

# Solar Energy Research Center

University College of Falun/Borlänge



Lars Broman  
Assoc. Prof., Director

Eric Båve  
MSc Civil Engineering

Kent Börjesson  
Engineer

Göran Eriksson  
Assistant

Kjell Gustafsson  
BSc

Svante Nordlander  
MSc Engineering Mechanics

Mats Rönnelid  
BSc

#### Associates

Arne Broman, Göteborg  
Professor

Lars Dahlgren, Norrköping  
PhD Meteorology

Sven Eketorp, Stockholm  
Professor

Per Isakson, Stockholm  
Licentiate in Engineering

Björn Karlsson, Älvkarleby  
Assoc. Prof.

Aadu Ott, Gislaved  
Assoc. Prof.

## SERC

University College  
of Falun/Borlänge  
P. O. Box 100 44  
S-781 10 Borlänge  
SWEDEN  
Phone +46-243 734 00  
Telefax +46-243 781 71

CENTRUM FÖR  
SOLENERGIFORSKNING  
Högskolan i  
Falun/Borlänge  
Box 100 44  
781 10 Borlänge  
Tel 0243-734 00  
Telefax 0243-781 71

Rapport från / Report from  
ISES Solar World Congress  
Hamburg September 13-18 1987

Lars Broman, Kent Börjesson,  
Svante Nordlander, Mats Rönnelid

ISSN 0284-1568

SERC-UCFB-013  
May 1988

Rapport från / Report from  
ISES Solar World Congress  
Hamburg September 13-18 1987

Lars Broman, Kent Börjesson,  
Svante Nordlander, Mats Rönnelid

ISSN 0248-1568  
SERC-UCFB-013  
May 1988

## Innehåll

Abstract .....	3
1. Allmänt .....	4
2. Informella kontakter .....	6
3. Några intressanta föredrag .....	9
4. Utställningen .....	11
Tack .....	12
Bilaga 1: Intervju med Harry Tabor ....	13
Bilaga 2: Broman, L., Rönnelid, M., and Sallah, S. O. A. On the Role of Solar Electricity in Rural Development .....	17
Bilaga 3: Nordlander, S. and Broman, L. A Method to Take the True Skyline Into Account in Simulation Programs .....	22
Bilaga 4: Carroll, D. Solar Shenanigans at High Latitudes (or How I Was Shanghaied to Sweden). SunWorld Vol. 11, No. 4 (1987)	27

## Abstract

The 1987 ISES Solar World Congress was held in Hamburg, FRG September 13-18. At this overwhelming conference about a thousand papers were presented, most of them as posters. Some of those are summarized in the report as well as our impressions from the large exhibition. The appendices include a transcription of an interview with Harry Tabor, the two papers that we presented and an article from SunWorld with roots in our Hamburg odyssee. Our participation was financed by the Swedish Council for Building Research (LB, SN), the University College of Falun/Borlänge (KB) and the Swedish Board for Technical Development (MR).

## 1. Allmänt

Vi reste till Hamburg för att delta i ISES Solar World Congress, och speciellt för att presentera två uppsatser, lyssna på ett antal föredrag och presentationer, knyta nya och återknyta tidigare kontakter, besöka den stora solenergiutställningen samt marknadsföra konferensen North Sun '88 som ska hållas i Borlänge i augusti 1988.

Att delta i en kongress av jätteformat är en stor upplevelse och Solar World Congress var helt överväldigande. På plats fanns 1700 delegater från hela världen. Rum stora som balsalar var fyllda med stora skärmar för posters, över 900. Två jättelika hörsalar, riktiga teatersalonger, användes för plenumsessionerna och myriader mindre rum för posterpresentationerna. Så mycket solenergiforskare samlade på en plats var en riktig styrkedemonstration, och mängden information som deltagarna spred till varandra var enorm. Bara sammanfattningarna av de ca 1000 presentationerna fyllde två tjocka volymer. När Proceedings småningom kommer lär de nästan komma att fylla en hel bokhylla. Ett bra mått på solenergiaktiviteten i världen!

Vi presenterade två posters vid kongressen (alla "contributed papers" som accepterats presenterades på detta sätt), vilket dels innebar att sammanfattningar av våra uppsatser sattes upp på varsin skärm, dels att vi fick två minuter (!) vid vardera två sessioner för presentation av postern. De aktuella skärmarna var inburna till dessa sessioner, så efter de korta presentationerna inför hela gruppen fick vi tillfälle till direkta samtal med speciellt intresserade. Ganska många talade med oss och fick ytterligare information. Speciellt intresse väckte vår presentation av "A Method to Take the True Skyline Into Account in Simulation Program" eftersom vi hade med oss en dator och kunde demonstrera metoden direkt.

Många av plenumföredragen var av hög klass och gav sammantagna en god bild av var solenergin står i världen idag. Våldigt många posters var också spännande och en hel del hade innehåll av speciellt intresse för oss. Kollisioner mellan olika samtida programpunkter gjorde att vi missade många presentationer som vi velat höra, trots att vi normalt delade upp oss på olika sessioner. Tyvärr var det också en hel del abstracts som väckte vårt intresse men där föredragshållaren och hans poster aldrig syntes till. Alla presenterade föredrag kommer att publiceras i Proceedings för vem som helst att läsa. Därför kommer vi inte att redogöra för några föredrag i denna rapport utan nöja oss med att (i avsnitt 3) lyfta fram en handfull som vi av ett eller annat skäl tyckte särskilt bra om.

Väl så väsentligt som föredragen och presentationerna är de möjligheter en konferens ger att träffa andra forskare inom sitt eget område, och Hamburg-konferensen var mycket givande för oss i den aspekten. Samtal med Duffie, Beckman, m fl har redan betytt mycket för vår verksamhet. En kortfattad redogörelse för våra viktigaste kontakter ges i avsnitt 4.

Till konferensen hörde en stor utställning med såväl universitetsinstitutioner som kommersiella företag som utställare. De fanns alla med i en utställningskatalog med uppgifter om adresser osv. I avsnitt 4 beskriver vi några av våra reaktioner på utställningen.

Vårt sista (men inte minst viktiga) skäl att vara med i Hamburg var att informera om North Sun '88. I BFRs monter i utställningshallen fanns en stor skärm om North Sun '88 som vi hade hjälpt till att ta fram. Såväl där som i kongressbyggnaden spred vi och andra ledamöter i North Sun '88-kommitteer över 1000 exemplar av "First announcement and call for papers". Denna och övriga marknadsföringsåtgärder tycks (tillsammans med ett bra program, förstås) i skrivande stund ha lockat så många forskare att årets upplaga av North Sun blir nästan dubbelt så stor som den förra.

