UNIVERSITY OF TAMPERE

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INTELLIGENT LIFE ON EARTH?

The Impact of the New Solar Economy on Communication Networks and Technologies Including the Search for (and possibly Communication with) Extraterrestrial Intelligence

Master's Thesis
Department of Journalism and Mass Communication
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The rapid changes in information technology which, to a large extent, took place in the 1990's have changed our society in important ways, in a very short period of time. In 2008 the humanity is again facing a major technological revolution. The next important technological change, which has already started to happen, will be the shift from a centralized energy system, dominated by steam turbines and fossil fuels, to a much more decentralized way of producing energy, an energy system which will largely be based on solar power and other forms of renewable energy. "Intelligent Life on Earth?" investigates, how these changes in the energy system will influence our (mass) communication technologies and networks.

The thesis has been divided into seven separate chapters. Chapter one analyzes the changes which are now taking place in our energy system. It also tries to assess, which of the numerous different alternative energy techniques might, according to the very latest information, rise into a dominant position in the near future. The second chapter analyzes the impact of the new energy system on television, radio and mobile phone networks and on the internet. The third chapter concentrates on a spesific, somewhat futuristic solar power plant concept known as a solar chimney or as a solar windmill. If the concept will be taken seriously, it will involve the construction of the highest structures ever built by humans. The third chapter discusses the energy production and economic potential of solar chimneys and tries to assess their potential impact on the development of various kinds of communication networks.

Many of the proposed solar power station concepts would consist of vast fields of large parabolic reflectors or Fresnel lenses. Such reflector fields could also be used, with certain modifications, as gigantic radio telescopes after they would no longer function well as solar power plants. Numerous different parabolic antennas can be linked to each other so that they form, together, a very large radio telescope. This means that some of the new solar power plants could also become important tools for radio astronomers. It would also be technically possible to use the same antenna fields for searching artificial radio signals which might have an extraterrestrial origin, or for sending radio messages to space.

Chapter number four takes a brief look at the history of radio astronomy and at its special branch known as SETI, the Search for Extraterrestrial Intelligences. The fifth chapter analyzes, how the changes in our energy production systems may influence the resource base available for radio astronomers and for the various SETI programmes. Chapter six tries to assess, whether it would be technically possible for the humans to send to the space radio messages which might still be detectable even in other, nearby galaxies. The seventh chapter concentrates on the question of the contents: if we some day decide to send radio messages to the stars, exactly what should we send?

TAMPEREEN YLIOPISTO
Tiedotusopin laitos

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Suurelta osin 1990-luvulla tapahtuneet hyppäyksenomaiset muutokset informaatioteknologiassa ovat lyhyessä ajassa muuttaneet koko yhteiskuntaamme merkittävällä tavalla. Vuonna 2008 ihmiskunta on jälleen samantyyppisen teknologisen murroksen edessä. Seuraava, parhaillaan jo käynnissä oleva teknologinen vallankumous liittyy energiatekniikkaan. Suuriin höyryturbiineihin ja fossiilisiin polttoaineisiin perustuva energiajärjestelmä tulee lyhyessä ajassa väistymään paljon hajautetumman ja pääsääntöisesti uusiutuviin energiamuotoihin perustuvan uuden energiajärjestelmän tieltä. Intelligent Life on Earth? (”Onko Maapallolla älyllistä elämää?”) tarkastelee, minkälaisia vaikutuksia näillä energiajärjestelmien muutoksilla on viestintäteknologian ja erilaisten viestintäjärjestelmien näkökulmasta.

Tutkielma jakautuu seitsemään eri lukuun. Ensimmäinen luku analysoi käynnissä olevaa energiajärjestelmien muutosta. Se pyrkii myös ennakoimaan, mitkä lukuisista erilaisista vaihtoehtoisista tekniikoista näyttäisivät uusimman tiedon valossa nousevan keskeiseen asemaan.

Toinen luku analysoi uuden energiajärjestelmän vaikutuksia televisio-, radio- ja matkapuhelinverkostoihin sekä internetiin. Kolmas luku keskittyy aurinkotuulimyllyksi kutsuttuun futuristiseen aurinkovoimalakonseptiin, ja pyrkii arvioimaan millä tavoin aurinkotuulimyllyjen rakentaminen vaikuttaisi erilaisten viestintäverkostojen kehittymiseen.

