was forthcoming . This was particularly disappointing, since the Kalahari, comprising a great part of the Northern Cape, exhibits the world's highest insolation (solar radiation), making solar power generation the first medium and long-term option in South Africa, whilst its cheap coal will only last 40 years [3].

2. WORKING PRINCIPLE

Visible radiation passing through the collector glass is absorbed by the floor, heating the air in the large, glass covered collector (∅ = 6,9km) by convection, i.e. hot air layers adjacent to floor rise in small turbulent vortices and mix with the upper air. The hot air causes an updraught by buoyancy in the large, centrally situated chimney (height = 1 500m) and drives a turbine with generator.

The hot floor also emits infrared radiation which is absorbed by the glass cover and reradiated to outer space through an "optical window". This loss depends critically on the floor's temperature which is inter alia reduced by vegetation inside the collector so that the outer two third area of the collector is used as a 2 500ha greenhouse.

The Solar Chimney utilizes diffuse light from an overcast sky and can be used in the tropical belt. Little power production is lost with an overcast sky due to the clouds´ high infrared radiation so that it is much less affected by bad weather than other solar technologies. It possesses controllable thermal water storage for up to six days of full power production. The envisaged base load power production is 400MW for the specifications above.

3. RISKS, GUARANTEES, INSURANCES

The following are seen as the possible risk areas of the GreenTower :

- The tall chimney flue of 1 500m
- A lack in generation performance
- Energy losses in the greenhouse by evaporation
- A lack of energy storing capacity
- Unreliability of the power train.

3.1 THE TALL CHIMNEY FLUE

The tall chimney is surely one of the best researched structures in the world, not only by the eminent and world renowned structural engineer; Prof. Schlaich, Germany [4], but also by Ben. C. Gerwick, USA [5]; Lars Tubro, India [6]; Prof. Harte, Wuppertal University, Germany; Mr. Haselwander, Hochtief, Germany; Mr. Prukl, Knight Piésold, SA; etc.. The structural risk is fully covered by professional insurances for design, based on the professional guarantees of Prof. Schlaich and Prof. Harte, and construction, based on the builders' insurances, so that there exists no risk for the prospective investors.

The secret behind the strength of the thin-walled and thus affordable chimney structure are the spoke wheels which keep the cross section of the flue at all places even under the heaviest wind loads (210km/h at 10m height, 400km/h at 400m height) standard at a circular cross section. This completely prevents denting and ensures that only compression stresses are experienced in the structure, so that the heavy reinforcement indeed ensures a very high safety margin. The spoke wheel construction is shown in Fig 2 as part of a computer simulation.

3.2 GUARANTEED POWER PERFORMANCE

When it became clear in 1997 that the upgrade from the pilot plant's 50kW to a 200/400MW commercial plant's power generation posed an obstacle to financing in South Africa, Prof. Kröger of ITM (Institute of Thermo-dynamics and Mechanics at Stellenbosch University) was contracted as the world´s foremost expert on cooling towers. He undertook to guarantee his professional expert findings on the Solar Chimney's/ GreenTower's power capacity, upon which insurance policies will be issued to cover the plant's power performance.

The understanding is that he will publish the worst case findings as he proceeds with his calulations. The reason is that the calculation of the updraught as driving force is always the result of a small difference of two big entities,

namely the weight of the inner and outer air column.Uncertainties of 1% in the latter can thus easily result in 10 to 20% uncertainty in the former. The goal of Prof. Kröger's work is to incorporate all the recent improvements of the GreenTower technology and to reduce the difference between worst and best case to 10%. At the end of the feasibility study he will guarantee the then worst case as the insurable power performance. The insurance company will take the 10% uncertainty below the insured performance as the maximum risk.

Please note that only the means to bring power generation to its orignal value is insured and the shortfall of power generation only for the short building period of the additional collector area to compensate the shortfall.