## 2. Informella kontakter

Vi träffade och diskuterade med många personer och fick många goda kontakter som redan hunnit betyda mycket för SERCs verksamhet. Några av dessa samtal gällde vårt arbete med datorsimuleringar:

J R DUFFIE, University of Wisconsin. Vi hade allmänna diskussioner med honom om lämpliga hjälpmedel vid simulering av solvärmesystem. Duffie ansåg att behovet var mycket stort, han var intresserad av vårt projekt och hänvisade i konkreta frågor till W A Beckman.

W A BECKMAN, University of Wisconsin. Han var mycket intresserad av grafisk front end processor till simuleringsprogrammet TRNSYS. Han berättade om deras eget utvecklingsarbete och om Eric van der Bulcks och Jim Brauns text front end. Han menade att vår planerade grafiska front end PRESIM skulle bli ett starkt komplement till dessa och till TRNSYS. En av oss (SN) bjöds in till University of Wisconsin och var där i januari 1988. (Vid den vistelsen drogs bl a riktlinjerna för ett formellt samarbete mellan University of Wisconsin och Högskolan i Falun/Borlänge upp.)

S ÖSTERGAARD JENSEN, Danmarks tekniska högskola. Han representerar Danmark i EG-kommissionens arbetsgrupp kring simuleringsprogrammet EMGP2. Vi diskuterade möjligheterna till ett samarbete. Kontakten ledde till att en av oss (SN) träffade arbetsgruppen vid ett möte i Bryssel i november 1987. (Gruppen är klart intresserad av vad vi gör, men ett samarbete mellan dem och forskare utanför EG är så komplicerat av politiska skäl att vi sedermera beslutat oss för att låta samarbete med University of Wisconsin och anpassning av PRESIM till TRNSYS komma i första hand.)

H ANDERSSON, BFR (numera EFN) och P ISAKSON, KTH. (Ibland visar det sig lättare att träffa svenskar

utomlands än på hemmaplan.) Vi hade några väldigt givande och konkreta sammanträden om det framtida arbetet med PRESIM. Som ett resultat av dessa pågår nu utvecklingen av PRESIM i samarbete med Isakson och E Figueroa på mätcentralen, KTH och till stor del finansierat av BFR. Isakson gav dessutom värdefulla synpunkter på ett av våra papers (SN och LB, A Method to Take the True Skyline Into Account in Simulation Programs, se bilaga 3) vilket föranledde en snabb omarbetning av datorprogrammet inför presentationen.

Några av våra samtal gällde arbetet med koncentrerande strutar för solceller:

J O'GALLAGHER, University of Chicago. Vi hade ett givande samtal med honom om datorsimuleringar av icke-avbildande koncentratorer och intensitetsfördelningens stora betydelse för solcellens prestanda. Även några samtal med T OKSA och M HÄMÄLÄINEN, Åbo universitet, om simulering av koncentratorer var givande.

P B McCORMIC, University of Western Australia. Vi diskuterade hans tidigare arbete med plana reflektorer (tråg) och solföljande solcellsmoduler. Han var mycket intresserad av vårt arbete med strutar och styrkte oss i vår uppfattning att användningen av sådana i många fall kan vara ekonomiskt försvarbara. Han hade också intressanta ideer om solföljare där samma solceller samtidigt är givare och ger ström till motorn som vrider panelen. (En svårighet med den föreslagna anordningen är dess ganska dåliga precision i inriktningen. Vi har en ide som vi håller på och utvecklar om hur noggrannheten ska kunna göras tillfredsställande hög.

K G T HOLLANDS, University of Waterloo. Med honom diskuterade vi icke-avbildande koncentratorer och vårt arbete med dessa. Vi sände efter konferensen över vad vi publicerat i ämnet, och kommer förhoppningsvis att få synpunkter på dessa under konferensen i höst.

Några av våra samtal gällde solceller och utveckling:

S O A SALLAH, Gambia Renewable Energy Centre och O JAMMEH, Gambia Ministry of Industrial Development and Economic Planning. Sallah var medförfattare till ett av de papers som vi presenterade i Hamburg (LB, MR och SDAS, On the Role of Solar Electricity in Rural Development, bilaga 2). Diskussionerna ledde bl a fram till att vi sedermera sökt pengar (från SAREC) till ett nytt samarbetsprojekt, Micro Electrification in the Gambia. Det är ännu inte klart om vi får något anslag, men projektet drivs ändå (om än med knapp styrfart).

En av oss (LB) återknöt kontakter med solenergi-  
forskare som han träffade i Prag tidigare under  
året:

R L DATTA, Bombay. Han bjöd in LB att hålla  
gästföreläsningar vid Indian Institute of  
Technology i Bombay (LB var där i mars i år).

A A M SAYIGH, University of Reading. Han bad LB att  
ställa upp som medlem i the International  
Organizing Committee för World Renewable Energy  
Conference i Reading, 1990. Han förmedlade också  
kontakt med D CARROLL, redaktör för ISES' tidskrift  
Sunworld. Hon följde med oss till Sverige och skrev  
sedermera en artikel om SERC och North Sun '88 i  
Sunworld nr 4, 1987 (se bilaga 4).

H TABOR, Israel Scientific Research Foundation. LB  
gjorde en bandad intervju med Tabor. Denna åter-  
finns i bilaga 1.

### 3. Några intressanta föredrag

JOHN R DUFFIE, University of Wisconsin: Farrington Daniels Award Lecture. Detta handlade om ISES publicistiska verksamhet och gav en liten historisk återblick på verksamheten och personerna i ISES - intressant för oss som inte varit med så väldigt länge. Duffie berättade också om det registersystem som byggs upp vid Solar Laboratory, University of Wisconsin. Man kommer att kunna ta del av registret såväl i tryckt form som på diskett med ett sökprogram. Registret täcker visserligen bara tidskriften SOLAR ENERGY, men med åren har det ju blivit ganska många artiklar och det bör ge en mycket bra överblick över vad som är gjort inom olika områden.

K KUHNKE, Institute fur Solarenergieforschung, Hannover: Solar Cookers for Developing Countries. A Worldwide Study. Kuhnke har försökt strukturera upp problemen med solkokare runt om i världen och visade på att i stort sett alla försök som finns idag har allvarliga brister.