Tutkielman viimeiset neljä lukua lähtevät liikkeelle siitä toteamuksesta, että tiettyjä näköpiirissä olevia aurinkovoimalatyyppejä olisi mahdollista käyttää myös suurina radioteleskooppeina, tai oikeammin sanottuna suurina lukuisien toisiinsa kytkettyjen radioteleskooppien muodostamina kenttinä. Toisin sanoen tietyt uudet aurinkovoimalatyypit voisivat käytöstä poistuttuaan tai mahdollisesti vielä käytössä ollessaan muuttua tärkeiksi radioastronomien työvälineiksi. Samoja antennikenttiä olisi teknisesti mahdollista käyttää myös keinotekoisten radiosignaalien etsimiseen avaruudesta tai radioviestien lähettämiseen avaruuteen.

Tutkielman neljäs luku käy lyhyesti läpi radioastronomian ja sen keinotekoisia radiosignaaleja avaruudesta etsivän haaran eli SETI:n (Search for Extraterrestrial Intelligences) historiaa. Viides luku pyrkii analysoimaan, millä tavoin energiajärjestelmissämme nyt tapahtuvat muutokset tulevat ehkä vaikuttamaan SETI-ohjelmien ja radioastronomian käytettävissä olevien resurssien määrään. Kuudes luku yrittää analysoida, olisiko ihmiskunnan teknisesti mahdollista lähettää avaruuteen viestejä, joiden havaitseminen olisi teoriassa mahdollista jopa toisissa galakseissa. Seitsemäs luku keskittyy kysymykseen mahdollisesti lähetettävien viestien sisällöstä.

CONTENTS

INTRODUCTION

The German physicist Heinrich Hertz made two important discoveries. First, he discovered the existence of radio waves. Second, he realized that sunlight falling on certain kinds of semiconductor materials produces free electrons, or, in other words, electricity. At the beginning of the 21st century these two observations and the related technologies may now be in a process of becoming, once again, intimately linked.

The last twenty years of the 20th century saw a phenomenal revolution in communication technologies, many of which were based on radio waves. In communication networks based on radio waves structures which focus radio waves, typically parabolic antennas, are one of the key elements. Television and radio networks use large parabolic antennae to transmit signals to faraway link stations which then broadcast them locally to all directions so that they can be received by the simple and small antennas of people's televisions and radios. People receive the broadcasts of satellite television with small parabolic antennas. Many types of communication networks that combine wireless technologies and cables utilize parabolic reflectors which concentrate radio waves to narrow, focused, directed beams.

The next great technological revolution, which is going to take place within the few first decades of the 21st century, will most probably be the shift from a centralized energy system, dominated by large steam turbines and huge, fossil fuel-consuming power stations, to a largely decentralized, modern energy system based on geothermal, wind, biomass and – above all – solar energy.

In all the countries which receive a lot of direct sunlight, the modern solar economy will almost certainly be based on systems in which sunlight is concentrated by similar structures which are so important in the mass communication based on radio waves: parabolic reflectors. Alternatively, they might use thin optical elements known as Fresnel lenses, which can also focus radio waves, but are seldom used to this purpose.

All the structures and materials that can focus sunlight can also be used to concentrating radio waves. Radio waves are easier to focus because they have a longer wavelength. Small deviations on the surface from the precise parabolic form do not matter if they amount to less than 1/15th or 1/20th of the wavelength of the radiation we want to focus. The other side of the coin is that the longer the wavelength, the wider antenna is required to achieve the same level of concentration.

In countries which only have a little direct sunlight and a lot of clouds and water vapour in the air various types of thin-film photovoltaic panels are likely be more important than the concentrating systems, because the latter can only concentrate direct sunlight, and not the solar radiation diffused by clouds.

However, most parts of the world – the areas where the great majority of the humanity lives – have plenty of direct sunlight. Therefore the modern solar economy is likely into lead to a situation in which Fresnel lenses and parabolic reflectors will become very common. Individual households may soon have their own reflectors and there will probably be different types of village-level solar power plants based on similar reflectors. Besides this larger solar power stations producing power for the national grid will almost certainly erect large fields of parabolic reflectors or Fresnel lenses.