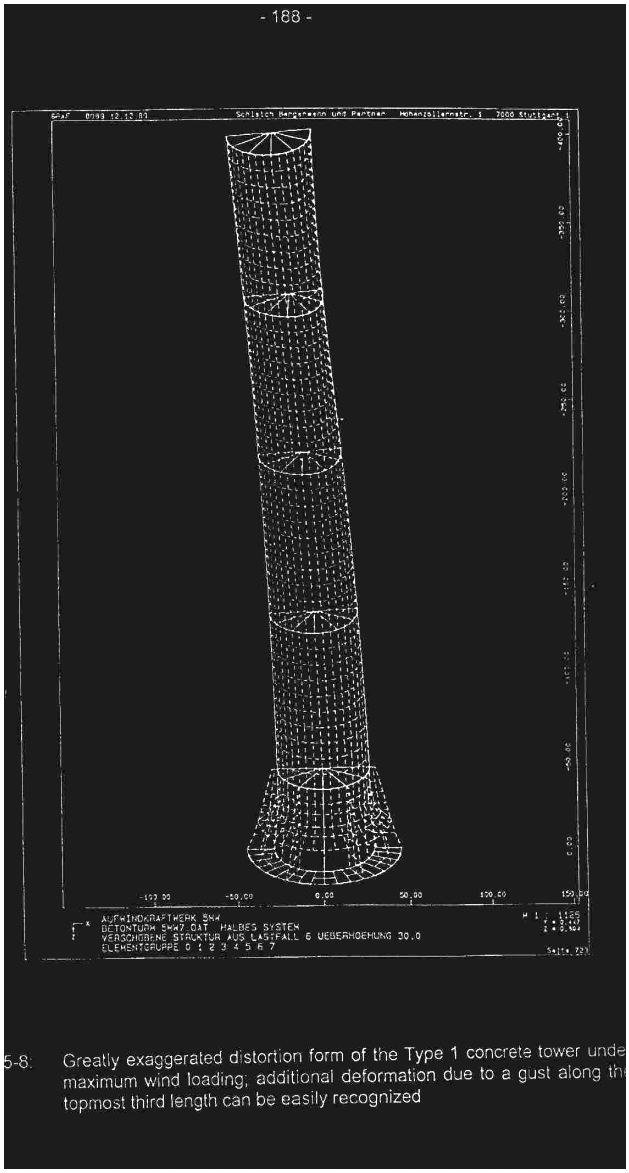
With the introduction of the greenhouse in the collector the increase of the collector area to be financed by the insurance company increases the greenhouse area by the factor 1,5. Since the greenhouse profits are more than double the profits from power sales (see Table 2), they can and will be used to finance the additional collector area. Hence the risk of the insurance company is nil and so is the risk of the investor. Thus no premium will be paid to the insurance company but only a small interest for keeping the building capital available, although the insurance company will "underwrite the risk" which will reduce the risk of a lack of performance to zero.

These insurance policies can also serve as performance guarantees for lending banks and big power clients.

3.3 ENERGY LOSSES IN THE GREENHOUSE

Calculations based on comprehensive price monitoring for fresh produce in Europe [7], intensive, humus- and drip irrigation based greenhouse agriculture in South Africa [8] and export costing by using refrigerated containers [9] showed big profits (see below) for a greenhouse comprising the outer two thirds of the collector area. The only hindrance was the general perception that evaporation by vegetation in the collector would reduce power production.

However, during his 1999/2000 initial research on the Solar Chimney/ GreenTower for the Northern Cape Province Prof. Kröger, ITM, found theoretically and experimentally that vegetation in the collector on the contrary increases power production, especially in combination with shadow nets.



5-8: Greatly exaggerated distortion form of the Type 1 concrete tower unde maximum wind loading; additional deformation due to a gust along th topmost third length can be easily recognized

Figure 2: Solar Chimney under wind load, computer simulation by Schlaich Bergermann & Partner

This important result assures that power and agricultural production support each other so that no bad compromise is required and the high greenhouse profits can directly be combined with maximum profits from power sales. These facts will also be part of Prof. Kröger's expert guarantees and thus of the insurance policies in § 3.2.

Table 2: Annual Pretax Profits from Greenhouse with Exports to Europe

Crop	Prod.cost million $	Hectare	Yield /Ha ton	Storage/transp.million $	Total cost million $	Prod.price $/kg	Total income million $
Tomatoes	1,60	300	140	9,71	11,31	0,80	33,60
Cherry tomatoes	1,37	200	80	3,71	5,09	1,43	23,77
Peppers	2,29	500	50	5,71	8,00	1,40	35,00
Melons	1,14	300	70	4,86	6,00	1,00	21,00
Cut flowers	5,71	300	50	3,43	9.14	2,86	42,86
Herbs/lettuce	2,44	400	20	1,86	4,30	6,66	53,17
		2 000			43,86		209,43
NETT PROFIT					166		

3.4 CAPACITY OF THE ENERGY STORE

Although it was found originally that the theoretical store capacity in the GreenTower´s controllable energy (water) stores had a capacity of up to 14 days full power production, this figure was reduced to six days due to possible interference with plant root temperatures in the greenhouse. Other promising store mechanisms are in an advanced state of investigation (provisional patents) and will be included in ITM's expert calculations, as the interaction between energy stores and power production is an integral part thereof. This will also include seasonal storage. They will automatically be included in the insurance policies in § 3.2.