Bidragen som behandlade koncentrerande system system var få. Tre abstracts om strutar, V-tråg och lågkoncentrerande system för solceller var anmälda från Brasilien, men författarna dök aldrig upp.

A GOETZBERGER och M ROMMEL, Fraunhofer-Institute, Freiburg: Use of Transparent Insulation in Buildings. De visade på ett övertygande sätt hur transparent isolering effektivt och drastiskt kan minska K-värdet hos en solfångare. Ett av de största problemen med transparent isolering är att så höga temperaturer kan skapas att isoleringen börjar smälta och luftcirkulationen avbryts. Detta problem har man dock löst med material med högre smältpunkt. Under samma workshop höll C G GRANQVIST ett initierat föredrag, Research Aspects for Future Glazings and Foils med en sammanfattning av pågående forskning på området.

W SORENSEN, Bubble Action Pump Ltd., Kingston, Ontario: The Bubble Pumped Solar DHW System, samt G ATAGNDZ och N ÖZBALTA, University of Ege, Izmir: Experimental Investigations on an Air Collector with Goatskin for Drying Purposes, var goda exempel på innovativ småskalig teknik. Sorensens apparat fungerar utan ström och rörliga delar och ska ändå kunna hålla cirkulationen igång i ett system med tanken i källaren och solfångaren på taket. Luftsolfångaren var en intressant konstruktion med lokala material, klart nydanande.

Många svenska var i elden med intressanta bidrag. Ett som tilldrog sig uppmärksamhet var presentationen av Kungälvprojektet av TORBJÖRN JILAR, Chalmers: The Sun Town Project - Swedish plans for the Biggest Seasonal Plant in the World. Planerna innehåller som bekant 116 000 m<sup>2</sup> högtemperatursolfångare och 408 000 m<sup>3</sup> bergrumslager med hetvatten, vilket ska förse 6000 lägenheter och 115 000 m<sup>2</sup> övriga byggnader med 75 % av erforderlig värme, 52 GWh årligen till en kostnad av SEK -:42 per kWh.

## 4. Utställningen

Tio minuters promenad från kongresscentret genom välkända Planten und Blumen ligger Hamburgs mässhallar, tolv till antalet. Hela Halle 10, åtskilliga tusen kvadratmeter i två plan, fylldes av över tvåhundra montrar med solenergi och annan förnybar energi.

En jättelik solspegel, 8 m dia. paraboloid, syntes bäst. Annars var det framför allt de många montrarna med solceller och PV-paneler som dominerade. Vi beställde ett antal 1/4- och 1/16-celler av japanskt fabrikat för att ha till pilotskalem modeller av PV-paneler med strutar. (Däremot köpte vi inte den utställda Mercedes som hade solluckan utstyrd till PV-panel med uppgift att driva en fläkt som håller luften i bilen sval när bilen står parkerad i solen.)

Var det gott om solceller på utställningen så var det desto mera tunnsått med vanliga plana termiska solfångare. Flera utställare visade dock olika typer av transparent isolering - mycket intressant.

En populär monter var den där man kunde få solens vandring över himlen uppritad för varje månad under året och för valfri longitud och latitud - det var en dator som ritade, förstås.

De svenska företagen hade samsats om en ganska stor monter med BFR och STEV som samordnare. Utställningsansvariga svenskar var nöjda med intresset för montern. I den ingick också en skärm som berättade om North Sun '88.

## Tack

Lars Bromans och Svante Nordlanders deltagande hade bekostats av Statens råd för byggnadsforskning, Mats Rönnelids av Styrelsen för teknisk utveckling och Kent Börjessons av högskolan i Falun/Borlänge.

## Bilaga 1: Intervju med Harry Tabor

(Tabor är israel, född och uppvuxen i England. Han tillhör legenderna i solenergivärlden och har varit verksam inom området sedan 50-talet.)

- om solen i jämförelse med andra energikällor.

I would like to start with a remark that I usually end my lectures with: There is no single magic solution to the energy problem in which you have one answer and it satisfies everything.

In each place and in each time you have to choose from a mix of possible alternatives which are available. The function of the solar energy people is to help the decision makers evaluate the right mix for each place and each time because, obviously, the decision makers are not experts in each field. They got to consider fuel and nuclear and so on. That's my initial remark: In other words, we are not going to solve all problems, at least not in this stage.

Now, with regard to the future of solar energy, there are two steps. In the first place there are many applications which today are viable, and I'll give you some examples of this in a moment. There are many applications which are on the border of viability which, in other words, if you do a calculation that's is going to say fuel, then it doesn't appear viable. However, if you are prepared to give any credit at all for the non-polluting character of solar energy and say, "well, it is equivalent, the pollution is going to add to the cost X dollars per square meter", then of course it moves more of the borderline cases into cases which are viable from an overall point of view.

Thirdly, there is a problem, which I discussed in one session, where the question is: Is it viable to the person who buys it, or is it viable on a national scale? Now let me explain. For practically all systems of solar energy today, the amount of energy you get back from a solar installation in the course of its lifetime is many times the amount of energy that went into manufacturing it. And that includes the energy of the people and everybody else. That means that the community as a whole has become richer in energy as a result of this installation. Right?!

But for the individual who made the installation, when he has to pay all the taxes and the rents and the profits and so on, he may not find it viable. So there is a difference between viability for the individual, as it works for him or not, and viability to the community. Unfortunately, usually it is very difficult to get the communal leaders to take the leadership and decide that something is viable on a communal basis and therefore they are going to push it.

Now, as time goes on, I am convinced that the problem with fossil fuels is going to get worse. I mean, it's just logical, one doesn't have to be a genius to realise that the amount of fossil fuel in the world is limited and the demand of energy from the population of the world is going up. Especially if we are taking into account the third world, which today uses very little energy, and they want to copy the western society and use more energy, then it's obvious that we are going to run out of cheap fuel supplies in the form of coal and oil.

The question of nuclear I don't want to touch particularly. A lot of people have a objection to nuclear energy for very good reasons. Some countries will ignore these objections and say we can only solve our problems with nuclear plants.

There are the countries, Denmark I know is one example, where the parliament voted that they would not have the nuclear energy at this stage. So that means that sooner or later people are going to have to look for an alternative source of energy which is renewable so that it doesn't run out every year. Solar in all its aspects, that includes wind energy (and you probably have a lot of wind in Sweden), these are forms of energy which will become more and more significant as time goes on.

- om solenergi i Israel.