In other words, the same structures can be used to focus radio waves even when they are also used to produce solar electricity, and they can still focus radio waves effectively when they are no longer able to focus sunlight.

What does this mean for the future of (mass) communication networks and communication technologies based on radio waves? What does it mean for ordinary radio and television networks? What does it mean for satellite television? What does it mean for mobile phone networks and for the different integrated wireless-cable-networks? What does it mean for our possibilities to receive and send radio messages which have covered or which ought to cover much wider, interstellar distances? The purpose of this thesis is to take a brief, tentative look at these questions.

The first chapter briefly discusses the most important new solar technologies, their implications, limitations and potential.

The second chapter provides a brief analysis on the main question of this thesis, on some of the key impacts these new energy technologies might have on the various global communication networks, and on how the development of the modern communication networks and the new renewable energy systems might feed each other. What comes to the conclusions on the matter, I have been forced to rely mostly on my own analysis and understanding, because it seems that practically no research has been conducted on this issue, in spite of its obvious importance. As a research subject the matter drops between the chairs of technological sciences and social sciences, so that it can only be properly dealt with a genuinely multi-disciplinary approach. This is probably, in this case, the most important reason for the almost complete lack of serious research attention.

The third chapter further investigates the same subject, but concentrates on a single, very specific and futuristic solar power station concept known as the solar chimney or as the solar windmill. The concept has been given a chapter of its own, because full-scale solar chimney projects would involve the construction of the highest structures (towers) ever built by humans. If such solar chimneys will ever be constructed, they will almost certainly also be utilised by television, radio and mobile phone networks.

Chapters two and three, therefore, aim at defining the rough outlines for the impact the new solar economy is likely to have on the (mass) communication networks and technologies on our home planet. However, when we look at the technological infrastructures which are likely to be created by the new solar economy, we can almost immediately notice that their emergence might have even wider implications. A shift to a modern solar economy is also likely to influence our ability to receive natural or artificial radio signals which have their origins outside our own planet.

Major solar power plants consisting of numerous large parabolic reflectors or Fresnel lenses could thus benefit radioastronomy and its different specialized branches, including a discipline known as Search for Extraterrestrial Intelligences (SETI). When the reflector fields would become too scratched to work well, some of them could perhaps be given a new life as gigantic radio telescopes, of course assuming that the price of the related equipment would drop drastically when it would be produced in very long series.

Chapter four provides a short account on the history of radio astronomy and SETI, and chapter five discusses the way these fields of investigation might be partially transformed by the modern solar economy.

Theoretically, the old reflector fields could even be used to broadcast radio messages to other solar systems – or to other galaxies – if we would, some day, like to do something like this. The last two chapters of this thesis are devoted to exploring this, admittedly somewhat exotic, possibility: CETI or Communication with Extraterrestrial Intelligences.

I have kept the discussion about the other fields of radioastronomy brief, but included four full chapters about SETI and CETI because the questions related to searching for - and the theoretical possibility of communicating with - extraterrestrial civilizations are, by definition, (mass) communication issues or (mass) communication problems, even though we cannot yet say, with absolute certainty, whether there is anybody to communicate with outside our own planet.

In principle, everything that has to do with mass communication (efforts) should be a legitimate subject in communication research, even though the issues related to SETI and CETI have not, this far, really existed inside the field of communication research and belonged to its traditions.

However, the issue is already taken very seriously indeed in several areas of scientific enquiry outside communication research. There is a whole new field of astronomy known as bioastronomy (which was formerly called “astrobiology”) that concentrates in the search of alien life, primitive or intelligent, from other planets and solar systems, for example by looking for “biosignatures” in the composition of the atmospheres of planets orbiting other stars (see for instance KIANG, 2008). Five million personal computers have been participating in a collective search for artificial radio signals through the so called SETI@home programme, by analyzing data collected by the giant Arecibo radio telescope in Puerto Rico.

