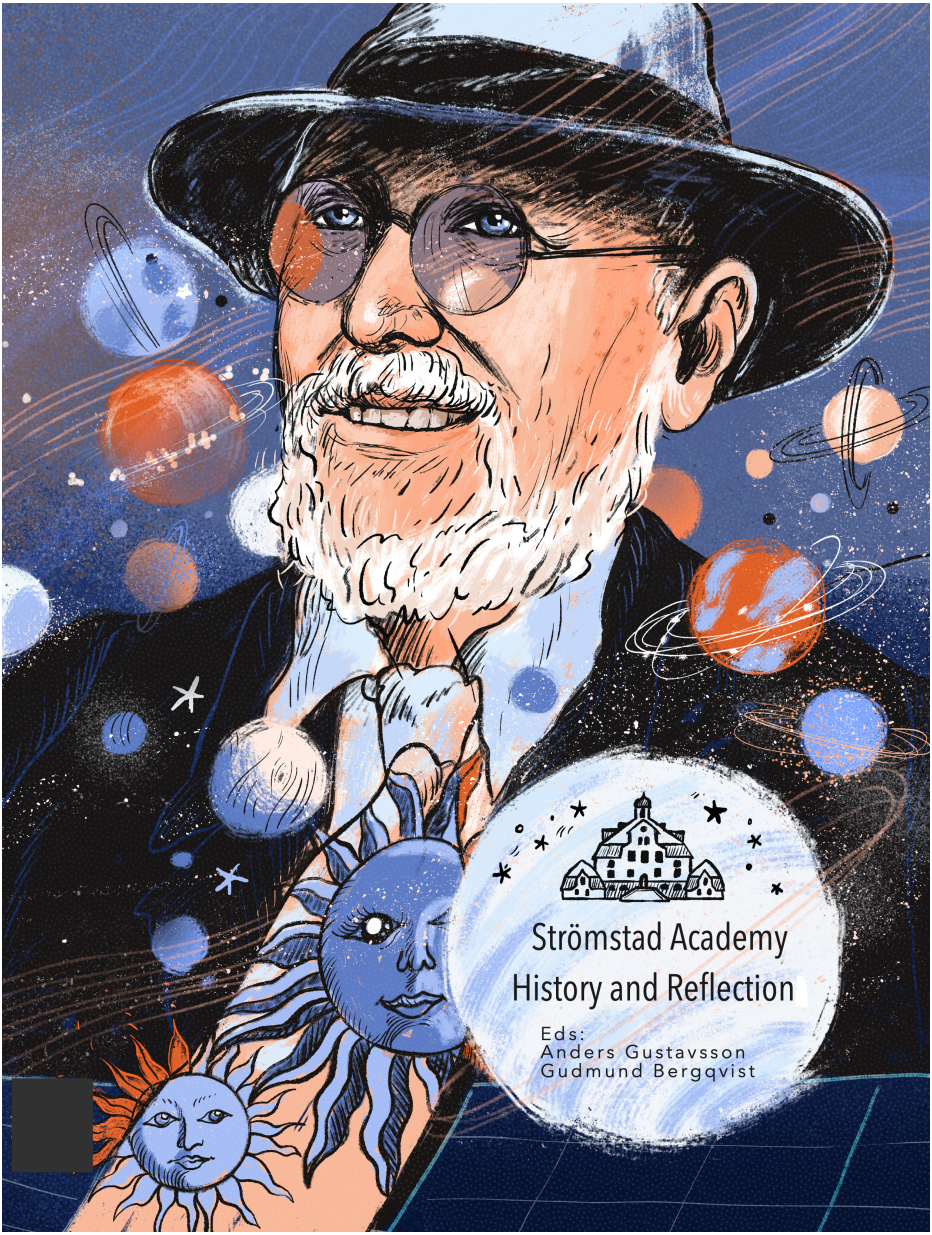
Strömstad Academy
History and Reflection
Eds:
Anders Gustavsson
Gudmund Bergqvist

Strömstad Academy

History and Reflection

In honour of Lars Broman, the first Vice-Chancellor of Strömstad Academy on his 80th birthday 8th of September 2020

Gudmund Bergqvist, Anders Gustavsson, (eds)

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Introduction

Strömstad Academy is a virtual society with around 150 members, including supporting members, mostly highly trained scholars.

It´s goal is to give the members possibility to do research and to publish, to meet in conferences but also provide public education, both in the form of lectures, articles and anthologies.

Lars Broman, one of the founders, has been its Vice-Chancellor and promotor since the start. He has laid his signature on the Academy and with great success.

Solar energy has been his scientific field for many years, where he has been one of the leading scholars in Sweden. Moreover, he has also a large interest in astronomy.

To honor Lars Broman for his outstanding work in Strömstad Academy, its editorial committee has asked some of the Academy's members to write a contribution in this anthology presented to him on his 80th birthday.

Furthermore, we have asked the Chairman of the Academy, his close friend, to contribute, as well as his successor as Vice-Chancellor.

Congratulations Lasse, we hope you will continue your scholarly work for many years to come!

Gudmund Bergqvist	Anders Gustavsson
Editorial Committee	Pro-Vice-Chancellor

Lars Broman - reflections on the person who was involved in starting Strömstad Academy

Peter Fritzell
Associate Professor of back surgery at Uppsala University
Chairman of Strömstad Academy

Everything in this section fits into my personal thoughts about Professor Lars Broman as a headstrong, energetic creative thinker and stubbornly creative researcher in his best years.

I got to know Lasse quite recently. Recently, a concept that can be perceived is completely different depending on where in life one is, and in this case it means about seven to eight years. At that time, there was a group of between 5 and 30 people from different areas and positions in Falun, who gathered at irregular intervals at each other's homes to discuss things that seemed interesting and / or difficult to understand. It could be anything between concepts like "expert" and "death", to something more specific like "An unexpected event - or some - that became crucial to your continued life" (one of Lasse's suggestions). The group was heterogeneous to express themselves mildly, interdisciplinary if you will, which ensured both broad and deep discussions, which, however, did not take more than a maximum of 120 minutes, between 18 and 20. You get very much in two hours! Depending on each person's orientation, the group was named differently, such as "Falu Doubters", "Falu Nyfikna", "Falu Grubblare" and "Falu Tveksamma". I myself belonged to the crowd of the curious, while I think that Lasse felt more at home with the thinkers. I may be wrong, and considering what he has accomplished, it almost feels that way. A phalanx wanted to call us "Falu curious thinkers", and maybe that's where you felt most at home Lasse?

Lars Broman, professor of physics, has for my part appeared in various public discussions and contexts throughout all the years I stayed in Falun, which I have done since 1974 when I felt it was time to leave my place of study Gothenburg and move somewhere quite far away, to new challenges. Lasse was a physics teacher and I got to know him and his activities from the beginning through my friends who went to the teacher training college. He had then designed, together with colleagues, a program that would make students love their subject. These included Teknoland in Falun and later Framtidsmuseet / Science centre in Borlänge[1, 2].

As chairman of the Swedish Environmental Protection Agency, and involved in the Green Party, he also started the Centre for Solar Energy Research at Dalarna University (SERC)[3] in the 1980s, and also the European School of Solar Engineering in Borlänge (ESES)[4]. As a politician, he was known as a stubborn opponent of nuclear power after making a complete U-turn on that very issue. After having, as a nuclear enthusiast, taken teaching colleagues and students on an information trip to Studsvik in Nyköping in the mid-1970s, he was able to change his position in the light of new findings/events and instead become an enthusiastic advocate for, among other things. sun-energy consuming. You have to appreciate that! Very many people, even know-it-alls, have a hard time changing their minds once they have decided on one. In my world, it means credibility when you can change based on new facts/findings.

Lasse has thus "always" been, and still is, a well-known profile in Falun. Also on streets and squares. For the past year, for example, he stands every Friday at five o'clock in the main square, and demonstrates in the spirit of Greta Tunberg with the group "Fridays for future" [5]. At six o'clock he then knocks over to Pitchers for an hour-long meeting with the other boys in Dala beer academy[6]. To say that Lasse has many strings on his academic lyre is an understatement.

One day five years ago, he contacted me after a meeting with Falu Nyfikna. He wondered if I did not want to become a member of Strömstad academy, and after a short period of reflection, I said yes because I consider it crucial that Sweden makes use of all its scientific competence, of all its research resources. Then, four years ago, he made new contact and asked if I could consider running for chairman. The academy had grown strongly, with members from both Sweden and other countries. Like Lasse, being chairman, headmaster and treasurer began to feel a bit heavy, and not relevant either.

Lasse described in detail the history of the academy. How he, together with, among others, three research colleagues; Aadu Ott, Erik Hofrén and Carl Olivestam, reacted to the order that then, as today, prevails in Sweden with regard to researchers and pension regulations. In general, it means that upon reaching retirement age, many are deprived of their rights to continue their scientific work. This includes difficulties in maintaining its functional place at the university, such as access to grants and supervision, but also to technical equipment and access to data banks, ie the functional basis for research itself.

For Lasse, this meant that he could not continue working at Dalarna University. He, together with the three colleagues who experienced the same situation at their universities, therefore contacted the municipal board in Strömstad City Hall in 2008 and asked if they were interested in a group of researchers starting a scientific academy in the municipality in exchange for access to their own room in the house, including computer and telephone connection. The purpose was to maintain scientific competence within Sweden, and also provide opportunities for interdisciplinary collaborations both within the country and internationally.

The insightful answer from the municipal board was Yes, and Strömstad Academy could be formed. The academy has since grown from year to year, and by 2016 the number of members had thus become so large that a strictly professional organizational structure had to be established.

After various tours, I was elected chairman of the academy at the annual meeting in Strömstad in 2016 and officially took office at the turn of the year 2017, while Lasse continued as rector. One can consider whether it is a good arrangement in a national/international association to have a chairman and principal in the same city, and attempts were made to, for example, get Bodil Jönsson in Lund (Thoughts on time) to shoulder the chairmanship. However, she refused because she is a busy professor in the middle of working life, and pragmatically it may have been an advantage in the administrative/financial situation where the academy is that Lasse and I have been at "arm's length distance".

In Lasse's and my case, this has meant that the headmaster and chairman have been able to discuss together at regular and irregular intervals, in addition to running via telephone and Webinar, also physically in each other's kitchens. These discussions are characterized by great openness and, figuratively speaking, the ceiling is very high. Both disagreements and disagreements are addressed, and the noise level is sometimes quite high.

If there is one thing that one must realize and respect in an interdisciplinary academy, it is that the cultures in different disciplines can differ considerably. It is therefore important to be honest, humble, transparent and inquisitive. That you can take on others' different views and perspectives on issues where you already consider yourself to have a clear opinion. If this is a challenge within one's own discipline, it is to a much greater extent in interdisciplinary meetings, both inter- and multidisciplinary.

At the same time, these meetings open up for powerful reflections. Being able to "look over the fence" at other people's specialties and realize what opportunities there are for new perspectives on "own problems" is a challenge that has been addressed by the Swedish Research Council, which has published insightful thoughts on the subject[7, 8].

An interdisciplinary institute such as Strömstad Academy has great opportunities to offer departments and universities advanced help with cutting-edge expertise in various areas, and this is something we have actively worked to realize in recent years. This is how the academy has on two occasions described its activities for RIFO in the Riksdag[9]. We have also contacted Sweden's young academy, SUA[10], to start a dialogue with the aim of strengthening research and education in Sweden. So far, however, this has not yielded the desired result.

The academy has many working groups, for example locally in Strömstad municipality "A fossil-free Koster" and overall via a "Future group". Five local branches in Strömstad, Falun, Stockholm/Uppsala, Gothenburg and Malmö/ Lund have regular meetings both internally and open to the public. A working committee with representation from all over the country via the rector, vice-rector, secretary, chairman and vice chairman, has regular and irregular meetings at least once a month, often several.

Via our website[11] under the leadership of an active web editor, we publish, among other things, a scientific publication series, AAS[12] and anthologies[13], both of which are the responsibility of the vice-chancellor. Video lectures by the academy's members[14] are also presented here. We also publish a monthly newsletter[15], and a monthly column in Strömstad's newspaper.

Members regularly participate in the current public debate, for example on high-speed trains versus magnetic trains[16], and we offer scientific courses for both high school students and researchers.

However, the resources with regard to scientific competence, together with the national and international contacts and networks that academia possesses, have so far not resulted in a relevant utilization of these by society.

This is most likely related to the view of, among other things, senior researchers that still exists in Swedish society, and which was what originally led to the creation of Strömstad Academy. The loss of intellectual capacity and ability to work as a senior is a widespread misconception that there is a lot of research that backfires. In line with this, the state established in August 2018 the “Delegation for senior labor”[17], with the task of; "Work for a more inclusive and age-independent approach to working life, as well as identify obstacles and find opportunities to better utilize the knowledge and experience of the elderly." It has thus been realized that the current view of senior competence means an ongoing waste for the nation, a waste that we in Sweden are relatively alone in the world. There are many examples of senior researchers traveling abroad to offer their services.

One of the anthologies published by the academy discusses the concept of values[18], among other things based on the World Value Survey (WVS)[19]. WVS is a worldwide network of researchers who study values and their impact on social and political life. Here, Sweden places itself year after year in a unique international position where it is clear that the citizens have a high trust in the state, which means a high sense of individual freedom, while we are secular, ie we generally do not believe in any heavenly power. If, on the other hand, you look at how seniors and older people are perceived / appreciated in

Sweden, we are in the absolute bottom layer with only one country behind us. This is a serious situation for a nation, since in this age group there are immeasurable treasures of competence and knowledge, which, properly utilized, serve the interests of the nation. Changing this state of affairs is exactly what Strömstad Academy is fighting for. A strange struggle to have to fight, one might think, because it is about offering universities the research resources that Strömstad Academy stands for, and which Sweden can use in principle for free. It is also completely in line with the assignment given to the Delegation for senior labour by the government.

What applies to the academy now is thus to get established institutions and higher education institutions to realize the opportunities that Strömstad Academy offers, and then not least to get them to take advantage of these opportunities.

We therefore work to provide the academy with a secure economy that can create the administrative base that is necessary in the continued work. All chores are run by unpaid members around the country, who often work non-profit many hours a week. Travel and conferences are also a concern. It has been estimated that today we need SEK 3 million annually to be able to run our scientific business in a good way. This includes, for example, the possibility of setting up a secretariat and gaining access to scientific databases. We are so far completely dependent on the members' annual fee, and the modest total budget that this entails does not even cover the creation of a secretariat.

Strömstad Academy is thus facing continued basics, and one may find unnecessary, administrative challenges. Regardless of this, Lars Broman and the other co-creators can look back on twelve years of creative, scientifically fruitful work. The academy today consists of more than 100 members from several continents and from about thirty disciplines[20]. Several are honorary professors with international fame. For example, three are Nobel laureates, one is a member of the Swedish Academy, four are members of the Royal Swedish Academy of Sciences and one is the rector of Karolinska Institutet in Stockholm. See the academy's folder after this chapter.

If you look at "Lars Broman's and his three co-founders' decade in Strömstad Academy", you can feel nothing but admiration. To continue working in this spirit of theirs is an incentive and challenge for us who have joined over the years. The recruitment of new members to leadership positions on the board and the many working groups is going well, and the regrowth in all positions is secured today.

In this context, it is also very gratifying that there are younger researchers who apply to the academy because they have understood the values and opportunities that the academy offers.

It must feel like a great victory for you Lasse, that based on your visions and together with hard and stubborn work together with many like-minded colleagues, have created Strömstad Academy! All credit to you Lasse, and to all these members!

And not least, all credit to the municipality of Strömstad who realized, and realizes, what potential the academy has both locally for the municipality, for Sweden and internationally. It is interesting to reflect on how a municipality like Strömstad, without an academic university, has committed itself to strengthening science and research in such an insightful and favorable way for Sweden.

Finally, I would like to emphasize again the importance of age for knowledge, learning and opportunities to help in the development of society. Age as such must not, as in Sweden today, be used as a "weapon to get rid of knowledge and skills", as these qualities often just follow with long experience that is achieved through lifelong work.

At the same time as this is being said, it must be made very clear that those who have worked a stipulated long working life, if they so wish, must be able to end this safely and honorably.

The important thing in this context, however, is that Strömstad Academy consists of the senior members who say the opposite; We want to continue to contribute to the development of research and science in Sweden. We are enthusiastic about the opportunities to continue research, and not least to help younger researchers!

I end with a picture and a quote by Luis Bunuel that describes how age can be a prerequisite for positive development!

En
KUNSKAPSRESURS
för samhället

Vi vill skapa förutsättningar för Sverige att ta vara på kompetens i alla åldrar

Många seniora forskare vill fortsätta forska även efter uppnådd pensionsålder, men långt ifrån alla har en plattform för sin verksamhet. Strömstad akademi erbjuder sedan 2008 aktiva forskare en akademisk hemvist, som gör det möjligt att fortsätta forska även efter 67 års ålder. Våra medlemmar, både äldre och yngre, kommer från olika länder och tillsammans skapar Strömstad akademi en gedigen kunskapsbank av vetenskaplig kompetens och beprövad erfarenhet. De flesta i akademin har forskat i många år. För samhället är det angeläget att ta tillvara dessa forskares samlade resurser och stora kontaktnät världen över. Akademin är i huvudsak virtuell, med kontor i Strömstad och lokala avdelningar i Stockholm/Uppsala, Göteborg, Malmö/Lund och Falun.

VAD AKADEMIN GÖR
- Möjligheter

- Samarbetar med en rad andra institutioner, bland annat Högskolan Väst.
- Deltar som experter och referenspersoner i akademiska verksamheter.
- Agerar mentorer åt yngre forskare.
- Publicerar akademins egen skriftserie, Acta Academiae Stromstadiensis, AAS.
- Publicerar antologier, senast: 'Värderingar'. Kommande antologier: 'Epidemier' m.fl.
- Arrangerar varje år en vetenskaplig flerdagarskonferens i Strömstad.
- Anordnar vetenskapsdagar i de olika lokala avdelningarna.
- Kan hjälpa till med tvärvetenskapliga kurser.
- Håller offentliga föreläsningar i Strömstad och skriver månatliga krönikor i Strömstads Tidning.
- Publicerar varje månad nyhetsbrev på akademiens webbplats.
- Kan initiera tvärvetenskapliga projekt.

HEDERSPROFESSORER
inom akademin:

Elaine Bearer
(neurovetenskap)

Annica Dahlström
(neurovetenskap)

Gunnar Eriksson
(körledning)

Christer Fuglesang
(rymdpartikelfysik)

Erik Hofrén
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Asger Høeg
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Frank Wilczek
(fysik, nobelpristagare)

ÖVER HUNDRA LEDAMÖTER FRÅN HELA VÄRLDEN

Våren 2020 består akademin av över 100 ledamöter från 14 länder och från olika discipliner. Antalet medlemmar ökat, vilket visar på att ett institut som Strömstad akademi fyller en viktig funktion i samhället.

Strömstads Stadshus

VILL DU BLI LEDAMOT?
Hör av dig, läs mer eller kontakta oss:
stromstadakademi.se

VÅRA DISCIPLINER
Akademins ledamöter har spetskompetens inom vitt skilda forskningsfält.