There are several reasons why solar energy is largely used in Israel. We have almost no intrinsic sources of conventional fuels, and therefore our energy has to be imported from outside. This not only costs a lot of currency, but it can create problems. If the outside world does not want to supply us with energy sources, then we can be in trouble.

And therefore, long long time ago, in the nineteen fifties, our prime minister was the very farsighted man Mr. Ben Gurion. He encouraged the development of solar energy research when in fact I don't think any other prime minister in the world even knew what the subject was. And this gave us a start ahead of most other people.

We chose the domestic hot water as the first case, and it turned out to be a good case because it is easy. We have a good sunshine and everybody wants hot water. Most of the people have electric water tanks and it's relatively easy to make a solar water system which will compete with electricity at the normal prices. Maybe it won't compete with electricity at two (American) cents per kWh, but at the price that we have to pay, which is about six or seven cents, it easily competes. The man who puts a solar water heater on his roof probably gets his money back in three years.

As a consequence, there has been a steady rise in the number of these. A few years ago, when the government woke up to the fact that this was a very good way of saving imported fuel, they made solar water heaters into an obligatory in all new housing systems up to three stories in height. The result is today that there are about 600 000 installations which means that 60 % of all the apartments get hot water from the sun. They have an electrical backup but it's only a small fraction of the total energy. This of course is a tremendous contribution, and it saves the country about 200 000 tons of fuel oil a year, which for a small country is quite a lot of money.

So that has made solar energy not only an act of practical value, but also the man in the street says, "well, solar energy is good", and therefore you can go further out to other stages along the line. And so we have been looking recently at solar energy for industrial use and, more importantly, for the production of electric power.

Solar ponds allow you to convert solar energy into electric power with the big advantage that there is built-in storage. Solar ponds show no difference in output between day and night, and even over a week or so you can hardly notice the difference. So this is a great advantage, and the technology is rapidly approaching the point where it will compete with conventional energy.

It will certainly compete with conventional energy from expensive fuels. The Israel electric system is recently on the switch from oil to coal to make it cheaper, because coal is a lot cheaper than oil. As a result they have made it more difficult for the solar community to compete.

At least we have installed a five megawatt plant, which is the biggest plant of this type in Israel. The Israeli company has its biggest installations in California. They have now got thirty megawatt plants, and several of them operating in California, and they are rapidly approaching economic viability. It depends on what the local situation is.

One of the reasons I think it goes well in California is that California is a state which is very pollution conscious. Therefore they are prepared to pay a bonus for energy which is non-polluting. I only wish that other governments would do the same.

(Fotnot: Solar pond är en grund damm med stor area. Den innehåller skiktat vatten, mycket salt vatten vid botten och färskvatten över. När strålningsenergi från solen absorberas av dammens botten värms saltvattnet upp men stannar ändå kvar vid botten på grund av sin högre densitet. Temperaturskillnaden mellan bottenvattnet och (t ex) ytvattnet kan utnyttjas av en värmemotor som får driva en elektrisk generator. Verkningsgraden är låg eftersom temperaturskillnaden är liten, men det uppvägs av att kvadratmeterpriset för en solar pond är mycket lågt jämfört med t ex en vanlig solpanel.)

## Bilaga 2

Paper presented at ISES Solar World Congress 1987, Hamburg, September 13-18.

### ON THE ROLE OF SOLAR ELECTRICITY IN RURAL DEVELOPMENT

Lars Broman\*, Mats Rönnelid\* and Saihou Omar A. Sallah\*\*

\*Solar Energy Research Center, University College of Falun/Borlänge, P.O. Box 10044, S-78110 Borlänge, Sweden

\*\*The Gambia Renewable Energy Centre (GREC), The Energy Section, Ministry of Economic Planning and Industrial Development (MEPID), Central Bank Building, Banjul, The Gambia

#### ABSTRACT

Rural industry development in developing countries using solar electricity is proposed. A preliminary survey of 12V DC equipment is presented. Square cornets for concentrating sunlight onto square solar cells are described. Tracking the sun is shown to be favorable in connection with village industry use. The Gambia is suggested for testing solar powered village industry.

#### KEYWORDS

Solar energy; photovoltaics; developing countries; concentrators; solar powered industry.

#### INTRODUCTION

Rural development is a necessity in most developing countries in order to lower the rate of migration into urban areas. This development includes social services such as schools and health centers, improved farming techniques and infrastructure, and small scale village industries. It has so far almost been taken for granted that the latter are of the extreme low-technology type.

The authors however disagree strongly with this. Village industries does not have to be limited to low-technology. When the number of trained engineers grows in a country, a good fraction of them can run small town industries where modern technology is employed. In the absence of electric grids, electricity has to be produced in situ. Solar panels can at present begin to compete favorably with diesel generated electricity in many instances (Cunningham, 1985; Sorensen and Wills, 1985).

Basic requirements of a majority of households in rural areas of developing countries have been estimated to a few Wh per day,

clearly most economically produced by PV techniques. Even basic community needs of electricity could well be met by PV systems (de Groward and Cornut, 1986). In the present paper, use of PV generated electricity also for industrial purposes is suggested. In fact, the cost per kWh used in manufacturing is much lower than the cost per kWh used by other parts of the community, since the industry's demand is typically during daytime while the community demand has a peak in the evening. Thus a higher percentage of the industry's electricity may be delivered directly from the PV panel, while community used electricity has to be stored before use. Battery banks are costly and not always trouble-free (Nilsson, 1987). There is no general agreement whether 12V DC or 220V AC systems should be preferred (Starr, 1985). We have however found a multitude of 12V equipment intended for mobile developed country use, and therefore believe that the higher simplicity and efficiency of the 12V DC system speaks strongly in favor of it.

As discussed in the present paper, there are certain advantages by concentrating the sun. Reflecting materials cost only a fraction per  $m^2$  of what PV cells do. Several authors indicate lower cost per kWh from PV concentrating collectors (Schueler, 1981; Berry and co-workers, 1982). Low concentration systems and even non-concentrating flat plate tracking systems have also been shown to be cost effective (Stacey and McCormick, 1985). Below, we present a cornet type PV concentration system, which may prove to be very cost effective, especially for small industry and other applications, where no or little storage is required.

#### SURVEY OF 12V EQUIPMENT

We have made a survey of 12V DC equipment available on the Swedish market. Our list is by no means complete, but we have entries under the following headings (with examples given):

Computers and electronics. Computers (Bondwell, Epson), printer (Epson), photo copier (Canon; available next year), oscilloscope (Hitachi), soldering equipment.