Therefore, even if it would finally turn out that we are alone in our galaxy and that all the ideas behind SETI and CETI would turn out to be too optimistic, the growing popular appeal of these ideas in the minds of hundreds of millions if not billions of people is a good enough reason for acknowledging, also in communication research, that the issue actually exists. Messages that have already been sent to space by radio or carved on metal plates incorporated in the structures of space probes which will soon be leaving our own solar system, have received enormous international attention. Therefore, the SETI and CETI projects are, certainly and definitely, already a form of mass communication even if the messages would only have a negligible or non-existing chance of being intercepted by aliens. In any case they have been, and will be, influencing the mental landscape of the six and half billion people living on the planet Earth in a most profound way, the importance of which has already become a bit difficult to notice because the ideas in question have become so self-evident and so deeply ingrained in the mental imagery of most of us.

For example the webpage of the SETI@home programme has been able to gather approximately 100,000 new, unique visitors per day (McCONNELL, 2001). Even if we would not otherwise consider SETI/CETI as a legitimate "communication issue", as a cultural and social phenomenon it definitely merits a closer look.

Even though the topic might be considered a little bit obscure, the chapters six and seven might still be the most ambitious part of this thesis, because they aim to provide an almost complete rethink of CETI and the strategies that might be used in it. The discussion in some parts of these chapters will include elements which could already be closer to science fiction than to proper empirical science. This problem, however, is built in the subject and therefore almost inevitable. Because we still know so little, it is not possible to say anything interesting about the subject without including a strong element of speculation into the analysis.

1. THE EMERGING MODERN SOLAR ECONOMY

The environmental problems caused by the extensive use of fossil fuels have grown more serious during the last decades. We may already be threatened by a full-scale, runaway greenhouse effect (see for example ISOMÄKI, 2008). James Hansen, probably the leading climate scientist in the USA, said in July 2007 that a scenario according to which the sea level would rise by five metres by 2107 now looks much more probable than the earlier predictions (HANSEN, 2007). The acid rains are still a major problem in many parts of the world, and the exposure to small and nanoparticle pollution kills millions of people, every year.

Thus it is, in any case, of utmost importance to move from a fossil fuel-based economy to an economy based on solar power and other renewable forms of energy. However, it now seems that this will be the most feasible alternative from the viewpoint of economics, as well.

On a long run most of our energy will inevitably be provided by the Sun. The Earth receives approximately half a billionth of all the energy that is currently being radiated to space by our home star (SAGAN, 1973a). This amounts to 170,000,000 gigawatts of solar radiation, a quantity that is equivalent to 12,000 times the humanity's present consumption of energy. However, a number of factors have slowed down a shift to a solar economy.

At present most of the production of electricity is based on steam turbines. Steam turbines are very complex machines, and their economic profitability is the better the larger they are. In other words, the present technology is biased for very large power production units, often feeding more than 1,000 megawatts of power into the grid.

When power production concentrates on very large units the result is a highly centralized power grid and a highly decentralized market for electricity. In such a situation big players, the large companies whose factories consume enormous amounts of electricity, get their power with a very cheap price, while the small and middle-sized companies and individual households have to pay much more.

For example in Finland small and middle-sized companies and individual households pay, for their electricity, twice as much as the largest buyers of electricity (ENERGIAKATSAUS, 2007). This means that individual households and small companies end up subsidizing the giant companies. The giant corporations become more productive because they get cheap power. This leads to concentration of wealth and income into fewer and fewer hands. Unemployment increases, because the small and middle-sized companies are wiped out from the market. The small and middle-sized companies always employ many more people for the same amount of production than the more automatized big factories.

When we shift to a solar economy, many things change. For example the concentrator photovoltaics technology is modular by nature. This means that power can be produced with either large or small units, because a large power producing plant is, essentially, nothing more than very many small plants concentrated on the same area. If power can be produced in small units at the village level small and middle-sized companies become more profitable than giant factories.

The large companies will lose their subsidies, and the small companies and individual households in villages no longer have to subsidise the energy consumption of the giant corporations. Moreover, power in the villages can be fed into small local grids as direct current or as alternating current. Thus the village economies do not have to pay high transfer prices for electricity. In a system dominated with a small number of very large power production units, the transfer price can amount to more than half of the actual price of electricity. Because solar economy would benefit small and middle-sized companies and village economies at the expense of large factories, it would probably create work for one or two billion people which are currently un- or underemployment. Thus it would also be likely to lead into a much more equal division of wealth and income.