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Biologi
Ekonomi
Etik
Etnologi
Fysik
Förnybar energi
Historia
Information
Kemi
Klimatologi
Kulturgeografi
Kommunikation
Litteraturvetenskap
Medicin/Farmakologi
Miljösystemanalys
Musik
Neurolingvistik
Neurofysiologi
Omvårdnad
Religion
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Sociologi
Språk
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STRÖMSTAD AKADEMI
Nordiskt institut för avancerade studier

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20. Ledamöter i Strömstad Academy kommer från många länder


14
länder
ATLANTIC
OCEAN
INDIAN
OCEAN

Strömstad Academy - an association with one or two s

Carl E. Olivestam
Professor of Education, The first Pro-Vice-Chancellor, Strömstad Academy
Associate Professor Department of Education, University of Gothenburg, Sweden
Doctor in Religious Science, Uppsala University, Sweden
Executive Chairman of the Swedish National Ecumenical School Board

Lars Broman was for me an unexpected and new acquaintance. The introducer was his colleague and best friend, Aadu Ott. We met without any warning in the City Hall of the Swedish town Stromstad on the West coast. He spelled his name Lars but made it clear to be pronounced Lasse. A combination so different from my own name, where spelling and pronunciation match. Nor could I understand the most concrete contradiction: that he was driving a red little thirsty sports car at the same time as he was an environmental activist.

First meeting in the City Hall

In the City Hall we were received - Lasse, Aadu and me and Mr Pettersson - by the leading politicians, Sven Moosberg, the Strömstad Party and Peter Heije, the Center Party. Around the coffee table we started our discussion. There were expectations in the air in the large room with its special history.

Strömstad had a shrimp academy for a long time, but the management realized that a supplementary academy would be needed, why not with an academic ingredient. The city with a relatively low level of education could need an academic boost.

Moosberg with his background in the business world where the decision-making processes are fast. Heije was a fan of keeping up. Before the meeting was over the decision to create such an academy with the city's name in detail was decided. The two politicians hurried on in their busy agenda. Heije stated that normally he was two hours behind, now after the meeting with us, a full four hours. But both could assure us that this decision would be accepted within each party and a majority decision in the city council. I felt as I was back in the medieval times when settlements were arranged between the pope and the emperor via concordat decisions. Lasse flanked by us, could march out like a triumphant pope.

We stayed when the politicians left us. Now we were in a hurry to create a structure for our association with all involved. Formalities, programs and vision. Moreover, Lasse was well prepared, through previous conversations with his friend Erik Hofrén in Falun. Unfortunately, his health hindered him to attend this historic moment of creation in Strömstad; Sad for him missing this moment of excitement.

Furthermore, with no hesitation, Lasse went on to form his agenda. Thesis, antithesis, synthesis characterized our reasoning. Aadu, with his extremely well-developed sense of good company and constructive consensus, was an essential prerequisite for achieving a successful result in just a few hours. Unfortunately, Mr Pettersson was not happy with the result. He left us with the prediction that Lasse's control would not lead anyone anywhere. But such disagreement is natural during development processes and we continued with no hesitation.

2s or 1s

Our next item on the agenda was the name: An association with one or two s. Strömstad´s Academy or Strömstad Academy. I cited the Swedish Football Association as a model in modern Swedish, and so the name was decided. Just one s, not two. Despite the many years that have passed since, some have demonstrated difficulties in pronouncing and writing the name correctly. But Lasse has always been quick with correction. When we came to form the first board, Lasse was the self-appointed Chairman, Aadu firmly refused to take a formal position, so then there was no one but me to become Deputy Chair. The year was 2008. We were able to get local and administrative help from the municipality and some financial support. Next task on the agenda was to give our organization a name and find the financial support. And with Lasse's tireless contacts with the municipal management and, above all, Sven's enthusiasm, a first annual celebration could take place in Strömstad the following year and the following years ever since until this pandemic obstacle.

Why on earth Strömstad?

I have been asked many times by colleagues and interested parties: Why Strömstad? An academic institute for advanced studies cannot be located in an old fishing village, later a popular resort. But there is a plausible answer to this: Lasse living in Falun spend his summer just outside this town. Moreover, there he had time to develop his ambitions. And just south the town University of Gothenburg already has established activities through its Department of Marine Sciences. Koster Sea with its unique and marine environment was the subject of that study.

Lars Broman has shown a strong belief in realizing a vision and what it takes to succeed. His idea was to give senior academics, who are looking for a new home after their active years at a college or university, a place to do just that. Then after some years he found out that when an organization grows in numbers new requirements for formalities and service was needed.

Lasse proved to have the capacity and skill to take on new challenges as they emerged.

Not without Aadu Ott

Aadu Ott was constantly engaged and enthusiastic about continued great deeds. Always present in the board contexts, reflective to contribute with constructive solutions. Behind our first Vice-Chancellor's proposal, his close friend was always at hand. Furthermore, Aadu's contribution was evident in books the Academy started to publish. He was the editor of our first anthology and with his unique sense of collaboration, he invited me to become co-editor. And his highly acclaimed lectures gilded the Academy's anniversaries. A master at illustrating deep scientific insights with toys as artifacts. In this festival publication, we miss the contribution that Aadu himself would have wanted to write.

I have had the unique, and since Aadu Ott's death in early 2020, unique position to follow Strömstad Academy from the start to this time of Lasse's 80th anniversary, I have had many opportunities to go a match with him, develop with him and explain to others with less insight of Lasse's unique ability. The only thing I do not understand is how this multifaceted personality goes together with a nickname. But that may have something to do with his marketing. The new Vice-Chancellor, who will take office at the turn of the year 20/21, seems not to follow this trick.

Friendship with unforeseen consequences

At Aadu Ott's home, the discussions could take unexpected turns when his wife Aslaug invited to dinner. Lasse and Aadu have been close friends since their studies at Chalmers. They had shared many experiences from experiments in academic physics to physical stresses in nature. I met Aadu as a playmate when I changed my academic career from a religious scholar to an educator. I took up a position at 'Pedagogen' at the University of Gothenburg.

At the dinner table intense conversations took place with Aadu as moderator. We could discuss the classic faith and knowledge problem. At that time Aslaug and Lasse's wife Anette switched to other commonalities. My Christian faith and humanistic education contradicted Lasse with his atheistic faith and scientific education. Aadu with his brilliant insight in both worlds was both a scientist and a humanist and filled the glass when needed to maintain that cordial and friendly table community. But Lasse and I had one thing in common. We had both got Emanuel as our third name. A name taken from the Bible with the meaning “God with us”. Here both humor and seriousness were mixed. But it provided an expanded contact area that was not just about an academy. Here we found the personal meeting that over the years has been both exciting and valuable.

One master of ceremonies and three musketeers

An academy has its ceremonies and that was of great importance for Lars Broman to maintain. He had trained for the role as an official civil registrar. Together we developed an academic agenda including insignia, procedures for decision making etc. Soon Lasse announced in the board that he needed a chain just as all the other as Vice-Chancellor. That was important with formal contacts with other colleges and universities. A special ceremony took place as members of the association received their academic status at the annual festive gathering in Strömstad. Vice-Chancellor Lasse promoted the professors and I, during my time as Pro-Vice-Chancellor, promoted the assistant professors. The promotion was accompanied by trumpet fanfare, music, song and speech. And at the end of the ceremony, we all gathered on the large balcony of the City Hall with its wonderful view of the North Sea. We said a toast reinforced with saluting. Through his contacts, Sven Moosberg had contracted the town's three musketeers dressed as Charles IX's dragoons and who fired from the courtyard. After some years the musketeers dropped out of the ceremony. But our master of ceremonies, Lasse, found compensation for this and for those who later were promoted, stories from the time of the musketeers have almost been perceived as a fairy tale. Therefore, photo proof is presented here:

Carl E. Olivestam and the three musketeers in Strömstad City Hall

The content of the Academy

With the growing number of members, development and broadening of the business was needed. Our annual festival gave all members who were interested an opportunity to make a short presentation of their research, an information that was much appreciated. In a short time, everyone was able to take part in the broad competence that exists within our Academy.

At the yearly meetings, the idea of publishing an anthology on a specific theme emerged. Aadu Ott and Carl E. Olivestam were elected editors of a first anthology. The title was: *Vision and reality,* published in 2010. It reflected exactly the situation the association was in. The vision of achieving accreditation as a university was established. This requires training capacity in the form of courses and programs. And in addition, research opportunities within the Academy. One step along the way was the continued creation of anthologies on current topics. It gave more members opportunity to show capacity and willingness to make their contributions to the theme. We went from oral presentation at the

Researcher careers - an anthology where experienced researchers give their best guidelines to what young people festivals to written documentation. Many anthologies have been produced over the years. The latest is about giving young people insights in how to manage an academic career. Hopefully, this anthology can become a textbook for newly admitted doctoral students. And that the Academy gets natural contacts with colleges and universities.

One single s

The only 's' is you Lars Broman, even if you like to pronounce the name with two 's'. Your life's work regarding the Academy, will not stop at eighty years of age and the resignation as Vice-Chancellor. We will meet at the board in the future, discuss various proposals, sometimes disagreements, sometimes consensus. This is how it has been and will remain: a dynamic that enriches life. Lars Lasse Broman with hat, ring and chain is dedicated this book of celebration.

From our kaleidoscope

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Introduction

On the windowsill here at home is a small statue of Edison with a light bulb in his hand. Almost every day, summer and winter, his light bulb lights up automatically when it starts to get dark, and it then continues to glow until it has utilized all the energy that the solar cells on his back converted into electricity earlier in the day. In the winter, the light bulb only flashes briefly (if at all), in the summer it lights up well into the wee hours.

We would like to let Edison's persona shine over this friend book chapter. Yes, it can simply be the putty that holds together our respective associations to you, time, the sun and energy. Edison was far-sighted enough to name the sun, the wind, and the tide as the forms of energy that man could confidently rely on in the future. Mainly of these, he set the sun, and he himself claims to have regretted that he would not be allowed to participate when the oil and coal resources were depleted or became obsolete.

So he would like to be here and NOW. Then he would have escaped the inter-period when people tried to develop fusion reactors on earth - today we can calmly let the sun take care of the fusion energy conversion and we ourselves only need to put solar cells on the roof to convert radiant energy into electricity. Just an impossibility - now both easy and with reasonable investment costs. It has already been shown how many people, like squirrels, want to collect the solar energy they can easily access. Soon it may even feel shameful not to do so. And who knows, it might even become illegal, also in Sweden.

In a friend book chapter for you, Lars Broman, who for so many years has not only been a champion of research on solar energy but also a champion of the local, it is of course an extra plus to point out how the large-scale far out there in the sun through technological development adapted to be small-scale here on earth. Almost as one might think, that was what he was thinking, Piet Hein, when he wrote in his grukk: "The clairvoyance of God falls on, sees the great in the small."

With this chapter, we ourselves want to gather just small glimpses of our respective lives when our paths have crossed yours.

Solar energy and Dalarna - SERC

When I (Göran) started at Dalarna University in 1984 and moved to Falun, you were already there, Lars. Then we colleagues remained there for twenty-four years. In the 1980s, Borlänge University was not very large, so even though we had different specializations, we met quite often. Among other things in the research committee where we were both probably odd figures compared to the representatives of metal research and transport research.

You made a big impression with your SERC, Solar Energy Research Center, but you had to fight for it. Despite your solid academic background in physics (you came to Dalarna as an associate professor from Chalmers at a young age), the establishment phase was surrounded by difficulties. Locally, SERC had to make do with a bunkhouse, and financially it was difficult to get resources. SSAB and the Swedish Road Administration were and are big in Borlänge, and the regional business community prioritized metal and transport research over solar energy.

It may be hard to believe it now, but virtually no one saw solar energy as a future area at the time. In any case, not for Sweden - possibly for countries closer to the equator. SERC had a relatively extensive international business with a focus on African countries in particular, but the biggest contribution you made for SERC was probably that you contributed to it actually surviving financially through external financiers. The academic success also increased all the time, and at your retirement, you all were several professors there and you had graduated several doctors. That little Dalarna now has such a prominent place on the international solar energy map is due to the fact that you were the first to build up SERC as the only research group in Sweden with a focus on solar energy. Today, it is a significant research center focusing on sustainable energy, especially solar energy.

You were also noticed in so many other ways in Falun, Borlänge and Dalarna in general. You started the Future Museum under Erik Hofrén's management, Teknoland (for a few years was the world's largest outdoor science center) and much more. All the time, you had your strongest commitment focused on energy and environmental issues, not only academically but also politically and socially.

With the history of technology as a meeting place

I (Bodil) have never worked in the same place as you, but we have still encountered each other in many contexts, often together with Aadu Ott. The Deutsches Museum was one such meeting place with Jürgen Teichmann as the spider in the web. Some, but far from everything, was also about the sun, both in terms of learning history and technology development, cf. [2].

Jürgen was both a physicist, historian of science, physics didactic and museum educator. I probably did not really understand it then, but like this in the rearview mirror I can see that that combination for a long period also applied to you, Aadu and myself. In parallel with being physicists with joy in the purely intra-scientific sense, all three of us realized how the history of science, history of technology, didactics and exhibitions could fertilize each other and have a decisive significance for the understanding of scientific connections. It was "only" that the three of us would help a little at that intersection for the benefit of teachers and through them their students. We worked with this for many years, usually separately but sometimes in actual collaborations. Here I just want to tell you about such a collaboration between you and me, Lars, one that is so unlikely that I have a hard time imagining it for any other person constellation than ours. Yes, it is hardly possible to believe even with you and me involved. But you are my witness that it's true.

The Museum of the Future, the black box and Einstein

I was invited as a lecturer to the Future Museum (or was it even a preliminary stage to the Future Museum?) Which in turn was the forerunner of the current Science Center in Borlänge. I took the opportunity to walk around and look at what you had just exhibited there and then found "the black box": a carbon black box on a shelf on the wall. At the front it had doors that could be opened and in the middle of the doorway there was a small round hole that looked even blacker than the outer walls of the box. So far remarkable. But when you opened the doors, there was a chalk-white room inside. Huh ?! Why then did the hole not look white or at least bright compared to the outside of the box, why was the hole instead looking blacker than black? Well, because the light that fell in through it was only reflected in there between the white walls and did not have a chance to slip out through the hole and reach the viewer.

In other words, the black box served as an eye opener for what reflections can do. It was also so well made that I asked if it was OK that I copied it for use in physics corridors in Lund where many future civil engineers moved around. Or - even better - if I could even buy one? No, it did not work, said Lars. Of course, it could work, I could get such a box, but only if he could trade. What he then wanted in return was a hologram of Einstein's face. Huh ?! "OK then," I said, and went home without having the faintest idea how this could be done.

Eventually I came to think of the wax cabinet within the Tussaud chain [3] that was in Copenhagen at the time. In a corner there stood Albert Einstein (in wax figure) talking to Niels Bohr, also in wax. What if I could borrow Einstein's head from there, take it to Lund and use the holographing possibilities at the physics department?!

It was not easy - but it worked. The physical was difficult in itself - bright distinct holograms require skilled experimental work. But the biggest difficulty lay in the logistics. Even being able to borrow Einstein's head required many rounds, persuasions, insurances and reinsurances. To then get caught in the customs between Denmark and Sweden and then make the customs official believe that this was just a loan (!) was not the easiest thing either. But everything worked out, you got your Einstein hologram and I got my black box. To the delight of many others.

Strömstad academy

As the visionary and entrepreneur you are, you have also taken the initiative and been the rector of Strömstad Academy, who now wants to greet you with a party script. You have gradually invited colleagues from near and far, including Göran from Dalarna and Bodil from Lund. "And the rest is history," says the Edison statue as he stands there shining in our living room window in the evenings.

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Photovoltaics Technology: Toward an All Solar-PV Electricity Future?

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Abstract

The birth of modern photovoltaics (PV) traces only to the mid-1950s, with the Bell Telephone Laboratories' development of an efficient, single-crystal Si solar cell. The inventors (Daryl Chapin, Calvin Fuller, and Gerald Pearson) did not envision that their 2-cm^2, 6%-efficient solar cell would lead to our world of electricity projecting terawatts generated from this simple device. They did not really foresee the surge of manufacturing and deployment in Asia, the embracing of the green-energy benefits in Europe, and the paradoxical investment in these technologies by the petroleum-abundant Arab countries—nor the evolvement from those *milliwatts* of the 1950s to the multi-GW production of today. Since then, Si has dominated the technology and the markets, from space through terrestrial applications. In this presentation, we examine the current status of PV—where we are with the technology (costs, manufacturing, markets) and the industry. We will examine at the status of R&D, markets, manufacturing, and technical investments. And look briefly toward what is coming—the prospects, potential, gaps, needs, and coming generations of solar electricity fitting into the current considerations of a *"100% renewables future."*

We illustrate the role and importance of innovation and vision in technology development. We will have a critical examination of the technologies (from crystalline Si through thin films—and beyond!). We will look back to time, providing insights into the early *innovators and visionaries*—their motivations, their expertise, and how these beginnings have brought us to this point at which the "future of photovoltaics" is already here!

1. Introduction and Historical Setting

Visions of a "100%-renewables future" are now being envisioned [1-4]. Solar photovoltaics (PV) has undergone rather incredible growth over the past decade. Current annual solar-PV markets approaching the 100-GW level have fostered multi-GW manufacturing facilities and approaching a TW of installations worldwide [5]. During this period, consumer prices dropped by more than an order of magnitude. When this author began his technology career more than 50-years ago, the group of contemporary PV researchers had the vison that this technology would eventually come to prominence—but at a more moderate scale, perhaps approaching 10% of electricity needs) and much sooner timewise [6]. The Bell Telephone Laboratories discovery of the modern solar cell in 1954 [7] was foundational to the PV revolution, and the media announcement did provide foresight of what was to come:

> "New York Times, April 26, 1954: MURRAY HILL, N.J.—A solar battery, the first of its kind, which converts useful amounts of the sun's radiation directly and efficiently into electricity, has been constructed here by Bell Telephone Laboratories . . . It may mark the beginning of a new era, leading eventually to the realization of one of mankind's most cherished dreams—the harnessing of the almost limitless energy of the sun for uses of civilization."

The initial market focus turned toward space, following the launch of the first solar-powered satellite, Vanguard, in 1958 [8]. Now PV is the power source of choice for almost every near-earth satellite and for major missions such are the Mars "rovers" [9,10]. The tipping point for terrestrial PV came as the result of a world crisis, the Arab oil embargo in the early 1970s [11]. This led to the birth of the world-solar programs—and a surge in enthusiasm for these scientific-device curiosities that produced electricity with no moving parts, silently, cleanly, and needing no fuel—except for the sunlight that fell on their surfaces. Major laboratories were established worldwide, including the Solar Energy Research Institute (later becoming NREL) in the United States and Fraunhofer ISE in Germany. (As an aside, an early player was the Solar Energy Research Centre (SERC) in Baghdad, Iraq, where this author first met Dr. Lars Broman in 1988 as part of a Middle East solar conference [12]. Of course, Dr. Broman himself was then Director of the different "SERC" in Borlänge, Sweden.) The terrestrial markets during this 1980s-period were tens of MW size—limited by political influences, resurgence of the fossil-fuels availability—and PV costs. It took Japan to show the world how to manufacture in the 1990s, then Germany how to realistically drive consumer markets with incentives in the 2000s, and finally China to show how to scale up and rapidly drive down prices in the period 2011 to present.

This paper primarily examines the status and development of photovoltaics technology and markets over the period 2000-present. Discussions of where this PV is manufactured show geographical shifts, ownerships, and technology investments. A look on where this PV product is being used worldwide provides insights on the markets, their trends, and some look at future world expansions. And finally, current materials and device technology and some projections of needs and potential trends. The possibility of a "100% PV electricity future" is postulated. Much of this is based upon the reality of the PV technology itself—and the experiences of the author.