School and education. Tape recorder, radio, TV, physics experimental equipment (PHYWE).

Domestic. Electric bulbs, fluorescent tubes, refrigerators (Electrolux), immersion heater, percolator, vacuum cleaner, flat-iron, shaver.

Tools and motors. Drilling-machine, circular saw, universal saw, grinding and polishing machines, engraving pen (Minicraft, Black&Decker), DC motors, fans, water pumps (Bosch), compressors, electric winch.

Transportation. Outboard motors (Johnson, Mercury), motor cycle, truck (Berix).

We are convinced that the list will grow and we would appreciate communication. Our aim is to make a special report with a more complete survey in the not so distant future.

#### THE CORNET CONCENTRATOR PHOTOVOLTAIC PANEL

Cornets belong to a class of concentrators called nonimaging concentrators. The cornet geometry has been mathematically

described elsewhere (L. Broman, 1983). One virtue of a non-imaging concentrator is that a large acceptance angle  $\underline{d}$  is possible.

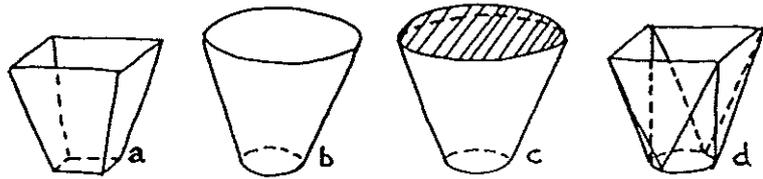


Fig. 1

We have done calculations and computer analysis of the cornets shown in Fig. 1: (a) square cornet, (b) circular cornet (c) circular cornet with a lens, and (d) cornet with square top and circular bottom (Broman, Nordlander and Rönnelid, 1987; A. Broman and L. Broman, 1987). The optimum geometry for PV applications seems to be the combination of square solar cell and square cornet, since this is a concentrator without "hot spots" at the bottom.

We have performed clear sky (direct light  $800\text{W/m}^2$ , diffuse light  $47\text{W/m}^2$ ) measurements of the maximum electric power output from a  $10 \times 10\text{cm}$  standard Solarex PV cell without concentration and with six different cornet concentrators made of polished aluminum. The only "customizing" we did was to solder two  $1.5\text{mm}$  copper wires onto four points each of the surface grid of the cell. The results are shown in Fig. 2 together with a calculated curve that takes mirror reflectivity and the fact that diffuse light cannot be concentrated into account but assumes constant cell efficiency. The experimental points fall only slightly under this curve; the discrepancy being easily explained by higher cell temperature and increased resistance losses with increased concentration.

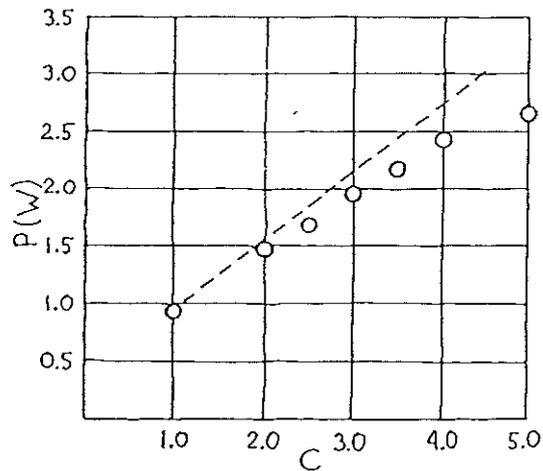


Fig. 2

TRACKING THE SUN

When concentrators are used, the sun has to be tracked. The use of cornets decrease the requirements of precision. As Robbins (1986) has described, so called passive sun-tracking using freon-filled tubes can easily track the sun within  $2^\circ$ . With an acceptance angle of  $5^\circ$ , manual redirection every 40-60 minutes will work fine. With higher cornets,  $10-15^\circ$  acceptance angle is easily reached with correspondingly longer intervals between redirections.

Tracking, even if it is un-precise, increases the energy output from a solar panel (even if it is just a flat plate panel that doesn't need tracking). Table 1 compares the daily output from a tracking and a fixed (latitude tilt) collector during a clear day (direct and diffuse light) at some different locations and dates. The output from the tracking collector is between 32 and 53 percent higher than the output from the fixed collector. The difference is even more striking if we regard the special case of a DC motor running directly on the current from a PV panel. In a crude mathematical model, current output from the

panel is proportional to insolation and the work done by the motor is proportional to the current squared. Tracking the sun increases the work done between 49 and 89 percent.

TABLE 1 Relative Daily Clear Day Outputs from PV Collector

Location	Equator		Tropic		
	Equinox	Solstice	Summer solstice	Equinox	Winter solstice
Tracking collector	100	97	111	97	77
Fixed collector	76	68	73	74	58

A third comparison between the two geometries uses the fact that the output from a tracking collector is fairly constant during several hours of a clear day while the output from a fixed collector has a typical "cosine" shape. Since the use of electricity in a small industry can be assumed to be fairly constant throughout the day, extensive use of electricity storage can be avoided only if tracking is employed. In Fig. 3 is shown how many hours the power output from a PV panel exceeds 75 percent of maximum during a clear day. The upper curve is for a tracking collector and the lower curve for a fixed collector.

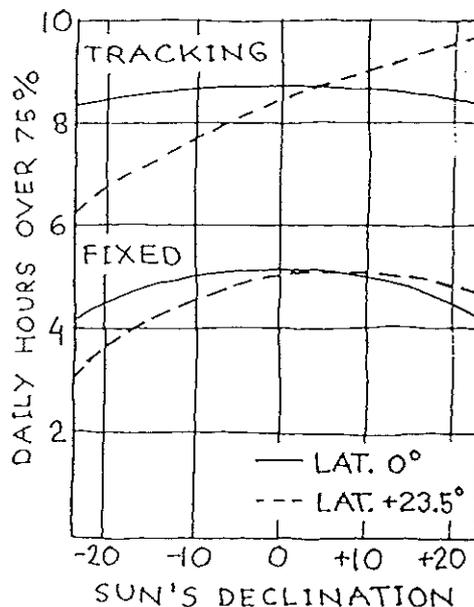


Fig. 3

#### SOLAR ENERGY IN THE GAMBIA

The Gambia is a good example of a country with great solar energy potentials, which fact has been discussed by Sallah (1986) and others. The country enjoys a well-balanced, seasonally and locally independent distribution of insolation levels that average more than 5 kWh per m<sup>2</sup> and day. The seasonal independence is primarily attributed to the fact that the shorter days of the winter are characterized by clear skies (except for periods of heavy dust pollution caused by the dry harmattan winds), while the rainy season during the summer is marked by intermittent cloudiness that reduces the effective insolation level.