Many would see these as desirable objectives, but this far they may have been the main reason for the slow progress in the field. People who have a lot of economic and political power in their hands through a salt monopoly want to maintain the salt monopoly.

Besides this, many of the challenger power utility companies which have been seriously interested in solar electricity and other forms of renewable energy, have been worried about the problems related to the backup power. Where does the power get from when the sun is not shining and when the wind is not blowing?

These factors have been slowing the adoption of solar electricity, but they are, in a way, fading away. There are now so many companies which will soon be able to produce affordable solar power technologies, that the companies which have a vested interest in the status quo cannot buy them all off the market. Besides, many of the most relevant key technologies have already lost or will soon lose the protection provided by patents. So it will not be possible to prevent the adoption of the new solar power technologies.

The price of the new technologies is going to drop very quickly in the near future, and there are also a growing number of different solutions to the problem of the backup power.

In the United States it is now estimated that the average price of solar electricity will drop below the average price of grid power by the year 2011 or 2012 (DAVISS, 2007). For example the venture capital investors of California's famed Silicon Valley have recently turned their energies and their funds towards the renewable energy sector. According to new statistics, renewable energy now receives more investment from Silicon Valley than any other sector. The Silicon Valley capitalists are now seeing solar power and the other new renewable energy technologies as the next big thing that "will again change the world", and economic journalists have started to speak, in this context, about the "six trillion dollar men" (MULLINS, 2008).

Bill Wiehl, often called the "Green Energy Czar of Google" says that Google is funnelling some of its profits to promising renewable energy technologies like solar, high-altitude wind and geothermal to make them cheaper than coal "within years, not decades" (BIELLO, 2008; see alsoVISE, 2005).

In the following pages I will first describe some of the most promising new solar electricity technologies and their potential. After that I will discuss a few different answers to the problem of the backup power.

The focus is in electricity because this is, nowadays, the most important form of energy whose demand is likely to increase in the future. However, the production of solar heat is much more simple than the production of solar electricity, and most solar energy systems could produce both heat and power.

I am providing only a very limited amount of references for the information contained in this chapter. Because the chapter discusses new, cutting-edge technologies there are no books and a limited amount of articles about them, and the existing books and articles often contain out-dated information. Much of what is being said below is based on personal communication with the various companies and scientists with an active involvement with solar power, or on the information available on the web-pages of the companies mentioned in the text.

Photovoltaics

Photovoltaics is probably the most elegant way of producing solar electricity. In photovoltaics solar radiation falling on semi-conductor surfaces produces electricity. The phenomenon was discovered already in 1887 by the German physicist Heinrich Hertz, who also discovered the radio waves. Another scientist born in the same country – Albert Einstein – later received a Nobel price for physics for explaining the theoretical basis of Hertz's observation.

The spread of the technology has been slowed down by the high price of effective semi-conductor materials. Solutions have been searched from thin-film technology, nanotechnology, screen-printing of solar cells, thermophotonics and low-cost organic semi-conductors. It has been predicted, that thin-film technologies might soon reduce the price of photovoltaic electricity by a full order of magnitude, by ten times or so.

In the USA, the price of photovoltaic power is expected to reach the average price of grid power in 2011 or in 2012 (DAVISS, 2007). The price of ordinary photovoltaic panels is not going to drop much, but thin film and cpv solutions are becoming cheaper (see the discussion below).

Concentrating Solar technologies

Concentrating solar power (cs) is the other main discipline in solar power production, besides photovoltaics. In concentrating solar technologies sunlight is concentrated by parabolic or trough-like reflectors.

In solar-powered Stirling engines solar radiation is concentrated with a parabolic reflector, and in turns expanding and contracting gas is driving a piston engine. According to some predictions such Solar Stirlings might soon be able to produce electricity with 6 us cents for kilowatt-hour (BERRY and WILLIAMSON, 1997).

In solar trough plants long, trough-like collectors concentrate sunlight on black tubes. The idea was originally proposed by the Swedish inventor John Ericsson, already in the 1840's. The heat produces steam which runs a steam engine or a steam turbine (see for example MASRI, 2002; PRICE, 2003; SKLAR, 2005 and STIRZAKER, 2006).