2. Progress in Photovoltaics: Production, Shipments, and Installations

The commercial growth in PV and other renewable-energy technologies can be represented by a number of metrics to highlight progress. Several organizations publish these on an annual basis to underscore how these clean energy resources continue to penetrate our energy systems [13-15]. One of these tracking parameters is the volume of the product shipped from the manufacturers into the worldwide markets [5]. *Figure 1* pre-

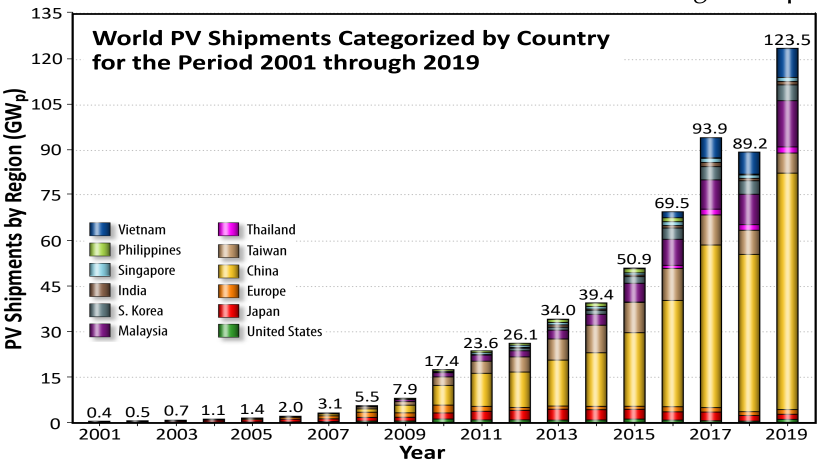

Figure 1. *Photovoltaic device shipments into the world markets over the period 2001-2019 [5].*

sents recent data provided by Paula Mints in her SPV Market Research Report [5,17], showing the shipments over the period 2001 through 2019 originating from manufacturing facilities various geographical regions in the world.

Since the 1970s, the growth in these shipments have shown annual positive growths—outside of the one outlier year, 2018.

For the past 5 years, this growth has averaged a more than respectable 26%/year. With the indicated growth in shipments of 39% (i.e., 89.1 GW in 2018 to 123.5 GW in 2019), the calculated corresponding revenue in cell and module sales had a ~$9B increase over this period. It should be pointed out that the average module prices decreased from $0.41/W in 2018 to about $0.36/W in 2019—a factor more important for the consumer. By comparison, The PV-module price was between $3.00/W-$4.00/W just 10-years ago. PV has shown substantial progress in both getting product from the suppliers and in the price for that product.

2.1 Where is this PV coming from?

In 2019, 63.3% of the PV shipped into the world markets came from China (Fig. 1). This dominance continues the trend begun in 2009-2010, when China made its appearance on the world PV scene. In the decade before that, Europe and Japan were the major suppliers. China gained the advantage by investing in manufacturing ramp up, collaborating with intellectual resource support from other country centers, making use of cooperative support from government sources, standardization, and shifting toward automation—and complete indigenous control of the technology value chain, from raw material through module design and production. In parallel, China has invested financial resources into compliance with international standards to provide the rest of the world a level of confidence in its PV product.

Certainly, Asia is the source for nearly 98% of the PV produced. Three other countries have shown significant emergence in their manufacturing status over the past 5 years—Malaysia, Vietnam, and India. The former two have benefitted from local subsidies to establish manufacturing plants—and somewhat from the tariffs imposed directly by some countries on Chinese products. India, of course, is spurred by its Government initiative–the National Solar Mission [19]–that has a target to reach a 100 GW solar capacity by 2022. This ambitious program has some provisions to increase country-specific product on its Approved List of Modules and Manufacturers [20], meeting specification and reliability criteria. It should be noted that China organization "own" >85% of the world PV companies though the manufacturing might be in Vietnam or the U.S.

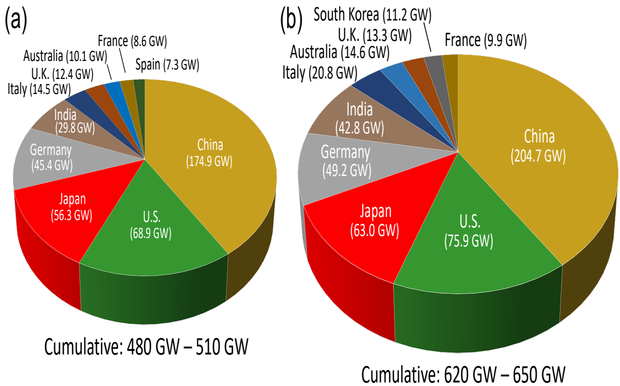

***Figure 2**. Worldwide cumulative PV installations over the through 2018 and 2019. Note that there is some spread in reports, but the cumulative installed through 2019 is between 620 GW and 660 GW.*

2.2 Where is this PV-product going?

Figures 1-3 provide some insight into who is supplying the PV and who is using it. The major markets remain "grid-connected" (~94%), but there is an increasing increment over the past 4 years of remote applications. Concerns with rural and remote populations in the world has provided some incentive to address these needs.

When China began to lead in manufacturing in the period 2009-2012, very little what they produced was used in China. This began to change with China's programs to increase clean energy shares within their electricity markets. Though their internal installations have declined over the past two years (mainly because of issues with incentives), they still lead the world in annual and cumulative installed PV—as represented in *Fig. 2*, showing the cumulative installation in 2018 and 2019. From various sources, the cumulative PV (producing electricity) now is between 620 GW to 660 GW [13]. In any case, the world electricity capacity for PV is approaching the TW level, about the current electricity generation capacity for the U.S. [13,21].

3. PV Technology Trends

3.1 Current Commercial PV

For commercial PV technology, we are currently operating in a "silicon world." If we transform the shipment data in Fig. 1 to show the percentages of the major absorber technologies, it can be seen that Si accounts for more than 90% of what was

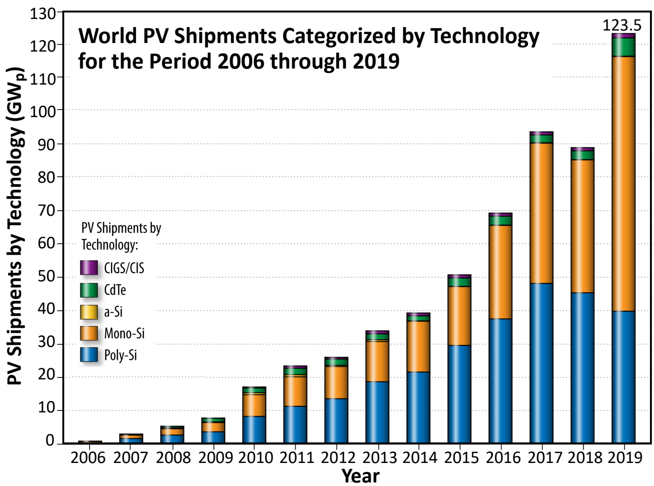

Figure 3. *World PV shipments categorized by technology (2005-2019).*

shipped in 2019. Figure 3 shows that for thin-film CdTe represented about 5%, thin-film CIGS about 1%, and a-Si:H based <1% of the total. This is still a respective number in "GW"—and the percentage of the thin-film PV did increase in 2019 over 2018. The new, higher-efficiency (<17%) and higher power (>400W) thin-film CdTe modules [22] certainly have gained some respect—especially for their better performances (kWhr/kW) in higher-temperature climate zones.

The data in Fig. 3 show presents other trends as well in the Si materials-of-choice. Monocrystalline Si is trending to continue as the material of choice among the Si technologies, with 62% or about 77 GW of the 2019 shipments compared to 40 GW of multicrystalline (or polycrystalline) Si. Thus, the higher quality Si technologies have surpassed the multicrystalline ones for the first time in the last 6 years. For the device configurations, about 80% of the devices were higher-efficiency 'passivated-emitter and rear-contact' (PERC) solar cells [23]. The choice of materials and the PERC device (Fig. 4a) reflect the importance of performance (efficiency) in continuing to lower the cost of the module technologies. The monocrystalline-Si PERC capacity was about 84 GW last year—and is growing. Of course, the major supplier is China, providing about 2/3 of this total. This movement toward more PERC and more monocrystalline Si will continue in the near future.

Another aspect is the interesting transformation of the module technologies. Discussions of solar cells that can collect light from both front and back go back to the 1980s. Pioneering R&D in Spain [24] brought this interesting concept—one that was far ahead of it time for implementation into the PV markets. These devices, called bifacial (Fig. 4b), have become reality in the market-place and are quickly being implemented by system developers. Every PV manufacturer has moved into this technology—with bifacial Si modules. These modules are becoming dominant, mainly because it adds almost no cost to produce the cells. And the modules can have enhanced energy output of 20% to 80% depending on the system implementation.

3.2 The PV technology device landscape

A good and comprehensive overview of where we have been, where we are, where we are going, and what has been our performance progress with PV-device technology is the NREL research solar cell efficiency chart (Fig. 5). The author first produced this chart in about 1984, early in his career at the Laboratory. NREL continues to update the progress of this chart available on its website [25]. Certainly, the chart depicts the growing complexity of the devices and the materials used. Figure 6 shows a group to show this—starting with elemental semiconductors (Si), through some binaries (GaAs, CdTe,), ternaries ($Cu(In,Ga)Se_2$), and now hybrids involving both inorganic and organic materials. The efficiency chart also shows the continuing improvements in research-cell performance. With the experience gained with past technologies and the expanding

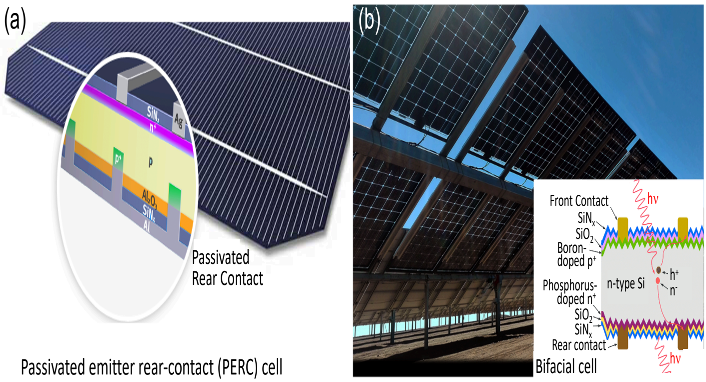

Figure 4. *Technologies of choice: (a) Cross-sectional representation of the passivated emitter and back contact (PERC) solar cell; (b) Bifacial module configuration; background is bifacial module installation.*

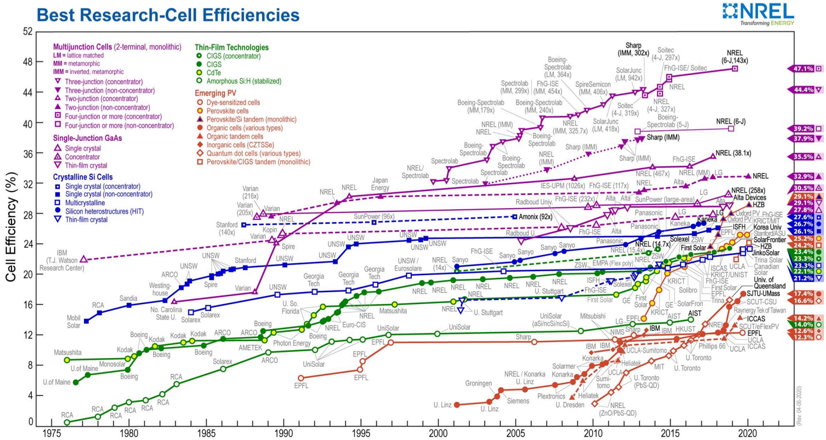

Figure 5. *Research cell efficiencies over the period 1975 through present showing evolution of "best" laboratory efficiencies over time. These cells have been validated in one of the world designated labs to perform this technical support. The chart is maintained by NREL [18,25].*

availability of complex experimental characterization and processing tools—as well as computational science support through theory—the time from lab bench discovery to commercial readiness has contracted significantly. For example, the CdTe technology were first investigated for terrestrial use in the 1970s [6]—and finally had commercial introduction in the early 2000s. The current craze with "perovskite" materials (Fig. 7) has compressed this time to less than a decade. PV research and commercial acceptance are both becoming smarter.

New materials and devices are not "dead" for PV technology. History shows that evolution, innovation, and creativity are required to bring about the next generation of solar conversion for the next generations of electricity consumers. Certainly, an examination of Fig. 5 highlights some recent advances. The first is that of the hybrid (organic-inorganic) perovskites (Fig. 7)—the subject of R&D (and funding) in almost every PV laboratory in the world [26]. Although there was some research on these materials in the 1990s and early 2000s, they really came on seriously with their device demonstrations—rapidly advancing from the 10% to the >20% regime for laboratory devices in 3-5 years. Now on the threshold of commercialization, the evolution is taking this material into two areas: (1) single-junction and multiple-junction "all-perovskites" (each cell tuned to a different portion of the solar spectrum); and (2) tandem cells [27] primarily with Si but also considered recently with other lower bandgap partners (e.g., CIGS). The Si tandem, in particular, is probably the closest to being introduced as a commercial product [26,27].

The other cell to consider is the organic PV (OPV) device. This "plastic" solar cell offers flexibility in structure, ability to manufacture continuously by roll-to-roll processing, perhaps the least expensive materials, and offer benefits for other markets, such as architectural design. These cells have also recently jumped in performance from the 10% to beyond the 15% level. This is used as an example for another reason. It was a solar cell that was seriously researched, brought to commercialization, and well-funded by various agencies.

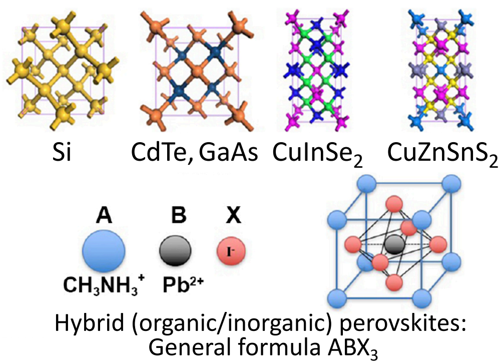

Figure 6. *Evolution of the complexity of PV materials, from elemental semiconductors through hybrid (inorganic-organic) perovskites.*

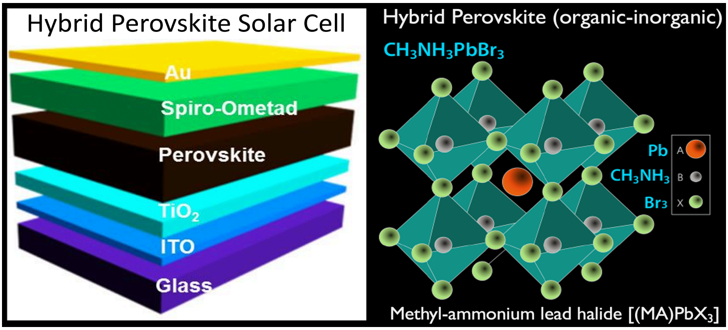

Figure 7. *Hybrid perovskite solar cells: (a) Cell cross-sectional representation; (b) Hybrid perovskite material showing atomic/molecular configuration.*

However, with the rise of the Si cell, the sources for support lost interest because of issues with being stuck at lower efficiencies at the time—and issues with stability. The example is that we do not have sufficient patience with technology development in our PV sector—and the worry is that we might throw out potential "technology killers" before their time. The message is to keep tuned and have an open mind. What the future might hold is not what we have today. Innovation is moving up for a future passing rectangular framed modules that are slapped on our rooftops or in our fields, toward a blend of energy-producing PV that is integrated into our living environment; architecturally beautiful and more than meeting our electricity requirements with exceptional performances.

4. The Future

Photovoltaics has become a viable and growing segment of our electricity structure worldwide. It is no longer a future, alternative energy source—it is real now. PV has become competitive to what have been termed conventional (coal, natural gas, nuclear) electricity generation—and in many parts of the world, can offer even stand-alone, off-grid residential costs compared to utility connections even with currently available storage. The shift toward renewable energy, especially the calls for a "100%-renewables" future by 2050, are including higher components of solar PV in the expected portfolios. The rapid price reductions along with excellent progress in PV system reliability have brought PV to the forefront of the clean electricity options.

Can PV go further? The good news is that PV, whether on the system, module, cell, or material level is driven by innovation, dedication, and competence. Can a "100% PV electricity" future become reality? The answer is yes, BUT ... Most of the renewable energy technologies have current limiting situation—in that they are not "24-hour" producers. The key is the development of adequate (energy density and energy density-to weight-ratios, cost, lifetime) storage technologies that can couple with PV to supply a constant, reliable electricity system.

Acknowledgements: The author gratefully acknowledges the discussions and PV market information provided to him by Paula Mints, who has continued to provide the world PV-community independent, traceable, and credible evaluations of the "world of solar PV."

Special Tribute: The author has prepared this short review of the status and possible future of PV for a colleague and friend, Dr. Lars Broman. Lars has been exposed to this presentation many times. As cited in this paper, we first met in Baghdad, Iraq, during the turbulent times of the Iraq-Iran war. The presentation that Lars gave in the opening session at that conference is one that influenced me greatly. Lars' lecture on "cornet" non-imaging concentrators included some "show and tell" in which he passed around models of these innovative devices. He engaged the audience and kept their attention! All my lectures since then have "stolen" Lars style to help me to connect with those listening by using such props—in my case whether solar cells or satellites! Lars and I had many opportunities to be together over the years. In fact, our next time was about a year later after Iraq, this time in Tripoli, Libya (is there some fatal trend here?). There, Lars was able to get the two of us "invited" by armed guard into a military facility for some illegal photo that Lars had taken. He was able to negotiate us out of the situation with his charming Swedish accent and giving up the film to the authorities. I was shocked, however, when Lars secretly snatched up the roll of film from the officer's desk as we left while being released!

Lars, thank you for some great opportunities to be with you (and there are many similar stories). Thank you for showing us all the value of life, clean energy, professionalism, ethics, and comaraderie. But especially, thank you for being a very good friend.

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Incentives for Promoting Deployment of Renewable Energy Technologies

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Abstract

Brief overview of some of the commonly offered incentives used to promote development and deployment of renewable energy technologies is presented. Attempt has also been used to discuss relative strengths and limitations of some commonly used incentives.

Global Deployment Status of Renewable Energy Technologies

As per the latest Global status Report from REN21 (2020) there has been rapid growth of renewable energy in power sector with more than 200 GW of incremental power generation capacity installed in the year 2019. Power purchase agreements of record amount were reportedly signed by the private sector essentially driven by substantial reduction in the investment requirement. New investments of approximately US $ 300 billion have been made in the renewable energy during the year 2019. On the other hand, there has been very little growth in the use of renewable sources of energy in heating and transportation sectors. Table 1 presents a summary of the incremental progress made during the year 2019 based on the REN21 report (REN21, 2020).

Table 1. Incremental Renewable Energy Capacity Addition Around the Globe in 2019 (REN21, 2020) .

S. No.	Renewable Energy Source/Applicat-ion	Unit	Incremen-tal Capac-ity Addi-tion Dur-ing the Year 2019	Cumula-tive Ca-pacity as on De-cember 31, 2019
1	Hydropower	GW	15	1150
2	Wind	GW	60	651
3	Solar Photovoltaic Power	GW	115	627
4	Bio Power	GW	8	139
5	Geothermal Power	GW	0.7	13.9
6	Concentrating Solar Power	GW	0.6	6.2
7	Ocean Power	GW	0.0	0.5
8	Modern Bio-energy based Heating	EJ	0.2	14.1
9	Solar Water Heating	EJ	1.4	1.4
10	Geothermal Heating	PJ	37	421
11	Ethanol Production	Billion litres	03	114
12	FAME Biodiesel	Billion litres	06	47

The following important additional information is obtained from the 2020 Global Status Report of REN21 that directly or indirectly pertains to the topic of incentives.

(a) Globally there are 172 countries with renewable energy targets.