The incident solar energy is monitored at various parts around the country. The monthly mean daily insolation in Yundum (1970-73) varied between 6.50 (April) and 4.99 (August) kWh/m<sup>2</sup> day, in Basse (1980) between 6.60 (March) and 3.96 (December), and in Sapu between 6.24 (March) and 4.20 (December). The monthly average of daily sunshine hours in Yundum varied between 9.5 (February) and 6.0 (July).

In The Gambia, solar generated electricity is presently used for pumping water (two installations), telecommunication systems

(nine single-channel VHF systems) and power for rural dispensaries and health centers (two installations). Present plans include conversion of twenty rural telephone stations to solar power, to equip twentyfive health centers and dispensaries with solar powered refrigerators and fluorescent lamps, and to install a number of PV water pumps - some 2000 drilled wells would provide enough potable water to satisfy the needs of the entirely Gambian population.

The Gambia would be a very suitable country for testing the thoughts advocated in the present paper. The insolation is high and evenly distributed over the year. Interest and competence in solar energy is quickly growing in the country. The organizational body for such an undertaking exists since the recent establishment of GREC, The Gambia Renewable Energy Centre, as well as CRES, Centre Regional d'Energie Solaire, with office in Mali and cooperation between several West-African countries. Project financed in part by Sw. Board for Technical Development.

#### REFERENCES

- Berry, J. P. and co-workers (1982). Photovoltaic generators with concentration. Solar Energy, 29, 235-243.
- Broman, A. and Broman, L. (1987). A special type of cornet concentrator for solar cells. Abstract book, Int. Conf. Applied Optics in Solar Energy II, Prague. p 9.
- Broman, L. (1983). Nonimaging solar concentrators with flat mirrors. Proc. Int. Conf. on Nonimaging Concentrators, San Diego. SPIE, Vol 144. pp 102-109.
- Broman, L., Nordlander, S. and Rönnelid, M. (1987). Computer analysis of solar cornet concentrators. Abstract book, Int. Conf. Applied Optics in Solar Energy II, Prague. pp 9-10.
- Cunningham, R. J. (1985). Photovoltaics: an advocacy statement. Proc. 6th E. C. Photovoltaic Solar Energy Conference. D. Reidel Publishing Company, Dordrecht. pp 539-543.
- de Gromard, C. and Cornut, B. (1986). Solar energy for pre-electrification in rural areas. Proc. 7th E. C. Photovoltaic Solar Energy Conference. D Reidel Publishing Company, Dordrecht. pp 20-26.
- Nilsson, A. O. (1987). Nickel-cadmium pocket plate batteries in photovoltaic installations. Abstract book, Int. Conf. Applied Optics in Solar Energy II, Prague. pp 51-52.
- Robbins, R. (1986). Sun-Tracking the Passive Way. Solar Age, February 1986. 14-16.
- Sallah, S. O. A. (1986). Renewable Energy Technologies in The Gambia, Report 0239/CRES/DTP/86. Ministry of Economic Planning and Industrial Development, The Gambia.
- Schueler, D. (1981). Overview - recent developments and potential of photovoltaic concentrating collectors. Proc. 15th IEEE Photovoltaic Specialists Conference. IEEE, New York. pp 367-371.
- Sorensen, A. and Wills, R. (1985). The economics of remote photovoltaic/generator systems. Proc. 9th Biennial Congress of ISES. Pergamon Press, New York. pp 1714-1718.
- Stacey, R. W. and McCormick, P. G. (1985). Seasonal performance of reflector augmented photovoltaic modules. Proc. 9th Biennial Congress of ISES. Pergamon Press, New York. pp 1674-78.
- Starr, M. R. (1985). Photovoltaic prospects for rural electrification. Proc. 9th Biennial Congress of ISES. Pergamon Press, New York. pp 1698-1703.

## Bilaga 3

Proceedings ISES Solar World Congress 1987, Hamburg, September 13-18 1987

### A METHOD TO TAKE THE TRUE SKYLINE INTO ACCOUNT IN SIMULATION PROGRAMS

Svante Nordlander and Lars Broman

Solar Energy Research Center, University College of  
Falun/Borlänge, P. O. Box 10044, S-781 10 Borlänge, Sweden

#### ABSTRACT

A method that makes it easy to accurately take the shadowing effect of obstructions surrounding a solar collector into account in simulation programs is presented. A fisheye photograph of the collector surroundings is transformed into a computer textfile using a digitizer pad. The file is implanted into a TRNSYS input file.

#### KEYWORDS

Solar energy; simulation; shadowing; fisheye lens; computer.

#### INTRODUCTION

It is difficult to correctly dimension a solar heating plant. The energy output is very dependent both on the frequently capricious sun and on the water temperature. It is therefore important to compute the yearly output of a planned system before it is built. There exist several programs that can be used for such computations. We have experience from two of these: TRNSYS (Klein and coworkers, 1983) and EMGP2 (Dutre, 1985). Lately, simulation programs are getting available also for micro computers like PC AT. Work is in progress (Broman and Nordlander, 1987) to make the use of such programs easier for non-computer specialists.

Especially for installations in built-up areas the shadowing effect of surrounding buildings etc. may be important to take into account. An elaborate program using a threedimensional view of the area has been constructed by Peterson and Taesler (1986) and Taesler (1987). In the present paper we describe a much simplified method. We have tested it together with TRNSYS, but the basic principles are of course applicable to any simulation program.

## PROCEDURE

(1) An SLR-camera equipped with 8 mm fisheye lens is placed horizontally at a characteristic place where the solar collector is to be built. A stick is placed a few meters directly south of the camera and a photograph is taken. Any fine grain film will do.

It would usually be sufficient to take just one photograph at the center of the site. In principle, several photographs could be taken and an intermediate horizon chosen; alternatively the simulation program is run several times with different horizons. In the following it is assumed that only one photograph was taken.



Fig. 1

(2) The picture on the film will be a circle, 23 mm in diameter. The skyline in the frame is transferred onto paper, e. g. by projecting with a slide projector and tracing the skyline. The following steps are simplified if the photograph is projected onto a paper where the circle and its center are already printed.