This far, solar trough plants have cost on average usd 3,000 per kilowatt in the United States of America, but according to an OECD study solar trough plants would become cheap enough to compete with coal and nuclear power without any subsidies or pollution taxes when 5,000 megawatts had been installed (PHILIBERT, 2004). At this time solar troughs should only cost about USD 1,500 per kilowatt, fifty per cent of their present price. The Australian company Solar System is predicting a roughly similar price curve on its own web-pages, but some researchers (see for example ZWEIBEL et al, 2008) have claimed that the drop of the price of solar trough power stations would not drop as much as the OECD study predicted.

In the South, where the labour costs are lower than in the United States or in Europe, economic sustainability could most probably be reached even with a much smaller level of investment. A solar trough project in Rajasthan, India, is aiming at an installation cost of USD 1,000 for a kilowatt of power.

Steam turbines and steam engines run by solar energy unfortunately consume a lot of fresh water, just like the coal-fired thermal power plants and nuclear power plants.

Concentrating Photovoltaics

Concentrating or concentrator photovoltaics (cpv) is a hybrid of the two main schools of solar electricity, and it might well emerge as the main winner of the race. I am personally convinced that this will be the most important way of producing electricity in the near future, nothing else makes as much sense.

Simple reflecting mirrors made of glass, metal or plastics are dozens of times cheaper per one square metre, and they can be used to concentrate sunlight.

Ordinary photovoltaic panels cannot deal with concentrated sunlight, they overheat and experience a brownout, which means that they stop producing electricity.

However, commercial companies and research centers in Australia, USA, Israel, Germany, Japan, Spain and other countries have found out that it is not difficult to cope with the overheating problem. The heat can be dumped for example by using highly conductive material, like copper, directly behind the cells in order to spread the heat. It is also possible to use different liquids or air cooling for the same purpose. The Umuwa power station in northern South Australia uses both air fluid cooling and a compensating system of polythene pipes buried 1.5 metres below the Earth's surface. The pipes make it possible for the plant to use the ground as a heat sink.

When the overheating is prevented, a photovoltaic cell produces at least one hundred times more electricity when exposed to a photon flow equivalent to one hundred suns (JONES, 2006). Sometimes the gains are even more than this. Concentrator photovoltaic systems now routinely attain efficiencies of 25, 30 or even 40 per cent, and because they can reduce the need of expensive semi-conductor materials by hundreds or even thousands of times

The CS500 concentrator photovoltaic (cpv) modules of the Australian company Solar Systems use concentrations of 500 Suns, but its solar panels produce, per square metre, 1500 times more electricity than the standard flat plate photovoltaics.

In 2006 the world record was in the name of the US company PhotoVolt Inc, which had been able to produce more than 400 kilowatts (400,000 watts!) of solar electricity on one square metre of its VMJ (vertical multi-junction) photovoltaic cells by concentrating sunlight by 2,500 times. Israeli scientists have been experimenting with even larger concentrations amounting to 9,600 Suns.

The concentrator photovoltaic systems use either parabolic reflecting mirrors or optical elements known as Fresnel lenses to concentrate sunlight to small patches of semi-conductor materials.

Fresnel lenses were first developed by the French inventor Augustin Fresnel in 1822. They consist of concentric rings and they are flat on the other side and ridged on the other.

Fresnel lenses are much lighter and easier to manufacture than ordinary lenses. Because they can be very thin, astronomers have been seriously wondering whether it would be possible to send even one-kilometre-wide, deployable plastic Fresnel lenses to space, where they could be used as giant radio telescopes.

The German company Concentrix Solar GmbH aims at manufacturing concentrator photovoltaic modules, in which Fresnel lenses concentrate sunlight by a factor of 500 on two-millimetre-wide-spots on the solar panel. The Israeli MST Renewable Energy Company has estimated that it would cost about USD 850 million to construct a 1,000-megawatt concentrator photovoltaic plant using this technology, and that a factory annually producing 1,000 megawatts of further plants would cost about USD 650 million (FAIMAN et al, 2005).

The Israeli scientists have calculated, that besides the construction costs the power produced by such cpv systems would only cost 0.5 (US) cents per kilowatt-hour for operational and maintenance costs. In other words, the plant should be able to pay its original investment costs back ten or twelve times during a period of 30 years, a fantastic rate of return for any investment (FAIMAN et al, 2005).