(b) 162 countries of the world have renewable energy policies
(c) Presently there are 87 countries that have feed-in policies and the cumulative number of such countries so far is 113
(d) While the cumulative number of countries that adopted the provision of tendering is 109, during the year 2019 only 41 countries followed the same
(e) There are 70 countries that have bio-fuel blend mandates
(f) 61 countries of the world have set the target of 100% renewable energy-based electricity

The above encouraging numbers notwithstanding, the overall share of renewable sources of energy in the total final energy consumption is still rather low (11% in the year 2018 excluding traditional use of biomass feed-stocks. Thus it is necessary to continue with prioritization of renewable energy based energy delivery over its fossil fuel based counterparts in a holistic manner so as to achieve greater penetration of the same in the overall fuel mix. One of the commonly used strategies for promoting renewable energy utilization has been the provision of different types of support measures so as to make them competitive with other available options. One of the major challenges for policy makers is to decide appropriate incentives so as to be able to achieve the envisaged targets. This article aims at describing the need and relevance of incentives for renewable energy along with a brief introduction to commonly used ones besides a bibliographic review of some of the recent relevant publications.

Justification for Providing Incentive(s) for Development and Deployment of Renewable Energy Technologies

The societal costs of fossil fuel based energy delivery such as that can be attributed to (a) air pollution, (b) greenhouse gas emissions, (c) water usage, and (d) fuel supply risk (fuel price volatility as well as geopolitical risk) are usually not fully internalized and consequently not reflected in market prices of energy delivered, leading to inefficient choices for energy supply. Internalizing these external costs is therefore important to facilitate an objective comparison of various energy delivery options. However, it is difficult to unambiguously estimate external costs of fossil fuel based energy supply – cost of damage or cost of avoiding damage (cost of avoiding or controlling variety of environmental emissions released at different stages of energy conversion, transmission/transport, distribution and utilization) and, as a consequence, considerable uncertainty could be associated with any such estimates.

In view of this challenge, most of the governments, instead, often use incentives for promoting deployment of renewable energy technologies so as to reduce air emissions, mitigate climate change impacts, reduced water usage and establish a more balanced electricity supply portfolio. A measure that eventually leads to a reduction in the cost of harnessing renewable sources of energy for the user and the society and makes the same competitive with other alternatives for meeting the same energy demand can, in principle, be defined as an incentive. Incentives are also expected to make renewable energy-based energy delivery financially competitive with fossil fuel based alternatives of energy supply. Thus, one of the key aspects is to identify appropriate measures that would help reduce the cost of energy supply based on renewable sources of energy so that levelized cost of electricity/energy (LCOE) is competitive with that of fossil fuel-based energy supply. Measures that reduce effective capital cost or reduce discount rate applicable for renewable energy projects through lower cost financing etc. would come under this category. Another consideration is to identify measures that would help improve the profitability of a renewable energy project or in other words that would increase monetary benefits accrued from the energy delivered by renewable energy projects. This can, for example, be achieved with higher tariffs, generation based incentives, tax benefits etc. Usually provision of incentives may also provide the benefits of learning by doing and result in much desired cost reduction by pushing the technology down the learning curve. It is also expected to help in job creation and economic development (though only the net incremental creation of employment avenues is to be considered).

In the specific case of renewable energy technologies, incentives may be given to:

(a) compensate for the high capital (up front) cost of renewable energy projects and thus reduce monetary cost for the investor; alternatively to increase monetary benefits likely to accrue (by way of additional revenue generation) so as to improve the financial attractiveness of the investment made

(b) (b) reduce investor's risk in renewable energy projects; with the risks that can be mitigated or reduced including Planning and Development Risk, Performance Risk (also technology risk, resource availability risk), Grid Connectivity Risk, Curtailment risk, Policy and Regulatory Risk, Market Risk, Currency Risk, Legal Risk, Counterparty Risk, Security Risk and Credit Guarantees

(c) To generate awareness, and to demonstrate the new technology to its potential users and obtain feedback on the performance of technology and its adoption, capacity building

(d) create a minimum market for the entrepreneurs to be interested and also to achieve cost reduction due to increased volumes, enhanced learning and experience, economy of scale, support after sales service and thus eventually leading to increased demand for renewable energy technologies

(e) compensate for the inherent subsidy (direct and indirect) provided since long time and still being provided to conventional fossil fuel-based systems

(f) encourage the use of renewable energy systems for their environmental and other intangible benefits

(g) improve energy security/self-reliance and reduce import burden

(h) stimulate private participation in the development of renewable energy technologies, facilitate low cost financing of renewable energy projects

(i) Reduce the likely impact of future volatility of price of fossil fuels on the cost of energy delivery

(j) Establish a quality control mechanism, promote research and development etc.

(k) Reduce cost of financing of the project by facilitating availability of lower cost debt and/or lower cost equity investments; this also includes approaches to reduce risks for both lenders and equity investors so that it is easier to attract finance for renewable energy projects while ensuring minimum acceptable return on investment for equity investors and lenders.

Each renewable energy system has associated life cycle present value cost and benefit for the individual and for the society. An incentive may be justified in situations where the lifecycle benefits of a renewable energy project to the society are more than its cost to the society (and for an individual the costs are more than the benefits). In other words, whenever the benefits of a renewable energy system for the society are more than its cost to the society but its costs outweigh the benefits for an individual, the provision of financial/fiscal/any other incentives to the individuals may be considered. Thus, the society (governments) may like to support the renewable energy system in view of its economic feasibility in spite of its financial unattractiveness to the individual user.

Financial and fiscal incentives have been widely implemented by governments (Central/Federal, State Level, Local) around the world to promote development and deployment of renewable energy technologies on a large scale. One of the key motivations for offering incentives to various stakeholders is to address key market barriers. For example, financial incentives can improve access to capital, reduce the burden of high upfront costs, lower cost of financing and support creation of new markets.

Commonly Offered Incentives for Renewable Energy Technologies

A brief description on some of the commonly offered incentives for promoting development and deployment of renewable energy technologies is presented in the following paragraphs:

Capital Subsidy:

In this case a certain fraction of the capital cost (initial investment required on the renewable energy system/project) is shared (subsidized) by the government. Such a cash grant essentially reduces the initial investment burden besides reducing the risk of the investor. Capital subsidy could be restricted to (a) duly certified system(s) in terms of performance and other characteristics of the technology, (b) certain sizes/capacities and (c) certain user/investor categories or geographical regions. In certain situations, the policy makers and planners may determine the amount of initial cash grant to be provided to the investor to make the renewable energy option competitive with conventional options. In such a case the capital subsidy/cash grant is called Viability Gap Funding (VGF) with its amount decided on the basis of making the project viable (or competitive) with respect to a pre-decided criterion. For example, VGF can be provided to a photovoltaic project so that it can deliver electricity at a pre-specified rate, or to a wind farm project for being able to sell electricity at prevailing market rates. The extent of VGF required may vary due to differences in the choice of technology, materials, locations and other parameters. The value (extent) of VGF can be decided for specific targets in terms of either of the measures commonly used for appraisal of renewable energy projects that include LCOE, Pay Back Period, NPV, IRR or Benefit to Cost Ratio. In view of huge potential and the need to have large capacities installed, it is worth mentioning that it would not be practically feasible to achieve large scale diffusion of renewable energy technologies by providing capital subsidy (or cash grant or VGF) alone.

Soft Loan / Interest Subsidy:

A certain fraction of the capital cost is provided to the investor as low interest (soft) loan for a specific repayment period (often with some moratorium period). The difference between the market rate of interest and the interest rate levied on the soft loan provided to the investor is paid by the government. Renewable energy systems should usually meet certain specifications to be qualified for the provision of soft loan implemented as interest subsidy and maximum/minimum limits on the amount of soft loan can also be specified.

Accelerated Depreciation:

Depreciation is an accounting principle that businesses use to express the declining value of assets with time over their long useful life on their balance sheets. It allows the capital investment made on assets with long useful life to be accounted for in the tax returns of the businesses. Thus, depreciation itself is not a tax incentive as most assets with long useful life are anyway depreciated for tax purposes. However, the provision of accelerated depreciation that allows most of the capital cost of renewable energy assets having expected useful lives of 20 - 25 years to be depreciated for tax purposes within the first few (often one to six) years certainly provides an incentive to renewable energy project developers with high tax appetite. Several countries have offered in the past the provision of 100% depreciation in the first year of operation of the project for some renewable energy technologies. The provision of Modified Accelerated Capital Recovery (MACRS) in USA is another well known example of accelerated depreciation for renewable energy technologies.

Investment Tax Credit:

A certain fraction of the qualifying cost of a renewable energy project is provided to the investor as income tax credit upon investment in the project. Investment Tax Credit is realized in the year when the project begins commercial operation. The amount of tax benefit is thus essentially dependent on the capital cost (and the share of the equity investor in the capital cost). Higher capital cost projects with lower annual outputs may benefit more from this provision (as against the Production Tax Credit). In the United States of America, the investment tax credit is realized in the year in which the project begins commercial operation but vests linearly over a 5-year period. Thus, if the project ceases to qualify for the credit over this initial five year period (for example, if the project owner sells the project before the end of its fifth year of operation) then the unvested portion of the credit will be recaptured by the Internal Revenue Service of the country.

Production Tax Credit:

It refers to the income tax credit (provided to an equity investor of a renewable energy-based power generation project) for the electricity produced during the year. Thus, Annual Capacity Utilization Factor of the plant is an important factor in deciding the annual amount of Production Tax Credit likely to be available to the equity investor. The rate of the Production Tax Credit could vary depending on the type of the renewable energy resource and is often adjusted with inflation. Production Tax Credit is usually given for a certain period of operation (not necessarily equal to its useful life) and the same is explicitly specified in the scheme. For example, in the United States the Production Tax Credit is 10 years after the commencement of operation of the project. The cumulative present value of all the Production Tax Credits availed by the equity investor would also depend on the time value of money (discount rate) applicable for the investor/project. The provision of Production Tax Credit is expected to be more attractive (as compared to the provision of Investment Tax Credit when annual electricity generation is high and the capital investment requirement is relatively lower.

The Production Tax Credit (PTC) has associated performance risks as the production would happen in future. In case the project under-performs (lower capacity utilization factor than expected) an Investment Tax Credit (ITC) may be more favourable (ITC offers more certainty in this regard even if PTC promises a higher expected overall benefits) for the project developer. However, the tax appetite required could be much larger for the case of Investment Tax Credit. The Production Tax Credit, on the other hand, is an incentive for the project developer to operate and maintain the plant for best performance. In principle, it is possible to determine the value of a cash grant that is equivalent to the provision of an Investment Tax Credit or a series of values of annual Production Tax Credits. In some cases, the provision of an equivalent cash grant may help project developer to access less expensive debt or equity capital than might otherwise be available with the provision of ITC or PTC

The provision of PTC may sometimes be linked with the condition that the sale of power be made to an unrelated party. Projects that aim at substitution of in-house consumed electricity (and not for sale to a utility) may thus not be eligible for PTC. The provision of ITC not stipulating any such requirement may therefore become a more widely acceptable incentive (for the project developer).

The provision of Production Tax Credit (PTC) may also necessitate that the project owner (availing the PTC) must also operate the project (to claim the PTC). Such a requirement effectively rules out the option of Lease Financing since in such an arrangement the owner and the operator are separate entities. On the other hand, the provision of Investment Tax Credit (ITC) usually may not require the owner and operator to be the same entity.

Renewable Purchase Obligation and Renewable Energy Certificates:

Regulations have also been used to incentivize adoption of renewable energy-based options for meeting the energy demand in several end use sectors. Typical examples include restrictions on the use of fossil fuels for specific applications (for example, heating of outdoor swimming pools), mandating a certain share of energy based on renewable sources (Renewable Purchase Obligation, RPO) in the energy supply with examples including RPO in (a) Fuel(s) used for district heating, (b) Transportation fuels and (c) Electricity supplied by utilities.

The key idea is to establish a mechanism for providing a certified 'green attribute' of renewable energy-based electricity and to create a market (through regulations such as the Renewables Purchase Obligation) for sale of certified Green Attributes and consequent revenue generation (Renewable Energy Certificates under RPO). The Renewable Purchase Obligation (RPO) aims to ensure that a certain fixed proportion of green electricity is generated by the producers /distributors /consumers of electricity. Such 'fixed quotas' or 'portfolio mechanisms' may however disregard economic efficiency since they neither take into account different production capacities and possibilities nor the individual costs to comply with the stipulated quota requirement. One of the remedial measures is to allow trading of quotas to enhance the efficiency of such a quantity-based mechanism. By allowing such trading of quotas the obliged entities are free to choose whether (i) to fulfil the quota themselves or (ii) rather pay another entity for covering their obligation (by buying energy produced by other generators). Such buyers would choose less costly options thus leading to economic efficiency. Locations with best available renewable energy resource would thus be considered for renewable energy project development. Thus, the stipulation of RPO with the provision of Renewable Energy Certificates encourages production of 'green' electricity at least cost.

In a broad sense, Renewable Purchase Obligation or Portfolio Standards or Quota Obligations can be developed and implemented for (a) Electricity (at the level of distribution utility) to include renewable based electricity in the generation mix (b) Transport Fuels (at the level of companies dealing with the same) to include liquid bio-fuels such as ethanol or bio-diesel in the supply mix (c) District Heating Systems (at city, municipal level) to use renewable and/or combustible wastes (d)

Industrial Process Heating to include a share of solar or biomass based systems (at each industry level) (e) Coal Thermal Power Plants to include the provision of Biomass Co-firing.

The RPO mechanism along with the provision of Renewable Energy Certificates involved, in case of electricity generation, allows for a separation of the renewable energy based (green) electricity (the physical amount) from the attribute (certificate) of producing green electricity. For each MWh of renewable energy-based electricity production (and supplied to the distribution agency at prevailing market rates) one (01) Renewable Energy Certificate (REC) or Renewable Obligation Certificate (ROC) or Tradable Green Certificate (TGC) is provided to the producer. These certificates representing the generation of renewable energy-based electricity (RECs/ROCs/TGCs) can also be sold in the market to generate additional revenue. The prospective buyers include all those distributors of electricity who are not able to meet their own quota (renewable energy purchase) obligations and also individuals and corporate interested in promoting renewable energy-based electricity generation. The regulator(s) may suggest Floor (minimum) and Forbearance (maximum) prices for these certificates.

The provision of Renewable Energy Certificates guarantees a strong regulation of capacity development and is expected to cost less than the FiT to public finances. However, as long as it does not distinguish across technologies, it would promote more mature technologies and would not favour less mature, and more expensive technologies. Additionally, it is less attractive to investors because of uncertainty with the price of RECs due market fluctuations. For example, in case of large-scale deployment of renewable energy projects the price of the certificate could theoretically drop to zero.

As mentioned earlier, under the Renewable (Energy) Purchase Obligation scheme, the governments can stipulate minimum shares of renewable energy-based electricity (or any other fuel or energy) on suppliers (distribution utilities) or consumers or producers. If the obligations are not met, financial penalties are to be paid by the defaulting supplier. The amount collected from penalties can be recycled back to suppliers in proportion to their respective shares of renewable energy-based electricity (fuel) supply. It is worth mentioning that the RECs provide revenue support in addition to the electricity price and used as proof of compliance of the Renewable Energy Purchase Obligation. Thus, a REC essentially represents the value of renewable energy-based electricity and facilitates trading of the green attribute of electricity.

Net Metering:

Net metering is essentially a mechanism that helps owners of renewable energy systems to sell electricity into the grid and account for the net difference between electricity taken from the grid and that fed by the system into the grid. Thus, net metering is a price-based support mechanism with the name of the support instrument referring to the meter measuring the electricity consumption. Obviously, availability of appropriate metering technology is crucial to facilitate the accounting required for proper execution of the power purchase agreement. Under this arrangement, independent power producers have the right to get connected to the grid and the local utility is obliged to purchase all excess electricity (not needed for local consumption). Any excess electricity fed into the grid is usually priced at the prevailing commercial rates though different arrangements may be stipulated in the power purchase agreement.

Preferential Pricing for Green Electricity:

Some consumers value the social and environmental returns associated with 'green electricity' (i.e. electricity produced by renewable energy-based power plants) and are willing to pay a special price premium or surcharge per kWh over regular commercial rates. Utilities can offer such a service to the consumers. In some cases, such a provision can be implemented as ‘Mandatory Green Power Option’ under which the distribution utilities provide an option to their customers to purchase green power either directly from their own company or from an alternate distribution utility.

Generation Based Incentives /Feed-in Premium:

The renewable energy based electricity producers may be provided a certain amount of generation based incentive for each kWh of green electricity fed into the grid. The amount of incentive would depend upon the annual capacity utilization factor of the renewable energy-based electricity generation plant, and thus on technology, location and time as well as the functionality of the project. The generation-based incentive could be provided for certain specific period during the useful life of the project (usually in the initial years of its operation). It provides an additional revenue stream and thus improves the possibility of securing higher debt capital and also improves the overall profitability of the investment made on renewable energy based electricity generation project. This provision is also called “Feed-in Premium” as a guaranteed premium is paid in addition to the income the project receives for the electricity from renewable energy sources that is being sold on the electricity market. Another indirect advantage of the provision of Generation Based Incentives is the need for operating and maintaining the plant and hence the motivation for the same.

Generation based incentive provides a secure additional return for producers of renewable energy-based electricity. However, such projects are exposed to the risk of volatility of electricity price in the market. Thus, the mechanism provides less certainty to investors as compared to the mechanism of Feed-in

Tariffs and hence implies relatively higher risk premiums and consequently higher total cost of capital. If the generation-based incentives are limited by 'Cap' and 'Floor' prices of electricity, the same would provide higher certainty and less risk of over-compensation as compared to fixed values of generation-based incentive. In this case the producers of renewable energy based electricity usually participate in the whole sale electricity market and hence may often decide to adjust their production according to the price signals on the market (i.e. the demand for electricity), particularly for systems with fuel costs (for example biomass based electricity generation systems).

The quantum of generation-based incentive (per kWh of delivered electricity) is likely to depend on future expectations for the unit cost of electricity generation from renewable sources of energy and the average electricity market revenues. Similar to the case of Feed-in Tariffs, the incentivizing mechanism involving Generation Based Incentives may also suffer from the risk of inducing additional costs for the society and windfall profits for the producer (if the future cost of generation is over estimated or the market prices of electricity and/or the learning rates of renewable energy technologies are under estimated by policy makers / regulators). Therefore, the Generation Based Incentives should only be provided for a reasonable time limit and should be periodically reviewed with latest updates on cost of the technologies and the market price of electricity.

Feed-in Tariff:

Under this provision the regulator obliges regional or national transmission and/or distribution utilities to feed-in the full production of 'green' electricity at pre-decided fixed prices. Such feed-in tariffs may be different for different types of renewable energy resource-technology combinations (solar, wind, hydro). In order to qualify for being labelled a Feed-in-Tariff, the scheme should satisfy three conditions. First, the purchase obligation obliges the nearest electricity grid operator to buy all renewable energy-based electricity independent of electricity demand. Second, the renewable power producer is guaranteed a certain amount of money per unit of electricity that is delivered to the utility. Finally, as per the third condition, the payment for the renewable energy-based electricity fed into the grid is guaranteed over a long period of time (usually 15 to 20 years) which increases investment security and allows for cost amortization.

The Feed-in Tariffs are expected to take into account the cost disadvantage of the electricity generation projects based on renewable energy sources. Most of the time, feed-in-tariffs are calculated so as to provide an investment bonus to renewable energy-based project developers. It is expected that the utility will pass on the higher costs for renewable source-based electricity to the final consumers. The overall impact of higher feed in tariffs for renewable energy-based electricity in a supply mix would depend upon the share of renewable electricity and the relative price differentials (between average power purchase cost of conventional electricity and that of renewable energy based electricity).