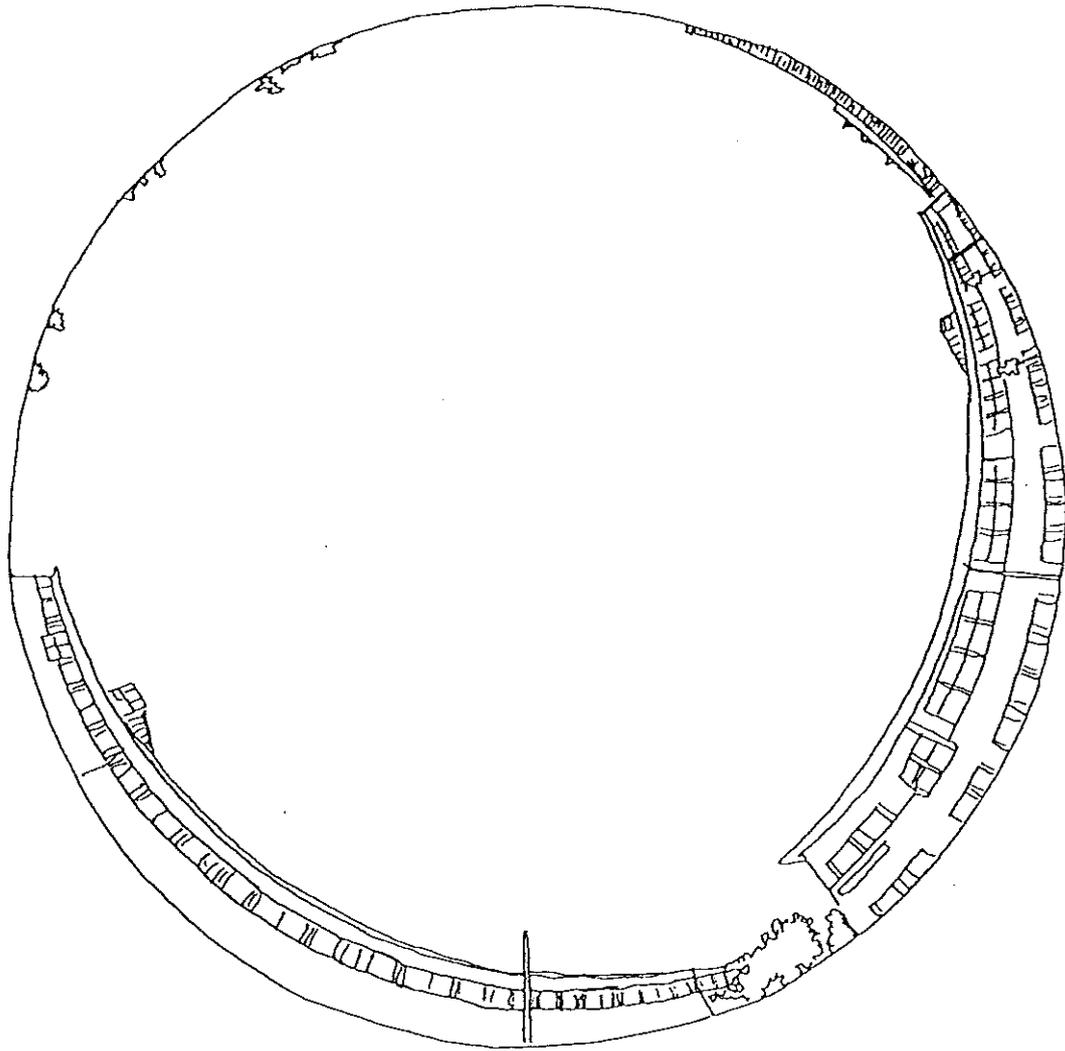


Fig. 2

(3) The picture is digitized with a computer program running on an IBM-compatible PC. This can be done in two ways:

- (i) With a standard digitizer pad (presently CALCOMP 2XXX series). The paper is placed on the digitizer surface and the horizon line is traced directly with a haircross cursor.
- (ii) "Poor man's method": With a mouse (presently MICROSOFT compatible). A transparent picture should be made instead of a paper one. The transparency is fastened onto the computer screen and the skyline is traced with the screen cursor which is moved by means of the mouse. This method is slightly less accurate than method (i).

The following applies to both methods:

With three initial locations the center, a point on the periphery of the circle and a point representing the direction of south are

defined. Then points on the skyline are digitized. Only end points of linear parts of the skyline are needed, for example, a flat roof needs only two cursor locations. As points are input to the program a picture of the skyline is generated on the screen for verification. The input procedure is a matter of minutes.