The break-down of the calculated price of USD 850 per kilowatt was very interesting. For each kilowatt about 64 one square centimetre solar cells would have been needed needed. They would have cost USD 160 for kilowatt. The cost of inverters amounted to USD 40 per kilowatt. The cost of the various concentrating and homogenizing optical elements was USD 64 per kilowatt. The bulk of the expenditure, USD 586 per kilowatt, came from the manufacturing of the systems that concentrate the sunlight and their tracking systems (which keep the reflectors or the modular panels consisting of numerous separate Fresnel lenses pointed towards the Sun), and the physical erection of the plant.

These costs, which amount to 70 per cent of the total, could probably be reduced to a fraction of the mentioned level if the systems were produced for example in India or in China. For example TinyTech India, a Gandhian technology company based in Rajkot, India, has tentatively estimated that it could sell 24-square-metre parabolic mosaic mirrors and their tracking systems with 1800 euros per unit.

If the price level outlined by the Israeli scientists can be reached in practise, the technology will most probably spread very quickly. By USD 3 billion, the typical cost of one 1,000-

megawatt nuclear power plant, it would be possible to construct a production facility annually manufacturing 5,000 megawatts of concentrator photovoltaic systems. In thirty years this would amount to 150,000 megawatts, one hundred fifty times more than the power producing capacity of the lone nuclear power plant which might have been acquired with the same price as our hypothetical factory producing concentrator photovoltaic systems.

Other companies, like Green and Gold Energy of Australia and SolFocus in the USA and Daido Steel in Japan are developing cpv modules, meant for individual households, which consist of numerous small parabolic reflectors. Green and Gold Energy started to sell its SunCube system for consumers in April 2006. According to calculations available then it seemed, that in the Australian conditions individual households should have been able to produce electricity for themselves with the price of euros 0,04 per kilowatt-hour with the SunCube system. This is considerably less than the price of grid power in Australia.

The chief executive officer of SolFocus, Gary D. Conley, has said that his company could produce a hundred megawatts of its concentrating photovoltaic panels with less than one dollar per watt, and that the retail price will drop to USD 0.35/watt when the orders reach the level of 1,000 megawatts. According to SolFocus, the prize could still drop a little bit after that, perhaps to USD 0.2/watt, but then it would more or less stabilize (CONLEY, 2005).

Ben-Gurion University of the Negev in Israel and the Australian company Solar Systems, which has already been mentioned above, use very large parabolic reflectors with a small photovoltaic panel at their focal point.

By the end of 2005 Solar Systems had already installed in the deserts of Australia 30 large instruments which looked more like radio telescopes than ordinary photovoltaic panels. Each 12-metre-wide dish currently produces about 25 kilowatts of power. The new solar cells used by Solar Systems have an average efficiency of 35 per cent.

Solar Systems aims to construct 5 gigawatts (5,000 megawatts) of concentrator photovoltaic plants in Australia before the year 2030 by 8 billion Australian dollars. At the end of 2006 this was equivalent to USD 6 billion or euro 5 billion, which amounts to USD 1,200 or euro 1,000 for each kilowatt of installed power-producing capacity.

The Israeli scientists have constructed, in the middle of the Negev desert, on their Sede Boqer Campus of the Ben Gurion University, an even larger solar dish. The instrument consists of a 25-metre-wide, 400-square-metre parabolic reflector and a 65-centimetre-wide photovoltaic panel placed at its focal point. The parabolic mirror concentrates sunlight by one thousand times, so that the photovoltaic panel can produce one hundred kilowatts of power. The Israeli scientists call the reflector ”the Big Dish”, just like radio telescopes are often called. The Big Dish of Sede Boqer could, also in reality, be used as a radio telescope.

According to the researchers of the Ben Gurion University it would be possible to produce such systems with less than a dollar for watt, if it would be possible to manufacture a 1,000 megwatt plant at once.