High degree of investment security with feed-in-tariff mechanism creates favorable investment conditions for utilities, small and medium size companies, and even private investors. Feed-in tariff offers flexibility of design as per national electricity markets and policy objectives. Moreover, the increasing share of renewable electricity can often be internalized in designing the feed-in-tariffs. The provision of feed-in tariff can also help in creation of national markets for manufacturing industry and thus offering secondary benefits such as job creation and it can also help in democratizing energy markets with sufficient competition by allowing a large number of actors to participate in power generation business.

The advantage of feed-in tariffs as compared to renewable energy purchase obligations lies in the long-term certainty of receiving a fixed level of support. This lowers the investment risk considerably. By guaranteeing the price of electricity fed in and also ensuring a secure demand, feed-in tariffs can reduce both the cost and market risks with arranging investment capital and create the much needed certainty for the investor regarding the rate of return of the project. It may also be noted that a lower cost for the investor would result in lower average cost to the society in terms of supporting the development and deployment of renewable energy technologies. The weighted average cost of capital for investments in renewable energy projects was observed to be lower in countries with established (feed-in) tariff system as compared with countries providing other types of incentives (such as renewable purchase (quota) obligations/portfolio standards).

The Feed-in tariff could either be decided on the basis of (i) the expected cost of electricity to be produced be a renewable energy power plant and a certain entrepreneurship margin for the project develop. / producer or (ii) a generation-based incentive added to the base tariff of conventional electricity. While the base tariff of electricity may escalate with time, the cost of renewable energy-based electricity is expected to reduce with time and as a consequence the difference between the Feed-in tariff and the base tariff for conventional electricity is expected to reduce with time.

The cost efficiency of feed-in tariffs for the society decreases when policy makers (tariff-regulators) over- estimate the cost of producing renewable energy-based electricity. Since the level of feed-in tariffs is based on future expectations of the cost of generating electricity from renewable energy sources, a possibility of a large profit to the project developers exists if the actual cost of generation turns out be much lower than estimated costs. Hence there is a need to review the feed-in tariffs on a regular basis to adjust the tariffs to the latest available generation cost projections and also to stimulate technology learning for cost reduction.

Though the feed-in tariff payments should be guaranteed for a reasonable time period (approximately 15-20 years) to allow payment of debt and recovery of equity investments, it should not be excessively large resulting in unduly large profits (as the actual cost of generation for new technologies would also have come down). An important consideration is to achieve reduction in the cost of electricity/energy delivered so as to make it competitive with other existing options. The FiT policy guarantees a stable and secure market for investors, raising a hedge against the volatility of electricity price and enhances market access for investors and participants. On the other hand, it has a number of limitations. It distorts electricity market prices and does not directly address the high upfront costs of renewable energy technologies. Moreover, it does not encourage direct price competition between project developers either.

Certified Emission Reduction Units (Carbon Credits):

To establish a mechanism for providing a certificate for the green houses gas emissions mitigated due to generation of renewable energy-based electricity and to create a global market for the sale of such certificates to earn additional revenue for the project (Certified Emissions Reduction Unit). For each tonne of CO_2 equivalent mitigated the project developer would get one CERU which can be sold in the market. Prospective buyers are those entities who require additional carbon credits for compliance with the carbon mitigation targets or those who on a voluntary basis intend to contribute to carbon mitigation benefits in the sector.

Miscellaneous Incentives:

A large number of other measures have also been used to promote adoption of renewable energy technologies. These include incentives on personal income tax, property tax and sales tax/value added tax/goods and services tax, research and development grants, translational grants for technology transfer, business development supports, capacity building grants, green jobs/recruitment grants, grants for feasibility study, insurance payments, site assessment fee contributions, lower import duties and income tax holidays, loan guarantees, property assessed loan programmes, tendering schemes, fuel disclosure programmes (that mandates the generation utilities to disclose their fuel-mix to the customers) etc.

Bibliographic Review of Recent Publications on Incentives

In view of the critical importance of incentives in development and deployment of renewable energy technologies, efforts have made to study and analyze various facets pertaining to their design, implementation, factors affecting their design, their impact on the economy and other relevant aspects (Finjord et al 2018; Fowler and Breen 2014; Masoumzadeh et al 2020; Patrick et al 2019; Rajendran et al 2019; Roberta et al 2017; Sawyer and Friedlander 1983; Tang and Rehme 2004; Yang et al 2019). Large number of studies have also been reported in the literature that deal with designing and implementation of incentives and associated policy and regulatory measures in different countries (for example studies by Abrell et al 2019; Aquila et al 2017; Cansino et al 2010; Cox 2016; Croonenbroeck and Hennecke 2020; Delmas and Montes-Sancho 2020; El-Karimi et al 2013; Foster et al 1998; Haas et al 2011; Hulshof et al 2019; Kreith et al 1996; Lantz et al 2007; Pettersson and Söderholm 2019; Roth et al 2020; Simsek and

Simsek 2013; Wang 2006; Washburn and Pablo-Romero 2019; Xiangchengzhen and Yilmaz 2020; Yaqoot et al, 2015; Zander et al 2019; and Zhao et al 2016). Such studies provide important insights for deciding appropriate incentivizing measures in different situations for specific renewable energy technologies. Moreover, studies have also been reported in the literature that present comparison of two or more incentives for promoting development and deployment of renewable energy technologies (Alagappan et al, 2011;, Bird et al, Carley 2009; Ciarreta et al 2017; Fagini et al, 2013; Finjord et al 2018; Groba et al 2011; Gunnar and Petersen 2006; Hao et al 2020; Matisoff and Jhonson 2017; Menz and Vachon, 2006; Mihaylov et al2019; Mitchell et al 2006; Nicolini and Tavoni 2017; Nilson et al 2004; Shrimali and Kniefel 2011; Yin and Powers 2010). The efficacy/effectiveness of incentives may also depend on the risk return tradeoff of the investor or risk aversion characteristics.

As expected, the provision of incentives affects the financial attractiveness of renewable energy projects. Studies have been reported in the literature that present the impact of different types of incentives on the commonly used measures for financial appraisal (Chandrasekar and Kandpal 2005; Chaurey and Kandpal 2009; Indora and Kandpal 2019; Sharma et al 2017 a; Sharma et al 2017 b; Sharma et al 2018). Attempts have also been made to determine the extent of an incentive required to acieve breakeven conditions.

Under the renewable purchase obligation (RPO) there is a provision for awarding Renewable Energy Certificates (RECs) that can be sold to earn additional revenue for the project. In the United States, some studies have concluded that there is a positive relationship between Renewable Purchase Obligation (RPO) and the wind power development in the country. On the other hand, a study (Carley 2009) concluded that the RPO does not appear to be a significant predictor of the share of renewable energy generation in the total energy mixes though it is positively related with total renewable energy-based electricity generation. A study by Delmas and Montes-Sancho (2011) reported that RPO may have negative impact on investments in renewable energy capacity. Instead Mandatory Green Power Option (MGPO) has been found to have significant impact on installed capacity based on renewable sources of energy.

The price of the RECs is likely to be highly uncertain as it depends on their demand and the performance of the renewable energy system. Since the producers of renewable energy-based electricity sell the electricity produced as well as the RECs in the open market, the risk in the REC market is added to the risk on the electricity market. Such an uncertainty increases the level of risk premiums and the cost of capital for the project developers. The higher cost of capital is eventually transferred to the consumers of electricity. Thus, the societal costs of supporting renewable energy-based electricity could be higher than that under the mechanisms of Feed-in Tariff or Generation Based Incentives.

The provision of capital subsidy offers definitive financial incentive for the investor. Moreover, the capital subsidy may often be linked with the capacity of the system as against the output or performance (energy delivered). Thus, the provision of the capital subsidy offers much better certainty about the net costs of renewable energy projects. Same is also applicable to the provisions of low interest (soft) loans or tax credits that depend on the investment made (accelerated depreciation and investment tax credits).

The provision of Net Metering is also expected to incentivize renewable energy-based electricity generation at residential/distributed level. The provision essentially allows the investor (such as households) to offset the cost of retail electricity price.

Feed-in Tariff is found to be more effective in renewable energy development and deployment as it reduces risk for renewable energy development in a more effective manner. Moreover, the provision of feed-in-tariff is more effective at relatively lower additional cost for customers. Feed-in Tariff is, therefore, often preferred over Renewable Energy Certificates (or Green Certificates) for their ease of implementation as well as lower administrative costs. Groba et al, 2011 have also observed that the provision of Feed-in- tariff leads to an increase in the renewable energy-based electricity generation capacity.

There is a need to understand the relative effectiveness of different types of incentives in enhancing the acceptance of renewable energy technologies for meeting energy demand in both centralized and distributed categories of applications in various sectors of the economy including residential, community, commercial, industrial, agricultural and transportation sectors. This information can be used to design policies to take full advantage of specific policy measures and economize on public funds allocated for less effective incentivizing measures.

Most of the times incentives are provided by the society – the Government. It may not be practically possible for the Government to provide incentives for the entire renewable energy sector in terms of all potential deployments (budgetary constraint). Money must be invested by the private sector and the role of public sector funds could that be just for providing stimulus. Thus, the efficacy of an incentive mechanism can be assessed in terms of private money leveraged per unit public funds spent to incentivize and different incentives can be compared on this basis.

Efforts towards assessment and evaluation of effectiveness for promoting some renewable energy technologies have also been reported in the literature (Matisoff and Johnson, 2017). Often the relationship between public funds used and incremental capacity installed has been studied for this purpose. For example, one of the studies for USA concluded that for each additional dollar of incentive an additional 500W capacity was installed per thousand residential electric consumers. Alternatively, the amount of private funds leveraged per unit amount of public funds used is considered as an appropriate measure to assess the efficacy of an incentive.

Different types of incentives may be appropriate in different stages of development of renewable energy projects. For example, studies have revealed that a requirement for incentives such as grants and soft loans at the feasibility and development stages is an important feature of renewable energy projects that involve citizens primarily due to their greater risk aversion, little or negligible technical experience and limited financial capacity besides their inability to balance risk across a portfolio of projects. At later project stages of renewable energy projects, market-independent supports such as feed in tariffs, cash grants, and income tax incentives have been found to relatively more effective in attracting private investment. It may also be possible to design market-based supports such generation based incentives and renewable purchase obligations/ quota schemes to motivate investors to consider renewable energy projects.

Conclusions

A wide variety of incentives have been used to promote renewable energy utilization. The preference for the incentive(s) has often varied with time, country and also with states within a country. Incentives are essentially cost to the Government while the same are expected to reduce the cost of harnessing renewable energy.

Incentives can promote innovations towards development and deployment of appropriate technologies to harness renewable sources of energy. However, it is yet difficult to reach a consensus on the relative effectiveness of different incentives for this purpose. For example, incentives that reduce the cost to the consumer at the point of purchase without excessive administrative hassles are likely to be more effective for harnessing of renewable sources of energy at distributed level. For electricity generation based on renewable energy, feed-in-tariffs have been found to be much better than the provision of renewable energy certificates. Specific combinations of incentives may turn out to be more effective in promoting deployment of renewable energy technologies. For example, for rooftop PV systems the combination of capital subsidy, net metering and financing have been found to be quite effective.

There are a large number of examples which reaffirm that if the incentives are not designed and implemented properly the same may not achieve the envisaged policy goals. Therefore, while designing and implementing incentives for promoting renewable energy development and deployment the efficacy considerations (for example, defined in terms of private funds leveraged per unit public funds spent on incentivization) are quite relevant.

With increased efforts to enhance the role of renewable energy in meeting the energy demand of various end use sectors and consequent increase in the overall deployment levels of renewable energy technologies more and more innovative ways of incentivizing the same are being developed thus contributing to progressive learning in this regard. In some countries the support schemes and policies for promoting development and deployment of renewable energy technologies are being phased out progressively and the same may be attributed to substantial reduction in the capital cost of the technologies and also increasing policy costs. In many countries, political factors may decide the policies for renewable energy (both at central/

federal and state level). Another issue is regarding the effect of incentives on consumer behaviour.

A variety of issues are to be considered while designing incentives for promoting deployment of renewable energy technologies. These may include issues pertaining to the approach to be used for incentivization, the extent of incentivization, deciding the beneficiary, the timing of providing incentives and the duration for which the incentives are to be provided etc.

An incentive should facilitate a reduction in the effective cost of investment in renewable energy technologies and /or help increase the benefits expected to be accrued from the use of renewable energy technologies. However, the provision of incentive(s) should neither compromise on the quality and long term prospects of renewable energy technologies nor on the economics of overall resource utilization for the benefit of mankind.

Market reforms, appropriate policies and regulatory frameworks can be used to create and nurture enabling environments conducive for adequate private investments in the renewable energy sector. Alternatively, public finance mechanisms that facilitate direct support to renewable energy projects can be established. Both these approaches have their merits and limitations and also requirements on the preparedness levels of the country for being effective and efficient.

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RENEWABLE ENERGY EDUCATION AND TRAINING FOR SUSTAINABLE LIVING COMMUNITIES

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Abstract

The existence of quality human resources is a necessity for any development process to continue successfully. Learning Science and new technologies is important for all participating in the development processes at the community level. The best approach for a better understanding of the public about new technologies was found to be the open public dialogues at the community level with the participation of all stakeholders. For the effective planning and management of such community-based educational programs, it was also found that well informed and skilled local personnel should be also trained to be involved in the decision-making process through the establishment of local Non-Governmental Organizations.

Three field projects are discussed in this paper. The Basaisa village project in the Al-Sharkiya Governorate, Nile-Delta (started in 1974), the New Basaisa community project in South Sinai Governorate, Egypt (started in 1992), and the Valley Paradise in the New Valley Governorate, Egypt (started in 2017). The three communities are small satellite communities where Renewable Energy education and training were used in an

integrated and participatory approach to achieve sustainable living and community development.

In this paper prospects on the development of proper and innovative approaches, systems, and programs at the community level are presented and discussed. Based on Transfer of Knowledge and Open Community Dialogues, the experiment used Community member's active participation and grassroots innovations to develop innovative approaches in the promotion of use of RE and access to Knowledge, Services, and Finance.

The paper presents the process of empowering such small and poor communities through transfer of knowledge and the utilization of innovative ideas to achieve Sustainable Living Communities in Rural and Desert Areas of Egypt and elsewhere. Results are discussed and recommendations are presented to face future challenges.

Key words: *Community-Based Development, Education, Training, Innovation, Renewable Energy, Sustainable Development, Basaisa, Egypt*.

Introduction

Sustainable community development can't be pursued as a sectarian initiative. In fact, the special importance of the effort outlined in this paper as a program of action lies in its integrated approach, its attempt to combine renewable energy technology promotion and youth employment, construction of new settlements, poverty eradication, social integration and equality into a coordinated and participatory plan of action. This paper reports on the progress of three unique grassroots initiatives: one that started 1974 in a small rural village at the heart of the Nile Delta called Basaisa, one that started 1992 in a new desert community called New Basaisa at 8 Km north of

Ras Sudr in South Sinai, Egypt, and one that started 2017 in the desert road to Kharga Oasis, the New Valley Governorate, Egypt. The paper describes the renewable energy technologies used and the approaches that work as well as the problems facing its wide implementation and the achievements to date.

Small photovoltaic power units were used in all sites as multi-function units, producing electricity for training and education, some time for TV, some time for the Friday prayer in the Mosque, and other times for production activities in small workshops for income generating activities. Knowing that one source of energy can't satisfy all needs in a community, other renewable technologies were introduced and used like biogas, wind and solar water heaters. The paper also presents a vision of the integrated approach to planned internal migration and construction of new settlements as productive eco-desert communities outside the overcrowded narrow Nile-Valley and Delta villages.

The recent national census showed that the average per capita share of cultivated land and inhibited land in Egypt continued to fall from 1.0 feddans, and 1.4 feddans in 1800 to 0.13 feddans, and 0.2 feddans in 2006 respectively. As Egypt's document for the 21st Century states "to get out of the old valley to the desert is not merely an option to select from available alternatives, but rather a matter of life not only for the present generation, but also for the future generation". Crowdedness leads to an overall gradual deterioration in urban utilities and loss of civilized image. It renders futile any efforts exerted in cleaning and beautifying cities and controlling pollution.

This work was supported by The American University in Cairo and the Basaisa NGOs.

METHODOLOGY

NEW APPROACHES FOR SUSTAINABLE COMMUNITY-BASED DEVELOPMENT

PROVIDING AWARENESS, EDUCATION, AND TRAINING, DEVELOPING IDEAS, TRANSFERRING KNOWLEDGE, AND PROMOTING NEW TECHNOLOGIES, PLANNING INTERVENSIONS AND IMPLEMENTING PROCESSES FOR SUSTAINABLE DEVELOPMENT USING OPEN, FREE, AND DEMOCRATIC COMMUNITY DIALOGUES.

COMMUNITY-BASED DEVELOPMENT

Different forms of participation add value to field projects by enabling beneficiary communities to influence the choice of priority assets and design features, which increase benefits in the short and long terms and ensure sustainability. They also demonstrate the importance of regular communication with the inhabitants to build a sense of local ownership, increasing cooperation and the maintenance of assets.

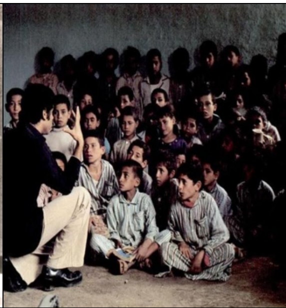
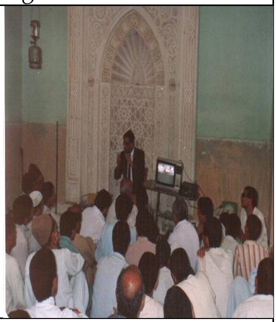
Community-Based Education:

Despite the popularity of community-based education (CBE), the effects of CBE projects on host organizations and their targeted communities have not been well examined. The Trent Center for Community Based Education (TCCBE) and U-links have facilitated more than 1000 projects since the 1990S in Peterborough and Haliburton area. In our research, we used the TCCBE and U-links databases to select and interview 17 host organizations, a faculty member/host, and a representative of both TCCBE and U-Links – the brokers to answer our research question: when the direct and contributing effects of CBE projects are to host organizations and targeted communities. Our results show that many host organizations had had positive experience with CBE projects, which help them to enhance their functionality, fundraise, and improve public recognition. However, there are still limitations with time, Communication and quality the TCCBE and U-link can address. We also suggest than a separate study is conducted to examine in depth the effects of community-based education on host organizations targeted communities.

Community-based Education Centers:

Given the benefits that placements bring about to the students and the host organizations, together with the complicated negotiating process between the education institutions and the community projects, independent programs such as U-links and TCCBE are extremely helpful. Their role can be visualized as that of a broker who matches the demand for human resources of organizations with support supplied by students; and the demand for practical learning of students with a workplace experience provided by the agency. Highlighting the importance of such brokers role, Rosing and Hofman (2010) point out that "collaboration among faculty and students from diverse fields is essential, but likely challenging without the support of a service-learning center" (p. 226). They also recognize that "most important, service-learning support centers provide an important role in sustaining relationships that can bring different research resources to community partners over an extended period of time" (p. 229). Pearce, and Cameron (2007) expand on this idea and argue that service-learning centers help broaden the focus of community-based education program to include the exchange, mobilization and utilization of knowledge, with the intent to mutually benefit the institution, and its local and regional communities. By directly matching the supply and demand between host organizations and students and facilitating a collaborative environment between community program and academia, the intermediary role of programs such as TCCBE and U-links is thus vital to the success and sustainability-based education[1].