3.5 RELIABILITY OF THE GREENTOWER

The Solar Chimney pilot plant in Spain was operated nearly continuously for seven years and for 32 months in fully automatic mode without losing a single second on faults. No other technology ever achieved this reliability especially for a first of its kind [12]. The concept of a slow turbine operating in a gust-free and non-corrosive environment ensures high reliability and a long life-span.

The GreenTower's special concrete with a high fly ash ratio for better workability has characeristics similar to the Roman pozzolanic concrete, which has now lasted 2000 years despite aggressive environments. The chimney in non-aggressive environments should last as long.

The extremely slow running hub and periphery-supported turbine with maintenance-free magnetic bearings and linear generators incorporated in the outer rim should easiliy reach the design life-span of 160 years taking the 80 year life-span of big water turbines into account, running at much higher speed in an aggressive medium. This long life-span automatically ensures the reliability of structure and power train. Strict measures including micro-crack testing will be taken to ensure proper workmanship and to detect faulty parts at an early stage.

4. CONCLUSION

Table 2 shows the high pre-tax profit of US$166m p.a. from greenhouse exports to Europe as a direct result of Prof. Krögers work in §3.3. Since exports are only envisaged during the southeren summer, the average profits from the greenhouse amount to US$114m p.a.and total GreenTower profits to US$167m p.a**.** [13**]** ≈ 30,4% return on capital. Loans can be paid back in 10 years.

The attractiveness of the GreenTower technology´s high profits despite low power prices and low risk through ITM guarantees and insurance policies recently resulted in serious negotiations for three GreenTowers in South Africa and four in Namibia. The GreenTower's long-term cheap power is the most important prerequisite for these two economies to grow sustainably. Both countries depend on low cost mining, beneficiation, manufacturing, desalinated water etc. for international competitiveness and job creation.
The GreenTower might be a good example for new solar technologies to show an alternative way to enter the market without waiting for grants and probably unsustainable incentives.

5. REFERENCES

[1] Institute of Mechanics and Thermodynamics, Mechanical Engineering, University Stellenbosch

[2] Stinnes W.W. *Pre-feasibility Study on a 200MW Solar Power Station in the Northern Cape May 1997* pp 16-18, www.greentower.net

[3] *Mining Weekly, July 18-24*, *2003,* p 4

[4] A. Holgate *The Work of Jörg Schlaich and his Team*, Ed. Axel Menges 1997, ISBN 3-930698-67-6

[5] Ben Gerwick *Letter to Prof. Schlaich, 21.12.95*, Pre-feasibility Study 1997 [2], pp 59-60

[6] W. Schiel *Private Communication*, May 1996 Schlaich Bergermann & Partner, Stuttgart

[7] Frau Kuckhoff, Dr. Bär *Direct Information*, May 1999, Zentrale Markt- und Preisberichtstelle Bonn, Kundenservice

[8] J. Alleman, *Private Communication*, May 1999, Roodeplaat Landboustasie, Pretoria

[9] L.A. von Broembsen *Private Communication*, 2000, Cape Span, Cape Town,
P. du Plessis *Private Communication*, 2000, Karsten Boerderye, Kanoneiland, NCP

[10] D. Kröger *Solar Chimney Power Plant*, ITM Report DGK/5/2000, see [1], not published

[11] A.Hille *Private Communication on experiments executed*, Albrecht Hille Consulting, Aachen, 1999

[12] J. Schlaich *The Solar Chimney,* Ed.Axel Menges 1995, ISBN 3-930698-69-2, p 31

[13] W.W. Stinnes *The GreenTower in a Nutshell*, pp 8-10, www.greentower.net

Author: W.W. Stinnes holds an B.Sc. and M.Sc. degree in Physics from Pretoria University. He is at present MD of GreenTower Ltd which developes the GreenTower technology with six Universities and 17 other research bodies. He is consultant to the Northern Cape Administration on energy and RE matters.

Presenter: W.W.Stinnes presents the paper himself