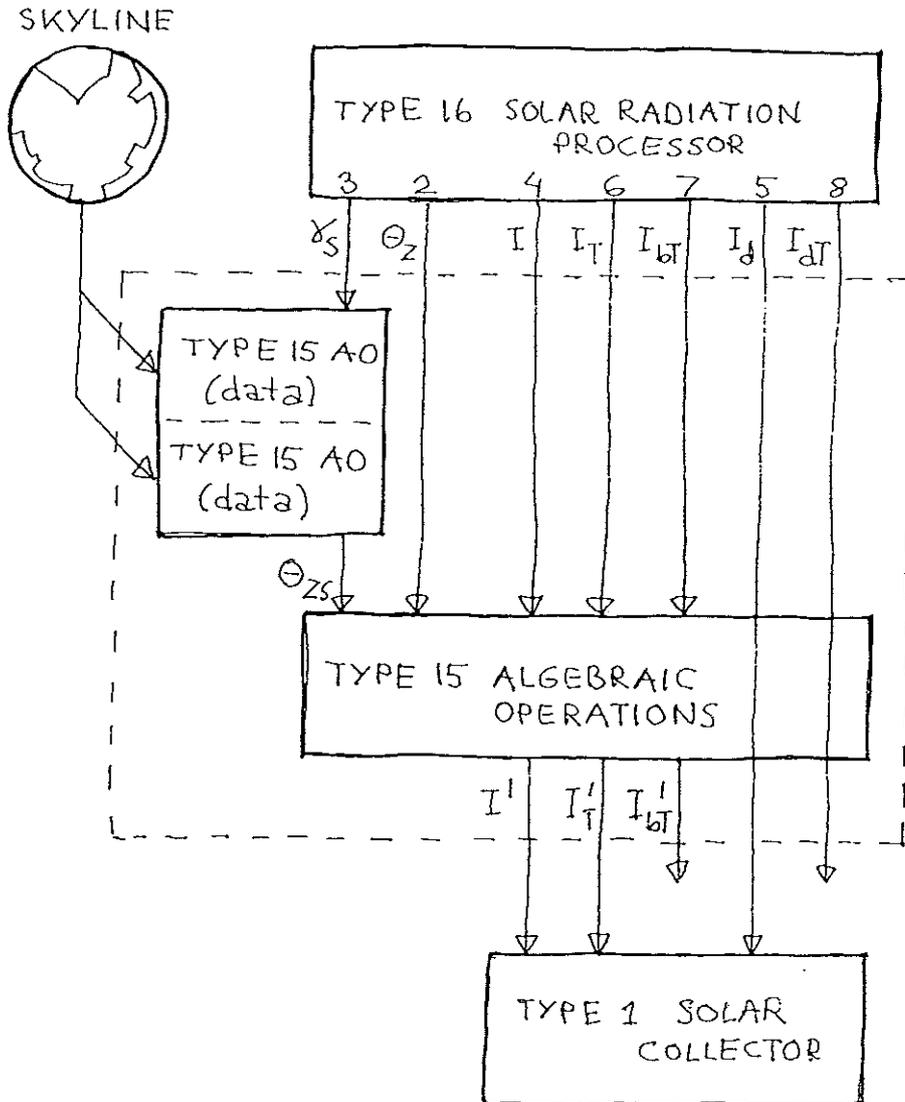


Fig. 3

- $\gamma_s$  = solar azimuth angle
- $\theta_z$  = solar zenith angle
- $\theta_z$  = skyline zenith angle
- $I$  = total radiation on horizontal surface
- $I_T$  = total radiation on surface of collector
- $I_{bT}$  = beam radiation on surface of collector
- $I_d$  = diffuse radiation on horizontal surface
- $I_{dT}$  = diffuse radiation on surface of collector

The program handles the data as shown in Fig. 3. Average skyline zenith distances for the 72 5° azimuth angle intervals are stored in two TRNSYS components type 15 (algebraic operations). During the simulation process, solar azimuth and zenith angles are calculated by the TRNSYS component type 16 (solar radiation processor). The solar azimuth angle is then fed into the type 15 twins, giving the corresponding skyline zenith angle as output. This value is compared with the solar zenith angle in a third type 15 component. When the sun is below the skyline, the beam radiation is given the value zero and else left unchanged. The diffuse radiation is not affected. The thus processed values for total radiation on a horizontal surface and on the surface of the collector are fed into the TRNSYS component type 1 (solar collector) as well as the (unchanged) value for diffuse radiation on a horizontal surface.

#### ACKNOWLEDGEMENT

We appreciate valuable comments by Per Isakson. This study was financed in part by the Swedish Council for Building Research (Project No. 860567-6).

#### REFERENCES

- Broman, L. and Nordlander, S. (1987). New Swedish simulation and design tool for solar heating systems, Report SERC-UCFB-005. University College of Falun/Borlänge, Sweden.
- Dutre, W. L. (1985). A European transient simulation model for thermal solar systems. D. Reidel Publishing Company, Dordrecht/Boston/Lancaster.
- Klein, S. A. and coworkers (1983). TRNSYS, a transient system simulation program. University of Wisconsin, Madison, WI 53706, USA.
- Peterson, F. and Taesler, R. (1986). Solar insolation calculations as help in projecting (in Swedish). The Heliograph No. 1. pp 14 - 34.
- Taesler, R. (1987). HORIZON - A program for calculating the local horizon in an urban environment. The Heliograph No. 1. pp 9 - 35.

SERC-UCFB-001  
PROGRESS REPORT 1984-85  
8 pages. November 1984

SERC-UCFB-002  
Arne Broman and Lars Broman  
A SUN CELL CORNET UNFOLDED  
15 pages. June 1985

SERC-UCFB-003  
Lars Broman and Arne Broman  
A PARABOLOID REFLECTOR APPROXIMATED BY  
SIMPLE SURFACES  
9 pages. November 1985

SERC-UCFB-004  
PROGRESS REPORT  
9 pages. December 1986

SERC-UCFB-005  
Lars Broman and Svante Nordlander  
NEW SWEDISH SIMULATION AND DESIGN TOOL  
FOR SOLAR HEATING SYSTEMS  
In Swedish with abstract in English  
43 pages. April 1987.

SERC-UCFB-006  
SERC RESEARCH PROGRAM 1987-1990  
In Swedish with abstract in English  
20 pages. April 1987

SERC-UCFB-007  
Lars Broman  
SOLAR ENERGY IN THE GAMBIA  
In Swedish with abstract in English  
13 pages. May 1987

SERC-UCFB-008  
Mats Rönnelid  
SOLAR ENERGY IN KARAGWE - REPORT FROM A  
STUDY TOUR IN TANZANIA IN JULY 1987  
In Swedish with summary in English  
27 pages. August 1987

SERC-UCFB-009  
Eric Båve and Lars Broman  
SERVICE NEEDS AND OPERATION EXPERIENCES  
OF SOLAR COLLECTORS IN SMALL HOUSES.  
A PRELIMINARY STUDY.  
In Swedish with summary in English  
20 pages. October 1987

SERC-UCFB-010  
Lars Broman, Svante Nordlander  
and Mats Rönnelid  
SOLAR CORNETS FOR CONCENTRATION OF  
SUNLIGHT ONTO SOLAR CELLS  
In Swedish. 4 appendix and abstract in  
English. 21 pages (appendix 23 pages).  
December 1987

SERC-UCFB-011  
Annette Henning  
ENERGY EFFICIENT WOODFUEL STOVES -  
WHERE TO FIND INFORMATION  
17 pages. April 1988

SERC-UCFB-012  
Lars Broman and Arne Broman  
RAPPORT FRÅN / REPORT FROM INTERNATIONAL  
CONFERENCE APPLIED OPTICS IN SOLAR ENERGY  
PRAG/PRAGUE JULY 7-9 1987.  
In Swedish with abstract in English.  
14 pages. April 1988

SERC-UCFB-013  
Lars Broman, Kent Börjesson, Svante  
Nordlander and Mats Rönnelid  
RAPPORT FRÅN / REPORT FROM ISES SOLAR  
WORLD CONGRESS HAMBURG SEPTEMBER 13-18  
1987.  
In Swedish with abstract in English.  
28 pages. May 1988