WORK DONE

		
Fig. (1): Villagers are curious seeing renewable energy technologies for the first time.	*Fig. (2): Meeting with the Village children after the general community meeting after Friday-Pray.*	*Fig. (3): Volunteers and Villagers in Education groups for men and women in the Village Common Room.*
		
Fig. (4): The villagers curious about watching the new innovation of "Art of the Sun".	*Fig. (5): A plate showing and demonstrating Art of the Sun and the Solar Energy in the Village.*	*Fig. (6): A presentation of the TV powered by solar energy in the Mosque after the Friday pray.*

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[1]REF: Alicia McDermott, Linh Phan, Maritza Queeley, and Claire Ryan, info@trentcentre.ca April 5, 2011

Fig. (7): Children watching Educational programs on TV in the Common Room of the Village.

Fig. (8): Children are trained to use and protect the New Technologies. Here is a Biogas Unit.

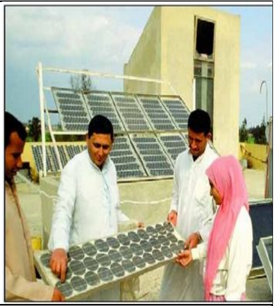

Fig. (9): Training Villagers from the surrounding area of Basaisa on different Solar Energy Technologies

Fig. (10): Training women on Sewing and making dresses.

Fig. (11): The nursery School at the Technical Center of the Village

Fig. (12): IT Training session to university students Men and Women living in the Basaisa Area.

Fig. (13): A model for Solar Cooking. Made and demonstrated onsite

Fig. (14): Building a Biogas Plant in the Village by villagers.

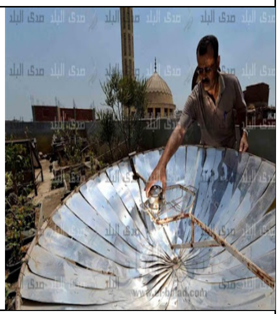

Fig. (15): Testing a Solar Concentrator for cooking..

Fig. (16): Planning for the New Basaisa Community in the desert of Sinai.

Fig. (17): The Building style and different Renewable Energy Systems introduced in the New Community.

Fig. (18): Monthly Community dialogue in the Common Building for the New Basaisa Community Members.

Fig. (19): Community Education and Training in the Technical Center of New Basaisa.

Fig. (20): The trained members are installing the house solar power units.

Fig. (21): Overview of the Buildings in the new Community with the solar power units on the roofs.

Fig. (22): Class of IT Training in the Technical Center of the New Basaisa Community.

Fig. (23): First Common Solar Energy off-grid distribution Network in the Basaisa Village.

Fig. (24): The inauguration of the Annual Basaisa Day at the American University in Cairo with participants of partners NGOs from different Governorates in Egypt.

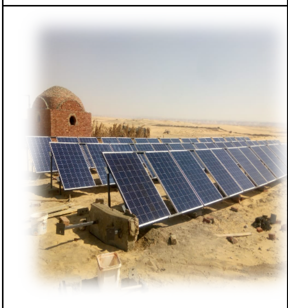

Fig. (25): The Solar System for Water pumping in the new community in the New Valley.

Fig. (26): Drip irrigation and plantation of the desert in the new valley community.

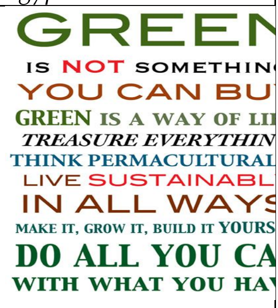

Fig. (27): Our methodology to establish a green sustainable living communities in the desert areas.

DISCUSSIONS & RECOMMENDATIONS

The figures show the methodology used in the field communities from open dialogues to effective participation with the involvement of children and women. Community-based education and training linked to better environment, good health and sustainable development was a key element in the success of the approaches used and in the high impact of the interventions.

We hope that the lessons learned, and the new technological developments will offer a better and greener sustainable future.

Human resource development should be one of the top priorities of all governments and local organizations. Education, in relation to Environment and Development, is the spark that ignites the torch, which will guide the way in the future. We need to reach all out to utilize local resources, involve all stakeholders, transfer knowledge and open citizen's minds, capture their imaginations and harness their potential for sustainable living communities.

Here are a few challenging issues where we must all join forces if we are committed to the goals of eradicating poverty and achieving other sustainable development goals.

1. Good quality education and training where all stakeholders are cooperating.
2. School bags powered by Solar for communication and better learning.
3. Promoting solar technologies in the informal sector and areas lacking services.
4. Planting trees in the street, windows and roofs of all buildings to absorb CO_2.
5. Constructing simple local training centers for Environmental and Renewable Energy so local citizens and school children can visit and learn.
6. Our open dialogues and media messages should concentrate on messages related to Children, Renewables, and Education for our Planet Earth.

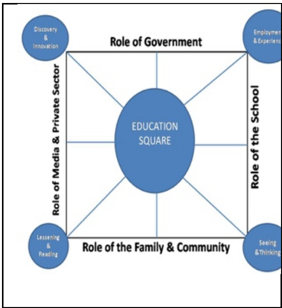

Fig. (28): The components of a successful and high-quality community-based education and training.

Fig. (29): A sunny bag for school children.

Fig. (30): Solar Units for poor communities in informal areas of town.

Fig. (31): Plant a tree should be part of our elementary environmental education.

Fig. (32): A model for Environmental Training and public centers to be established at least one in each Governorate of the Country as a good Reach Out and Knowledge Transfer.

Fig. (33): Celebrating and encouraging innovations for Green Sustainable Planet Earth is of Vital importance.

Access to renewable energy technologies is vital to improve rural and desert community living standards. Its benefits were an inspiration for socio-economic growth in many communities and clearly demonstrated and seen by community members in many and different areas including agro-industry, healthcare, treating water, education and training, family production and small-scale projects and additional income.

The above recommendations, based on our field experiences, will help solve some of the current energy, education, waste, sanitation and health issues faced in small villages and desert communities in Egypt and elsewhere.

WORKING TOGETHER … WE CAN DO IT

Acknowledgments

Thanks to the people of Basaisa village and to all participants in the field projects. Special thanks to AUC and all faculty and student volunteers. It is an opportunity for me here to state that the idea of a rural community development work was born in Uppsala, Sweden when I visited for the first time as a fellowship candidate of the International Physics Seminar. During my second visit to Sweden in 1971, I visited my host family of Mattsson and met face to face with Dr. Lars Broman in the Building of Hogskolan in Borlange. The visit was the support of knowledge for the solar energy education and its implementation as part of the technologies needed in the development of rural and desert areas of Egypt. To Dr. Lars Broman we in Egypt greatly appreciate and acknowledge his support to the projects reported and to me as fellow professor of the Stromstad Academy.

International Association for Solar Energy Education - IASEE

ISES Working Group on Education

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Abstract: After a session with papers on Solar Energy Education in the conference North Sun in 1988 in Borlänge, Sweden, Lars Broman, Aadu Ott and Konrad Blum initiated the founding of IASEE - the International Association for Solar Energy Education, that later became ISES Working Group on Education. During the 1990s the membership grew to several hundred scientists and teachers from more than twenty countries. Especially the organization of thirteen International Symposiums on Renewable Energy Education (ISREE), the member information and communication by *IASEE Newsletters* and the edition of a periodical *Progress in Solar Energy Education* (PiSEE) were instrumental in this process. In 2017 Lars Broman, united two of his projects, Strömstad Academy and IASEE, in the *ISREE 2017* conference in Strömstad.

Swedish Abstract Efter en session med artiklar om solenergiutbildning på konferensen North Sun 1988 i Borlänge, Lars Broman, Aadu Ott och Konrad Blum tog initiativ till grundandet av IASEE - International Association for Solar Energy Education, som senare blev ISES Working Group on Education.

Under 1990-talet ökade medlemskapet till flera hundra forskare och lärare från mer än tjugo länder. Särskilt organiserandet av tretton internationella symposier om utbildning för förnybar energi (ISREE), medlemsinformation och kommunikation av IASEE Nyhetsbrev och utgåvan av tidskriften Progress in Solar Energy Education (PiSEE) bidrog till detta. 2017 förenade Lars Broman två av sina projekt, Strömstad Academy och IASEE, i ISREE 2017-konferensen i Strömstad.

Introduction

It is widely understood that the transformation of the world energy system into a sustainable, renewable state needs, besides technically and economically viable solutions, acceptance and basic understanding of the general public as well as decision makers in politics and commerce [4]. General education and vocational training in the field of energy, energy efficiency, and especially renewable energy, was not so well developed in the beginning of the rise of RETs in the 1980s [2]. More or less local/regional initiatives on all levels of the educational system lacked support and the impression was that "the wheel was invented over and over again" (personal communication Mark Koltun) – thus after a session with papers on Solar Energy Education in the conference North Sun in 1988 in Borlänge, Sweden Lars Broman, Aadu Ott and Konrad Blum initiated the founding of IASEE.

International Association for Solar Energy Education

In a period of not as long as two years, IASEE was established as "ISES Working Group for Education" and members from all continents joined the association. With the distribution of a newsletter (later an internet-based discussion list), the series of International Symposium on Renewable Energy Education (ISREE) and the edition of a periodical (Progress in Solar Energy Education – PiSEE) the activities reached a level that demanded a lot of time and resources.

Eventually the founders had to accept that their main professional duties demanded that they transferred the task of conducting IASEE onto other shoulders.

But although ISREE continued, PiSEE and the newsletter expired during the 1990s [5]. Therefore ISREE 2017, organized by Strömstad Academy in June 2017, and the special edition of *Solar Energy* with the proceedings of the conference give hope for more international activities in the field of Renewable and Solar Energy Education [1].

Sequence of events

- Educational Session during North Sun 1988
- Foundation of IASEE in Gothenburg 1989
- Formation of By-Laws and presentation of IASEE in ISES WC 1990
- ISREE 1 - 1991 in Borlänge /Sweden
- PiSEE Vol. 1 (1992)
- ISREE 2 - 1992 in Oldenburg / Germany
- PiSEE Vol. 2 (1993)
- ISREE 3 - 1993 in Borlänge /Sweden
- PiSEE Vol. 3 (1994)
- ISREE 4 - 1994 in Bangkok / Thailand
- ISREE 5 - 1996 in Oldenburg / Germany
- PiSEE Vol. 4 (1996)
- PiSEE Vol. 5 (1997)
- ISREE 6 - 1998 in New Delhi / India
- ISREE 7 - 2000 in Oslo / Norway

- ISREE 8 - 2002 in Orlando, Florida / USA
- ISREE 9 - 2003 in Gothenburg / Sweden
- ISREE 10 - 2004 in Perth, Australia
- ISREE-11 - 2005 in Orlando, Florida / USA
- ISREE 12 - 2017 in Strömstad, / Sweden
- ISREE 13 - 2019 in Santiago / Chile

Personal Remarks

There are important facts that cannot be found in publications about the first years of IASEE [3]. Many discussions and decisions took place under informal circumstances. If I can trust my memories, the association would never have been created without Lars Broman's initiative after NorthSun'88. Without his experience in international cooperation in the fields of solar energy research and astronomy, IASEE would not have had the necessary organizational structure. It was also his imagination and his contacts and connections that created the ISREE series. Lars has always been the central personality who brought people together and initiated new movement as well as necessary correc-

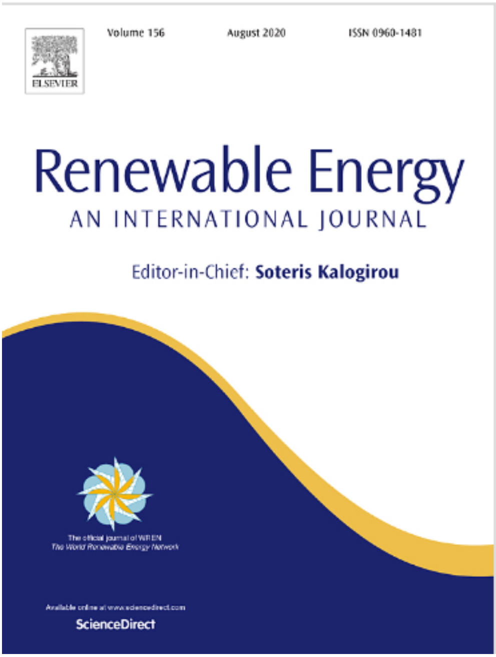

Figure 1: Title page of IASEE Periodical Progress in Solar Energy Education *Vol. 5*

tions. His friendly, collegial style, his calm, balanced nature and his almost inexhaustible energy and willingness to work, were crucial for the initial growth of the association and the integration into ISES as a working group for education.

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SOLAR COOKER DISSEMINATION IN NEPAL

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Preface

This article is a modified version of a conference paper presented in 1997 about some results of a development co-operation project conducted in Nepal in 1994-1997[2]. This paper

[2] Lampinen A, Virtanen H, Wahlström R & Sharma R (1998) Solar Cooker Dissemination in Near-subsistence Economies. Proc. 3rd Int. Conf. Solar Cookers - Use and Technology. Coimbatore, India, 1997, 7p.

deals with a core component of the project, but the project contained many other components that are not covered here. Many papers were written about this project. This paper was selected to be included in the publication at hand in 2020, because it is most descriptive of the part of the project that lead Ari Lampinen to meet Lars Broman for the first time at a renewable energy education conference held in Thailand in 1994. At the time Ari Lampinen was assistant professor of physics and manager of this development co-operation project dealing with renewable energy technologies; and Lars Broman was professor of physics and chairman of an international solar energy education organization that was responsible for organizing the renewable energy education conference in Thailand.

The enclosed photo, taken by an author in the project area in Nepal in 1994, was not published as a part of the conference paper and has not been previously published at all. It illustrates deforestation originating from cooking energy utilization in poor living conditions and starting of cooking fuel collection duties at a very early age. Solar cookers were offered within the project to help alleviate poverty and deforestation problems as well as direct health impacts of smoke originating from fuelwood cooking by 3-stone technology. This photo tells the core reason why the project in Nepal was conducted and why Ari Lampinen met Lars Broman. Technical photos of solar cookers are not included, because here "why" is considered primary objective instead of "what".

Abstract

This paper discusses some difficulties of dissemination of solar cookers for people living in absolute poverty but not in refugee

camps. A neo-indigenous parabolic cooker technology (PT-LIFE) is suggested and a pilot project in Nepal is described.

Introduction

Solar cooker (SC) dissemination success stories have involved either middle class people or refugee camp inhabitants as target groups. A third important group, and the largest of them with some 2 billion members, are people living in absolute poverty but not in refugee camps.

People who collect their cooking fuel themselves are a difficult target group for solar cooker dissemination because they do not save money by using SCs, i.e. the payback time of a SC is infinite. Use of SCs means time-savings for family members with collection duties but it does not directly benefit the persons with cooking duties. Thus, from the SC acceptance point of view the validity of the fuel collection time-savings argument is questionable.

Reasons for SC disacceptance

Pre-project acceptance surveys, like ours [1], often show high interest in solar cooking. However, usually very few continue using their donated ready-made or self-built cookers after a few weeks. The reasons for disacceptance are diverse and many are cultural [2]. We bring up the three most important reasons, according to our experience in Nepal:

1) ALIEN TECHNOLOGY: While women take good care of their houses and men take good care of their tools and machines, say micro hydro mills [3], transferred technology frequently suffer from lack of maintenance, even as simple as wiping dust off cooker's glass. People consider SCs alien technology and request continuous support from outside.

2) LOW PERFORMANCE: The overwhelming main reason for disacceptance in our project, a fact that women always mention, is the slowness of the box SC compared to their traditional 3 stone biomass stoves. As Table 1 shows this is a very natural reaction, especially when not considering the wood collection time-savings as an advantage, as mentioned earlier. Also, although many local dishes can be prepared, with low nutrient losses [4] and water pasteurized [5], baking and frying cannot be done.

Table 1. Approximate boiling times [min] of 2 liters of water using various cookers (SC values apply to high solar insolation, i.e. about 1 kW/m2). (SC=solar cooker, ICS=improved cooking stove)

Box SC (cardboard or plywood)	100-200
Three stones with fuelwood	20-25
ICS with wood	12-15
Chinese parabolic SC (2 m^2 reflector)	8-10
Electric stove (2 kW)	7-8

3) HIGH PRICE: Low price is a crucial requirement of SCs offered for people who do not pay money for their fuel and who are extremely poor money-wise. The price should be of the same order of magnitude as utensils people find important enough to purchase. Appropriate targets are the price ranges $1-$3 of metal cooking pots and $0-$6 of improved biomass stoves.

Technological alternatives

The cultural requirements of appropriate SC are, from previous chapter:

- Design, fabrication and maintenance in the villages using existing resources (neo-indigenous technology)
- Match the performance of 3 stones
- Cost at most a few dollars

The most popular of cooker types, box cookers, may reach the performance requirement, but with a price tag of over $1000. Most existing models that cost $30-$50 are slow (Table 1 and [6]). Due to the requirement of many factory made parts (glass, metal tray and pot, reflecting material) it is very difficult to build or produce in series, a box SC for under $10, even if the box itself can be made in villages where useful materials like clay, dung, wood, bamboo and grass are available. The use of factory-made parts also raises a difficult maintenance problem.

Panel cookers used successfully in refugee camp conditions are cheap but have lower performance than box cookers. They also require many factory-made parts: plastic bag or cover, metal pot and reflector material. These cookers have good potential for upsizing with low price increase. However, to reach our performance target the reflector would need to be very large.

Parabolic cookers are popular in Tibet where 140,000 have been sold [7]. The Chinese steel cookers are 2-3 times faster than 3 stone ovens and they can match electric oven in performance. Later we show that parabolic SC can be made almost with skills and materials available in Southern Nepal. The only required factory made component is reflecting material (2 m^2 of Al foil costs about $1). Not even a metal pot is needed because if the cooker is made well enough a clay pot will do. Also, baking and frying are possible, and food can be stirred during cooking.

Lessons learnt from a box cooker project in Nepal

With some experience of box SCs (BSC) in Namibia [8] TFL started a BSC project in Nepal in the spring of 1994. Within 1.5 years, 8 workshops were organized (in Kathmandu, Bardiya, Makwanpur, Saptari and Sihara) where 80 BSCs were built increasing the amount of SCs in Nepal by 40% [9]. Centre for Rural Technology organized the Kathmandu workshop (1994) and PFL organized the rest and has been the implementing agent of all the other parts of the project, while TFL has taken care of financial and technical support. One of two workshops in Hawpur village in Bardiya (1994) [10] was arranged in collaboration with BASE, a Nepalese NGO, and Building with Books, a US NGO. Most of the trainees were rural women or couples but also volunteers from a few organizations (e.g. UNV) were trained. In addition, several demonstrations and photo exhibitions were organized.

BSCs were made of cardboard, clay-dung, cement and plywood. Both vertical and tilted tops, single and double glass, with or without reflectors, were built using paper balls, peddy husk, plant leafs, peddy straw and corn sheath as insulation. Tilted double glass plywood box with reflector and paper ball or peddy husk insulation ($22) performed the best but only marginally better than the corresponding clay-dung box costing $15. The most indigenous and the cheapest design, a single glass clay-dung box ($11) cooked a meal of 0.5 kg of potatoes, 0.5 kg of rice and 5-6 eggs in 2.5 h. This is a meal for 1/3 of family.

The BSC project (except in Kathmandu and in the first Hawpur course) was organized the same way as the other subprojects of the integrated rural development program of PFL [11,12] that is in Saptari and Siraha a part of GTZ Churia Hills Forest

Development Project (ChFDP). First, in the awareness creation phase, PFL staff members told about and demonstrated SCs in villages. Secondly, interest groups were formed by villagers or SC interest was born in existing women's interest groups (women's committees). Third, workshops were applied by the interest group. Fourth, workshops were delivered by PFL staff to couples chosen by the interest groups. And finally, follow-up and SC user support was conducted by PFL (and TFL, to a lesser extent).

Most of the workshop participants used their cookers at least for a few weeks. In Saptari, where people were the most motivated, they cooked within 4 months in average 10% of their food with SCs, i.e. saving 10% of fuel because space heating is rarely needed in Terai. For those buying their firewood this means saving a bundle of firewood per month, costing $1 in countryside. Thus, the BSC payback time is 1-2 years. In Kathmandu, where firewood costs 4 times more, the payback time would be 3-6 months with 10% usage. The most motivated family in the city of Hetauda, Makwanpur, reported 30% savings of kerosine.

Now, very few continue using their BSC for reasons described earlier (and due to disturbances by children, animals, rain and clouds but, surprisingly, no religious impediments have been given). Moreover, no independent BSC fabrication, i.e. self-spreading of the technology has been noticed. So far none has applied for funds for purchasing the factory-made parts for self-constructed BSC. And, none has applied for micro loan within the PFL income generation program for establishing a handicraft workshop for commercial manufacturing of BSCs.

Due to the poor BSC dissemination results among the adult population, we continue the program only in two elementary schools (in Makwanpur and in Saptari) where BSC workshops were conducted in 1996. Since fall 1995 we have concentrated more on parabolic cooker (PT-LIFE) development.

The PT-LIFE parabolic cooker

During our SBC program we noticed that villagers in Terai have existing skills and materials for almost cloning a parabolic SC (PSC). We have purchased a few Chinese double dish PSCs ($80) for demonstrations. Their performance (Table 1) has been found convincing by every target group.

A cooker design workshop was conducted (spring 1995) with interested villagers in Saptari. The villagers with PFL staff members as facilitators designed and built a clone of the Chinese PSC out of large traditional bamboo baskets covered by clay-dung mixture, as in their buildings, Al foil and bamboo support structure imitating their building architecture. Description of the prototype construction process of the PT-LIFE cooker is given in [13] and [14]. The cost of the prototype was 18 person-hours of work and $3. The only required factory made material is the Al foil costing about $1.

The cooker technology has not yet matured to a level acceptable to villagers. The performance is 2-3 times lower than 3 stones, although by about the same amount higher than BSCs. The main reasons for low performance are too small reflector area, the quality of dish surfaces and the shape of the dishes.

In addition, the prototype was very heavy and horizontal tracking required moving the whole system. These problems have been addressed during further development during which 11 PT-LIFE cooker variants were built. The latest variants include horizontal and vertical bamboo axels for easier tracking, and lighter bamboo dishes.

The performance problems are currently being dealt with, the dish shaping being the main concern. The parabolic shape for the mold can be plotted using a simple tool that can be made of wood and strings. With deep focus mirrors the shape would not be so critical.

Discussion

In this pilot project in Nepal we want to offer poor people the chance to develop their own solar cooking technology or choose from other options: improved cooking stoves and biogas [12]. We have created awareness of these different alternatives to 3 stone (and kerosine) cooking by demonstrating technical options in the villages in the framework of a wide scope rural development program.

The PT-LIFE cooker concept, i.e. technology designed and manufactured by target group members, has a good potential to become accepted and spread without external contributions. The main components of this design, i.e. a parabolic basket and a disk support system, can be done everywhere. However, the technology is not yet mature.

Our alternative approach is commercial artisan manufacturing, a strategy behind the breakthrough of many ICS programs. We are offering IG loans for this purpose for various SC models, including BSCs and metallic PSCs.

Sunlight can put sunshades in place to control global temperature

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The Sun is the source for energy that supports life on Earth. Thanks to the Sun, we have a temperature on Earth that lies in a narrow band that allows most of the water to be in a liquid state, which is a necessity for life. At least as we know life today.

However, the temperature on Earth would be too cold if we did not have an atmosphere that traps part of the Sun's incoming heat. An atmosphere that works as a greenhouse. Without that, the average global temperature would be -18° C instead of today´s 14° C. During the last fourteen millennia, during the Holocene epoch, the global temperature has been unusually stable, which might be one of the reasons that a civilization could evolve on Earth. This civilization now has reached a point where it by utilizing resources, which has been accumulated in Earth's nature over millions of years, in a very short time span, is significantly modifying the composition of the atmosphere. This change in the atmosphere makes the atmosphere a more efficient greenhouse and thereby increases the average global temperature. Is this a problem? Some believe it is a threatening catastrophe, a few think it might even be positive but most seem to consider it a problem that must be handled, somehow.

The problem, stated in a more quantitative way, is primarily that due to increased CO_2 level in the atmosphere, around 1% more of incoming energy from the Sun is now trapped on Earth than before the industrial revolution [1]. This has led to an average temperature increase of about 1° C. If a drastic cut in CO_2 emission is not soon implemented, the temperature will increase another few degrees. Or, if something else is done.

Something else, could be some form of geoengineering, often divided into those that aim to remove CO_2 from the atmosphere, referred to as carbon dioxide removal methods, and those that aim to manage radiative forcing in order to compensate for greenhouse gas emissions, referred to as solar radiation management. Many of the proposed geoengineering methods could however have other effects also, which are hard to foresee and could be negative or even destructive.

Decreasing the amount of light reaching Earth from the Sun by placing sunshades in space, though, could be a way to decrease the greenhouse effect without possible bad side effects. Certainly, the technological challenge for this is large, but it seems it is now within reach. The idea has been discussed in the scientific literature before. Already in 1989 James Early proposed a 2,000 km-wide glass [2] and in 2006 Roger Angel showed how 16 trillion flying space robots, 1 g each, could divert 2% of sun light to Earth [3]. A concept that would also take into consideration the variation of the average temperature increase with latitude, has been more recently presented [4].

The idea of sunshades in space has, however, never been taken seriously, so far. One reason being that it has been very expensive to launch anything to space. Typically it used to be around 10 000 $/kg but the cost is now falling rapidly. The lowest price today is with SpaceX´s *Falcon Heavy*, around 1500 $/kg [5]. In a decade it could be as low as 20 $/kg, if Elon Musk´s vision with SpaceX´s next generation launcher *Starship* comes true [6]. At the same time, the cost for the global economy and society from a few degrees´ increase of the global temperature is, although very difficult to estimate, probably enormous. Thus, it is worthwhile to study the possibility of placing sunshades in space to counteract a too large greenhouse effect.

The best place for a sunshade in space is close to the Lagrange point 1, L1, between the Sun and Earth. At that point the gravitational (and centrifugal) forces of the Sun and the Earth-Moon system cancel out and therefore a spacecraft placed there is in a (semi-)stable position. L1 is about 1.5 million km from Earth, in the direction of the sun, almost exactly 1 % of the total distance to the sun. (There are four more Lagrange points where the forces cancel out, two of which are stable equilibria, in contrast to L1.)

In principle, sunshades could be put in orbit around the Earth also. This is of course less expensive and simpler; however, it turns out to be less efficient and has other complications. Less than half of the time during the orbit the spacecraft will actually cast its shade on Earth and it will interfere with other satellites (and space debris) in Earth orbit [7].

The sunshades should be made as light as possible, since the driving cost will be the amount of mass to launch to space. The same requirement, a large area for a small mass in space, solar sails have and it is natural to look at that technology. Indeed, there is another very interesting aspect, and that is that solar sailing is probably the best method to reach L1 once the spacecraft with the sunshade is in space.

Solar sailing has nothing to do with the solar wind. Solar sailing utilizes the reflection of the light from the Sun to create a very tiny force that can be used for spacecraft propulsion. When a

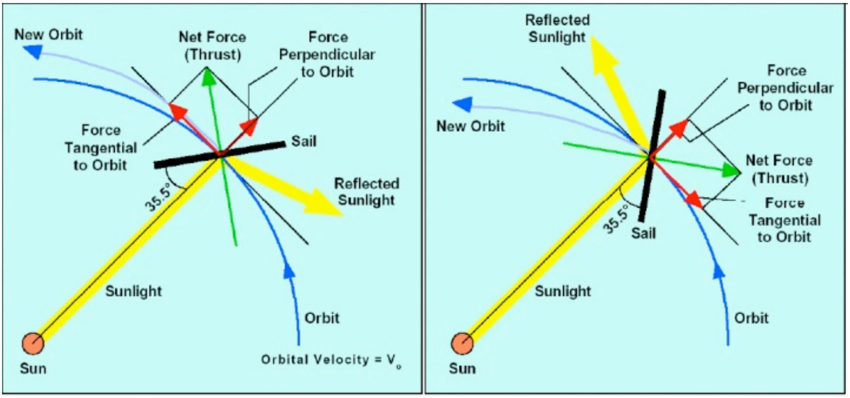

Figure 1: Illustration of idea forces on a solar sail from solar radiation (sunlight) pressure and how orbits can change. To the left to an orbit further away from the Sun, to the right to a closer orbit. Picture taken from [8].

light particle, a photon, bounces off the solar sail, it transfers a small amount of momentum to the sail. The higher the reflectivity of the sail, the more efficient the propulsion will be. In the ideal, and simplest case, the force is perpendicular to the plane of the sail, in the normal direction. By angling the sail, the direction of the propulsion force can be changed (see Fig. 1 [8]).

Naively, it might feel counter-intuitive that one can sail towards the Sun. It works because by changing the orbital speed around the Sun, the Sun´s gravity can pull the spacecraft closer to it. The only reason that Earth and the other planets are not falling towards the Sun is that they have high velocities around it. Orbital mechanics is not very intuitive. To get closer to the Sun (or the Earth for a satellite) one has to decrease the orbital speed of the object. It then falls into a lower orbit, but in the end it actually gets a higher velocity! The closer a satellite orbits Earth, *or* a planet orbits the Sun, the higher its velocity. The joke for space travelers is: “To speed up, slow down!”

The idea of solar sailing has been around for a long time. The "Father of spaceflight", Konstantin Tsiolkovsky is claimed to be the first to propose it for propulsion, but Svante Arrhenius predicted in 1908 the possibility of solar radiation pressure distributing life spores across interstellar distances [9]. Since then many proposals to utilize solar light in various ways for spacecraft propulsion have been made. So far, though, only two have made it to space and demonstrated many of the necessary techniques. In 2010, the Japanese *IKAROS* sailed to Venus [10] and

Figure 2: Picture from LightSail-2 over Horn of Africa and part of the solar sail [10].

in July 2019 the non-governmental, nonprofit foundation Planetary Society´s *LightSail-2* unfurled its sails in orbit around Earth (see Fig. 2) [11].

The characteristic quality of a solar sail spacecraft is the so-called *lightness number* β. The lightness number is a dimensionless parameter that gives a measure of how large acceleration the spacecraft can achieve due to solar light pressure. It is defined as the ratio of the maximum possible acceleration from solar radiation pressure to the solar gravitational acceleration.

Because both the solar radiation pressure and the solar gravitational force have an inverse square relation with distance from the Sun, the lightness number is independent of distance of the sail-craft from the Sun.

In practice, much of the design boils down to make sails with as little mass per area, *σ,* as possible. With *σ* in g/m^2, the lightness number is expressed as

$$\beta = Q \cdot 1.53/\sigma, \qquad (1)$$

where Q is the reflectivity of the sail. For the best solar sail performance, Q should have the maximal value of 1. *IKAROS* had a lightness number of 10^{-3} and *LightSail-2* has 10^{-2}. However, a spacecraft with a large sail and minimal payload (the payload of a sunshade is basically the sail) can obtain much larger *β*. For example, the planned *Sunjammer* mission had a *β* of 0.036 [12]. *Sunjammer* was well advanced in planning and testing when it was cancelled in 2014. *Sunjammer´s* sails, which had been built and their deployment tested, had an area of 1200 m^2 and the plan was to fly to the Sun-Earth L1 point.

It is possible to reach the L1 point from Low Earth Orbit (LEO) by solar sailing. In a recent Master Thesis at KTH, María García de Herreros Miciano shows that with a lightness number *β* of 0.035, starting from LEO at 2000 km altitude, the spacecraft can escape from Earth´s gravity in 537 days and then in another 317 days reach the desired point in the vicinity of L1 [13].

With a higher *β*, it would go faster to reach L1, but time is not critical in these circumstances. Once the sunshade is in place to help cool the Earth, it is expected to stay there for a very long time; probably centuries, or until it has degraded so much it must be replaced. Indeed, as further discussed below, from a shading point of view, a low *β* is desired. This is because the solar radiation pressure on the spacecraft will move the force equilibrium point from L1 towards the Sun, called here L1´. The larger β is, the further away L1´ is from L1 and the Earth.

From a shading point of view, the further away from Earth, the less shade one gets for a given sunshade area. With larger mass, keeping the area and reflectivity Q constant, the equilibrium point L1´ can be closer to L1. However, keeping the total mass down is important from a launch cost reason. One can vary the parameters to find a good solution. Choosing Q=0.2 and β=0.035, puts L1´ at 2.2 million km from Earth, about 50% further away than L1 [13]. A similar result is found in [4].

So how large sunshade is needed? A report from 2000 estimates that to offset completely the effect of doubling the CO_2 content in the atmosphere from the pre-industrial value of 280 ppm to 560 ppm, it is necessary to decrease by 1.7 % the incoming solar flux [14]. Without any measure, their model gave a temperature increase of 1.75 °C in that scenario. However, it may not be necessary to completely offset the temperature increase from pre-industrial times. The consensus seems to be that a 1.5 C increase is acceptable. The goal should be not to surpass that, and certainly not beyond 2 °C, according to IPCC. Another, more simpleminded, way to look at it, is that solar irradiation on Earth corresponds to 340 W/m^2 and the recent emission of greenhouse gases, traps returning heat radiation which in effect increases the energy balance with 3 W/m^2 [1], i.e. a 1 % increase. For simplicity, here the assumption is made that decreasing the solar influx by 1% is sufficient to control the temperature increase, combined with the measures taken to reduce the CO_2 emission. The results are anyhow easily scalable if a larger area would be needed.

Since the apparent area in the sky decreases with the square of the distance, one has the relationship

$$A_{shade}/A_{sun} \cdot D^2_{sun}/D^2_{shade} = \Delta \quad , \qquad (2)$$

where A and D are true areas and distances from Earth, respectively, and Δ is the relative decrease of solar radiation to Earth due to the shading, assuming the sunshade is in a position where it is seen from Earth to fully be in front of the Sun. The requirement that Δ be 1%, translates to $A_{shade} = 3.3 \cdot 10^6$ km^2 at the L1´ point given above.

An area of $3.3 \cdot 10^6$ km^2 is a lot. About 7 times Sweden. If one would make one circular shade, it would have a diameter of slightly over 1000 km. With current technology, or in the foreseeable future, this is unrealistic to build. What is realistic, though, is to build many small sunshades and let them independently solar sail to L1´. A circular shade with radius 100 m would have an area of 31 400 m^2 = 0.0314 km^2. In total around 100 million of such spacecraft would be needed. In the end, though, it is the total mass to launch to space that will be the driving cost.

LightSail-2, mentioned above, uses 4.5 μm mylar for its sails, with mass/area σ = 6.5 g/m^2. The bus, or base, of the spacecraft is a 3U Cubesat and the total mass is 5 kg. *Sunjammer* would have had an overall (including the bus) σ of 27 g/m^2. The larger the sail, the smaller the mass/area is likely to be, because the bus that holds system parts, like computer and radio, can be more or less the same for any sail size. A NASA study in 2006 for a mission towards L1 to be an early warning of solar storms, *Heliostorm*, concluded that a 10 000 m^2 sail with a total σ of 15 g/m^2 is achievable [15]. That is including the necessary payload for the space weather mission. With further technology development, a total mass/area of 10 g/m^2 within 20 years is clearly realistic, perhaps even half of that. Anyhow, if one assumes 10 g/m^2, one ends up with a total mass of 33 million ton.

The *Starship* launcher, which will be fully reusable and is now under development by SpaceX, is stated to be able to put 100 ton in low Earth orbit [16]. Although the cost per launch might never be as low as claimed by Elon Musk, $2 Million per mission [6], it nevertheless shows where the launcher technology and market is going. A program that would launch millions of spacecrafts could tailor-make launchers for its optimal use and keep the cost down. A not unrealistic assumption is that the final cost could be $50 per kilogram. The total launch cost would end up at $1.7 trillion ($\$1.7 \cdot 10^{12}$). The manufacturing cost would probably be less, due to the extreme mass production of identical spacecraft. It could be compared with the price of popular cars, which are in the order of $10 000 per ton. From this, one could assume that the total manufacturing cost would be about 20 % of the total launch cost and the whole program would be at $2 trillion.

Two trillion dollar is a lot of money. It only makes sense if it is compared to alternative costs. If our civilization does not manage to cut CO_2 emission quickly enough, the cost of the temperature increase will probably be much more. Alternatively, the cost of implementing a stringent enough CO_2 emission reduction could also be much more than $2 trillion. It is arguably very hard to predict the cost of temperature increase, but in a study from 2018 the authors write "we project 15%–25% reductions in per capita output by 2100 for the 2.5–3 °C of global warming implied by current national commitments" [17]. The global GNP today is around $100 trillion per year, so the loss by a temperature increase to 3 °C above pre-industrial levels would be around $20 trillion per year, following that study. That is ten times more, *per year*, than what a space sunshade system would cost in total.

The space sunshade system would not need to be in place until around 2050. Only if the global temperature continues to rise and the perspective to limit it looks bleak around 2040, a decision should be taken to implement it. If a launcher similar to *Starship* is used, 330 000 launches are needed. If one allows 20 years to launch all sunshades, 45 launches per day are required. Thus, several fully reusable launchers are needed as well as several launch sites. Until 2040, though, research and development should be performed to verify and test the technology. If – as everyone would hope – the space sunshade system is not needed, the technology of solar sailing will anyhow be very useful for interplanetary travel. E.g. by 2050 some people will likely be already living on Mars and the necessary transport of goods between Earth and Mars could probably be done cheaper by solar sailing than by other methods.

To summarize, it is possible to use the force from the Sun´s light to propel spacecraft. The same sunlight that today threatens global warming on Earth, due to human greenhouse gas emission, in particular CO_2. If the global warming is not limited by reduction of CO_2 emission, a plausible method to control the temperature on Earth is to put sunshades in space. The best point to put them is in the vicinity of the Sun-Earth Lagrange point L1. The cost is in the order of a few trillion dollar, however, this is likely much less than the cost of a significant temperature increase compared to today.

Acknowledgment

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Basic astronomy: common misconceptions and public beliefs according to the audience survey at Kyiv Planetarium.

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Abstract. Results of a Kyiv Planetarium audience survey are discussed. Kyiv Planetarium has a "Big Zeiss 4" projector, a fulldome projection system, a dome 23 meters across, and 300 seats. Having presented a program to up to 300 visitors at once, it is not easy to examine the general public understanding of basic astronomy, to get feedback on the program, and to estimate the educational impact on the public. Strategically designed questionnaires were used to find out what are visitors' personal experiences and previous knowledge. Questions in the questionnaire can be conditionally divided into several groups: - a) personal data (age, education); - b) astronomical knowledge and observational experience (attendance of astronomy lessons at school, observation of interesting astronomical phenomena such as eclipses, comets, meteors, experience of watching the sky through a telescope, age of the Earth and the Universe, reasons for seasonal changes and Moon

phases, the brightest star, constellations that the visitor knows, number of planets in the Solar system, the biggest planet in the Solar system, how often do visitors read about space related topics); - c) visitors' personal beliefs like their attitude towards horoscopes and extra-terrestrial life; and - d) visitors' attitude towards planetarium itself, likes and dislikes, topics for future programs, expectations, sources of information about Planetarium, and number of their visits to planetarium. I discuss the results from 147 questionnaires that were gathered back, the most common misconceptions and public beliefs are revealed.

1 Audience survey

147 questionnaires were gathered from family visitors who were attending several planetarium programs on different days. The programs attended are: "Myths and legends of the starry sky", "Guests with tails – comets", "Dinosaurs – the great error of nature?", "Trip to the greatest observatories of the world", "Astro-Quiz". Results from the questionnaires are given below in Table 1.

Besides basic statistics some cross-study has been done to compare the results and attitudes towards astrology/astronomy in such samples: 1st time visitors to 3rd and more times visitors. It was also interesting to see if there is any difference in astronomical knowledge and astrological beliefs depending on visitors' age, education, astronomy lessons at school, experience of observing through telescopes. Results of the cross-check study are given where appropriate.

2 Results

The survey results (see Tab.1) show that many people visit the planetarium for the first time (58%), while 26% have visited 3 or more times. Even first-time visitors have some basic astronomical knowledge (they marked that they read or listen from time to time to space news in the media). The easiest question for the audience was "What is bigger - the Earth - the Moon - the Sun?", 98% gave the right answer, while the most difficult question was about the age of the Universe (6% of correct answers). The age of the Earth got 48% of correct answers. Surprisingly only 12% of respondents chose the wrong answer on the question about change of seasons (88% correct), and 73% chose the correct answer about reason for Moon phases. Only 53% called Jupiter the biggest planet. 23% of our audience had astronomy lessons at school, and the same fraction has experience of observing through a telescope. Very few (27%) named Sirius as the brightest star in the night sky, while 39% said Polaris was the brightest. Most popular constellations are Ursa Major and Minor, Canis Major and Minor, and the Zodiac constellations (not surprisingly). Some visitors listed quite a lot of constellations, not only the most common, while other visitors invented their own constellations such as Polar Cross, Colliseum, the Pleiades, Snakes. 66% mentioned they had observed phenomena like eclipses or comets. 56% believe in extraterrestrial life, and 68% believe in horoscopes.

Table 1. Results *of the audience survey.*

	All visitors (%)	1st time visitors (%)	3rd time visitors (%)
Percent of visitors	100	58	26

	All visitors (%)	1st time visitors (%)	3rd time visitors (%)
Age: 6-10 11-15 16-20 21-30 Above 30	38 25 14 7 16	37 31 17 10 5	42 5 11 5 37
Audience with education past high school	25	21	37
Had astronomy lessons at school	23	17	42
Have experience of observing through telescope	23	17	47
Have observed celestial phenomena (eclipses, comets, meteors, strange celestial phenomena – possible UFOs)	66	57	74
Do believe in horoscopes	68	67	63
Reason for the Moon phases – correct answers	73	81	53
Reason for seasons' change - correct answers	88	83	95
The biggest planet in the Solar system is Jupiter - correct answers	53	50	58
Age of the Earth is about 4.5 billion years	48	50	32
Age of the Universe is about 14 billion years	6	10	5
The brightest star on the night sky is Sirius - correct answers	27	19	37

	All visitors (%)	1st time visitors (%)	3rd time visitors (%)
Do believe in extra-terrestrial life existence	56	52	74

3 Discussion

The results correspond in general to the world trends published as a result of previous studies [4-15]. The cross-study reflected that the majority of categories of questions correlate with public knowledge of astronomy. For example, among 3rd time visitors there are more people who had astronomy lessons at school (42% vs. 17% in case of 1st time visitors), had looked through a telescope (47% vs. 17%), had observed interesting celestial phenomena (74% vs. 57%), do not believe in horoscopes (37% vs. 33%), are readers of astronomy magazines and web-sites (79% vs. 60%). More 3rd time visitors in comparison to 1st time visitors chose the correct answer for explaining why seasons change (95% vs. 83%), which is the biggest planet in the Solar System (58% vs. 50%), and which is the brightest star in the sky (37% vs. 19%).

Surprisingly, fewer 3rd time visitors in comparison to 1st time visitors know about the reason for the Moon phases (53% vs. 81%). Fewer 3rd time visitors know the age of the Earth (32% vs. 50%) and the age of the Universe (5% vs. 10%). More 3rd time visitors (74% vs. 52%) do believe in extra-terrestrial life existence. These unexpected trends are to be explained. May be the reason lies in the age distribution among 1st and 3rd time visitors: there are more people aged 6-10 years or above 30 in the 3rd time visitors' group. The younger ones may not yet know the answers, and the older ones may have forgotten the numbers (like age of the Earth or of the Universe) already.

In case of horoscope believers versus non-believers there is no correlation with higher education - education past high school (surprisingly, 72% of visitors with higher education do believe in horoscopes, and the fraction of people who believe in horoscopes among all visitors with all kinds of education amounts to 68%). Similar situation is seen among those who observed celestial phenomena (73% of horoscopes believers with observing experience vs. 68% of all the horoscopes believers), but some correlation exists with astronomy education at school (65% vs. 68%), experience of observing the sky through a telescope (59% vs. 68%), and number of visits to planetarium (60% vs. 68% in case of 3rd and more times visit to Planetarium).

One may suggest that people with education past high school should be more critical thinking and less likely to be horoscope believers. According to our data, that suggestion is not supported (72% of visitors with higher education do believe in horoscopes, and the fraction of people who believe in horoscopes among all visitors with all kinds of education amounts to 68%). In spite of this difference with education is statistically insignificant at the level of 94%, one explanation may be that people with higher education have access to more sources of information (for example, internet) in comparison to people with basic education. And these sources may be overwhelmingly contaminated with horoscopes predictions and astrological propaganda.

The biggest impact on believing in horoscopes based on the data, is the experience of observing the sky through telescope (59% vs. 68%), and number of visits to planetarium (60% vs. 68%). Our data has shown that depending on age there are fewer horoscope believers among 11-15 years old children

(61% vs. 68%), and adults above 30 years old (58% vs. 68%), while the critical number of 100% horoscopes believers is reached in the age group 21-30 years old.

As a conclusion, according to our data, it is statistically significant that people with astronomy experiences (observing the sky through telescope, higher number of visits to planetarium, astronomy lessons at school) are less likely to be horoscope believers. And correlation of higher fraction of horoscope believers among those with education past high school and among those who observed celestial phenomena (such as eclipses, comets, meteors, strange celestial phenomena – possible UFOs) is not statistically significant at the same level.

The results will be used as a base for creating new and modifying already existing lectures and audio-visual shows, and for developing exhibits.

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The legacy of Lasse - a challenge!

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Incoming Vice-Chancellor

It should have been in October 2010 or possibly 2012 that I met Lars Broman for the first time. There was an academic celebration at University West and academic notabilities would go in procession. First came the flag, then the principal, new professors to be installed, doctoral students to be promoted, then visiting principals and after them existing professors, associate professors and doctors. I stood in the front row for existing professors and in front of me stands an elderly gentleman, with a white beard, wearing a tailcoat and chain. While we were waiting to enter, I asked where he was the Vice-Chancellor. Yes, it was at Strömstad Academy and so it was Lasse Broman who stood there. Next to him a slightly shorter and slightly chubby gentleman, Aadu Ott. This latter, we said, got to know Tärby well, the small village of 150 inhabitants where I live. He had lived nearby when he came to Sweden as a child at the end of the war.

Lasse told me about Strömstad Academy and thought I should apply for membership. I was pretty positive, but it didn't really work out. It was not until the turn of the year 2017/2018 that I got my thumbs loose and submitted an application. 28 Jan 2018 I was appointed member of Strömstad Academy and participated for the first time in the science festival 2018. My impression of Lasse can be summarized as follows: A kind and careful older gentleman. But this changed the following year, when I joined the board and noticed that Lasse, in addition to being kind and careful, could also be very determined. I then think of the discussion about our titles. Lasse turned out to be one of the few people who put an end to all discussions when he spoke and made his opinion known. It was on this issue that comments on Wikipedia made the academy's reputation worse. But Lasse believed that it was completely correct according to traditional academic rules and that people would leave us if they were deprived of their titles. My suggestion was simple: We take it in English! But it is also strange to have English titles in a Swedish academy. Then we should actually change the language entirely to English. But it's so wonderful to write in your mother tongue!

At the next academic festival, 2019, I was elected to the board and both Lasse and Peter came and sat at the same table as me and Helen (my wife) and talked about this and that. Nice to be noticed, I thought. And I had had some comments during the board and annual meeting. I got more and more assignments in the Academy, i.a. web designer and layouts for newsletters also eventually anthologies and some other texts, i.a. this. So Lasse and I have a monthly contact when I send the newsletter to him and he sends it back. He said several times that I was doing well and of course I was happy.

But then in the late autumn of 2019, I received an email from Lasse asking if I wanted to go with him and talk to some old men in Strömstad. A new municipal director had been appointed and the chairman of the municipal board was certainly also new. Lasse explained that his ulterior motive with this was that I would run as a Vice-Chancellor candidate when he retired next year! I was about to fall backwards! Vice-Chancellor of Strömstad Academy! At the age of 74! Well, Trump is just as old and both Biden and Sanders are older. But I realized that I had to wind up some of my other commitments (such as chairman of the local community association, active in politics and circle leader. No, by the way, not circle leader! I will lead a climate circle at the senior university this fall). Helen was not entirely dismissive of the idea of me as Vice-Chancellor, so after a few days of reporting, I said I would candidate. And I was elected and now have the delicate task of writing something in this tribute in the nature of Lasse's successor.

Lasse has a burning interest in science communication. In the first anthology, published in 2010, he writes:

> During the planning work with Sweden's first science center Framtidsmuseet with Kosmorama space theater, I gave seven reasons for creating such an institution (Broman 1984, slightly revised 2004): (1) Give insight that science is understandable. (2) Arouse curiosity. (3) Give people the courage to experiment (4) Scientific education. (5) Provide preparedness against superstition and scientific heresies. (6) Pleasure and entertain. (7) Provide aesthetic experiences. The seven reasons are set out in Appendix 1. This may be another way of describing the importance of scientific general education.

In the same writing, he points out that science is not just science, but quotes Bauer:

> To quote Bauer again, science "includes engineering and medicine, the social sciences and humanities, old and new disciplines with clear boundaries, but also ... fuzzy transdisciplinary techno-sciences.

In these matters, I have the same opinion as Lasse, where a change of Vice-Chancellor will not make any difference. I usually say that I should at any time be able to explain my research to an intelligent (and patient!) 15-year-old. If I do not know, I do not understand myself. When I review articles and essays and the author expresses a relatively simple problem through the use of an advanced and complicated non-standardized nomenclature, I usually write ABS at the edge. That means Academic Bull-Shit! So far, I have not had reason to use it when I read Strömstad Academy's writings. In this matter, I am therefore more radical than Lasse.

Another of Lasse's major interests is astronomy. We also have that in common. We talked about it at some point and it turned out that we both have a grade in astronomy. We read it mostly as a hobby, but Lasse has done more of it than I have done. I have contented myself with getting an 8 ″telescope and trying to take pictures of planets and the moon, while Lasse has set up a planetarium and conducted large-scale public information. So here I am definitely less radical than Lasse.

Lasse has had other activities going on than Strömstad Academy and research. He has also been politically active. I have that too. In addition, within the same party: the Green Party. We have not actually talked about party politics, but we are both passionate about environmental issues, so not much is changing there. But I, who is a social scientist / humanist, see more threats than opportunities, while Lasse, who is a scientist / technician, sees more opportunities. If humanity is to survive, both the whip and the carrot are needed, and I am more pessimistic than I think Lasse is. I have now left politics, for the most part. At the turn of the year 2019/20, I left the environmental party because I considered they sold their souls for the sweetness of power. The climate progress that has been made is, in my opinion, far too modest. I had actually expected much more from my commuter colleague, Gustav Fridolin. We used to meet on the train between Lund and Hässleholm and talk politics. Then he was very sensible. Instead, I had intended to get involved in the new party Partiet Vändpunkt, but then Strömstad Academy came in between. So even here I think I have become more radical than Lasse.

It is a clear advantage to be somewhat familiar with how municipal politics works and I myself have been a school politician in both Lund, Trollhättan and Borås. Lasse claimed that I behaved well ("handled the municipal politicians" as he said) when we met the municipal politicians, so it should probably go well. But there is a small problem: I have no connection to Strömstad, except that a couple of my wife's oldest friends have a summer cottage in Långekärr where we can spend the night. But I can use the internet to keep myself posted on what happens in Strömstad.

Another thing we have in common is that we dealt with layout. Lasse was a layout designer for previous publications, and he has designed the covers of our publications in our writing series. I designed the website and gave the newsletter a new design. Since then, there have been more and more layout assignments that I solve with "Word dribbling", ie I use a couple more percent of Words all possibilities than usual. There will be a standard template that all our publications, memos and letters must follow. A beginning to a unified graphic profile. Slightly stricter requirements than what Lasse had, one can expect.

This brings us to a difference between me and Lasse. I will use a lot of IT, e.g. I will often email instead of calling. I will use the discussion forum more and maybe even start developing our own academic system, Systemae Academia (both me and Lasse have a certain preference for Latin, another similarity). But this is far in the future.

Another similarity between me and Lasse is our attitude to academic ceremonies. When I got my doctorate, the only luxury I paid for myself was that I had a tie under my wool sweater. I had class as usual in the morning, defended my dissertation in the afternoon and had a small party in the evening. There was never any talk of being promoted, so I have neither a hat nor a laurel wreath. But over the years, I have become increasingly fond of academic ceremonies and am very tempted to make a stately, grand and Latinized version of our installations. Bodil Frisdal writes in the anthology "Inner and outer reality":

> So far, the gatherings have mainly involved installation lectures in Strömstad with a subsequent academic celebration with promotion with music, champagne and three men dressed as Carolines from Carl XII's army firing nutmeg shots echoing over the city and the archipelago[3].

This is a ceremony I would like to reintroduce! But I suspect there are more important things to spend time on.

Now I have unwittingly entered the future. How do I want to manage the legacy of Lasse? How do I want to contribute to Strömstad Academy being successful, well-known and respected? Yes, it's largely about money to set up an administration. We can get this in three ways: 1) Membership fees 2) Grants for research or teaching 3) Donations. I think you have to bet on all three. The first can be increased by getting more members or raising the annual fee. The latter is probably not relevant, but it is important to recruit more members and to offer such an interesting business that they stay. Here, I believe that lively local chapters can play a big role, because despite all the IT-supported meetings: Nothing compares to a F2F meeting. I read somewhere that 75% of all communication takes place through body language.

Donations can be very useful, but you have to get them. I'm not much for begging, I have no training in it and I think you should earn rewards. So, donations are not something I will work hard on, but if something comes up, I will of course not oppose.

Appropriations then remain. Getting funding for research and / or teaching is the most desirable thing and probably the one

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[3]Bodil Frisdal, "Strömstad Academy - ett flaggskepp mot framtiden", i *Inre och Yttre Verklighet, red Aadu Ott, Anders Steene och Gunnar Windahl*, Acta Academie Strömstadiensis 1, 2011, 9–12.

that gives us enough money the fastest. A prerequisite is that we can become a manager of research funds and that requires order, order and security. I will devote a great deal of time to developing, together with the Members, various administrative procedures to meet these requirements. This is facilitated by the fact that I have been teaching the subject for almost 50 years! But it will take time; not because it is particularly difficult but because it is so deadly boring that you fall asleep all the time! These routines must be discussed, presented and anchored with the members.

Another important thing is our reputation in the rest of the academic world. The first comment should not be: "Well, it is you who promote lecturers to professors!" A creative solution is needed in this matter and it must be solved. It is clear that a senior lecturer would like to be called an assistant professor and if the person in question has once received this title, it applies, in my opinion. The ultimate cause of the problem is that "docent (associate professor)" and "lector (senior lecturer)" can only be given by credited universities, while "professor" is a completely free title. Anyone can call themselves a professor and anyone can hand out professorships. This is ultimately because there are no formal requirements for a professor. The person in question does not even need to have defended their dissertation! My first professor, Börje Langefors, never wrote a dissertation. But he started the subject "information processing-ADB" and became its first professor and received the world's finest award in computer science: "The LEO Award for Exceptional Lifetime Achievement in Information Systems" by the Association of Information Systems.

To get a good reputation, you have to run a high-quality business. Routine descriptions play an important role here, but even more important is the quality of the content. What makes a scientific journal of high quality is the difficulty of getting your article published in it; in short, high rejection rate is a sign of high quality. By tightening up the review process and by writing both current and useful articles, you can increase both demand and the number of citations. Current overviews in a certain area I think can be something like that. Anders Gustavsson has just completed such an overview of cultural science literature in the Nordic countries during the 2010s. Setting selling titles is extremely important. I talk about this in my article about my research career. By choosing an interesting title, I got over 2500 downloads, compared to my colleagues who usually get a maximum of 100 pieces.

Strömstad Academy is an interdisciplinary academy where about 70% of the members are at least associate professors. This means that we are well placed to create a qualified review committee with a double-blind review in the traditional style. One could even imagine setting up a special series for extra high quality and giving it a selling name.

Most of the members of Strömstad Academy are more interested in research than in teaching. But there are those who like to teach, me and Lasse included. I have some ideas for collaboration with other universities and colleges that could be a win-win situation. Åsa and I are working out the concept and I have sent out a questionnaire.

As far as Strömstad municipality is concerned, Gudmund has good contact with, above all, school politicians, and when the schools start up this fall, we will run a drive for increased cooperation. One third of those who graduated from high school this year failed, so the municipality has problems and we have many professors in educational science and similar subjects. We will not get any big money this way, but we can get a good reputation. It's well worth that much.

One opportunity to raise more money is cooperation with the business community. Former Governor Kjell A Mattson tells in our first anthology about how Strömstad developed from an agricultural society to a stonemason society and an industrial society and has become the tourist society it is now. But the corona pandemic hit Strömstad hard. The Norwegians, who account for a large part of the income disappeared overnight, the trade lost millions of kronor a day and one would think that the municipality would like to receive help from the Academy with open arms. But that was not the case. Maybe we presented ourselves incorrectly, maybe we were out too late or maybe the message was too vague? In the local chapter, Gothenburg, where I am involved, we have a collaboration with Rotary and it should be a way into the business world to get different assignments from there. This can generate a lot of money, but it requires us to speak the language of business. We have members who master this.

What is unique about Strömstad Academy is a high level of scientific competence, interdisciplinary, unpretentious collaboration and perhaps the most interesting thing for the individual member: Freedom to research exactly what the person in question wants! Right now, this freedom is total because we have no funding, but we must be aware that it will decrease on the day we receive external research funding. Then we have to align ourselves with what the research councils consider important. That is the price we have to pay and we must be aware of that.

In summary, there will be no radical changes with me as Vice-Chancellor. But I will try to build on the increased commitment we have seen in recent months. The future group will soon present its report (This is written on July 14 and their report is expected to come in September) and there is a road map outlined. There is a skeleton and we must put meat on this together. Some of this meat is described here, other parts can be found in the June newsletter, in my letter of intent and in a column in Strömstads Tidning on 28 June. So, dear Lasse, your Academy is in good hands!

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Strömstad Academy is a virtual society with around 150 members, mostly highly trained scholars. It´s goal is to give the members possibility to do research and to publish, to meet in conferences but also provide public education, both in the form of lectures, articles and anthologies. Lars Broman, one of the founders, has been its Vice-Chancellor and promotor since the start. He has laid his signature on the Academy and with great success. Solar energy has been his scientific field for many years, where he has been one of the leading scholars in Sweden. Moreover, he has also a large interest in astronomy.

To honor Lars Broman for his outstanding work in Strömstad Academy, its editorial committee has asked some of the Academy's members to write a contribution in this anthology presented to him on his 80th birthday. Furthermore, we have asked the Chairman of the Academy, his close friend, to contribute, as well as his successor as Vice-Chancellor. Congratulations Lasse, we hope you will continue your scholarly work for many years to come!

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