The costs could be further reduced by efficient wind-breaks. For example a narrow strip of forest would break the wind so efficiently, that the reflectors could be very light, which would greatly reduce the raw material costs. 20-metre-high trees have a wind-shading effect up to a distance of 400 metres or so, which means that they can be used to break the wind without shading the reflectors from the sun. A narrow strip of forest is more efficient than a dense wall of trees, because if the wall is too dense the wind just jumps over it, without actually losing strength. Needless to say, the trees should preferably belong to species which produce popular food or something else the local people really need. Such wind-breaks would also hide the reflectors, so that an area used for power production would look, from a distance, like a forest and not like a power plant. There could even be beautiful paths, shaded from the wind, inside the narrow strips of forests. This might be a very nice and comfortable arrangement from the viewpoint of the people living nearby!

The cheapest way to mass-produce the parabolic reflectors would probably be to make them from plastic covered by a highly reflecting metal film. Similar material solutions are nowadays used for example in the balloons sold for the children during the 1st of May celebrations. In mass production the square metre price for such a system might finally drop to less than one euro, and the cost of mass-produced multi-junction solar cells might drop to one euro for a couple of tens of centimetres. This means that the cost per watt might finally drop to very, very low levels (to 0.5 eurocents or less), excluding the cost of the tracking systems which keep the reflectors directed straight towards the Sun, and excluding the transfer price of electricity. Because the transfer price of electricity is about one half of the current price of power, grid power will not be significantly cheaper in the future. Even though the technologies used in transferring power are improving, electricity has to be transmitted, an average, for longer distances. However, solar power produced locally for local consumption may become so cheap that it will be regarded as a free commodity.

Israeli scientists have calculated, that 54,000 megawatts of concentrator photovoltaic plants would require 450 square kilometres of land, roughly twice as much as the combined area of the reflectors. In the tropics it might be a good idea to install at least some of the plants on agricultural areas.

The reflectors would reduce the amount of sunlight on the area by almost one half. If the heat is not dumped on the ground, this shading effect should significantly reduce soil temperatures and thus lessen the evaporation of water from the ground. In the tropics the amount of sunlight is very seldom a factor limiting the productive capacity of the plants, the availability of water is much more important. In experiments conducted in Abu Dhabi food plants were able to produce eight times more with the same amount of water when the temperature dropped from 45 degrees to 30 degrees Celsius (PEARCE, 2002). In other words crops crown among the reflectors would receive less sunlight, but might actually benefit from this. Moreover, the reflectors could, during rainy days and during nights, be turned into a horizontal position and used to collect rainwater, which could be led straight towards the roots of the plants. Because the metal surfaces would cool quickly in the evening, they might even be able to condense significant quantities of water from the air, at least when the day and night temperature differences are large and the moisture content of the air is not minimal.

Solar CHP (Combined Heat and Power) and solar CCP (Combined Cooling and Power)

Most photovoltaic and concentrating solar systems can be designed so, that they can produce, with only marginal additional costs, both power and heat whenever there is demand for industrial process heat, heat for desalination purposes or heat for warming the houses. This is especially easy in connection with the concentrator photovoltaic systems which use very large reflecting mirrors, because many such systems already use the ground as a heat sink and channel heat into the soil through plastic pipes. With a little bit more complex arrangements the same plants could also provide power and district cooling.

Numerous different industrial processes require mild heat, and it can also be used for desalination of sea water. Depending on the efficiency of the photovoltaic cells that are used, a 400 square-metre solar dish can produce roughly 100 kilowatts of power and 300 kilowatts of heat, or 150 kilowatts of power and 250 kilowatts of heat. It is almost needless to say, that all such solar CHP (combined heat and power) arrangements will further improve the economics of the modern solar energy technologies. The same system which is used for example in the Australian Umuwa solar power plant can also be utilised to harness the heat for useful purposes, instead of just dumping it into the ground.

The Problem with the Back-up

Many companies realize, that the price of renewable energy will fall down when the necessary equipment will be produced in large series. However, they are worried of the back-up power.

Where does the electricity come from, when there is no wind and the sun isn't shining?

Luckily there are a number of realistic solutions to this dilemma. If we combine wind, solar, biomass and geothermal energy, the problem will be much reduced.

Wind power could be transmitted along long HVDC-lines from many different regions, whose winds rise and fall with a different rhythm. Solar power could be transmitted with similar HVDC –cables along the East-West-axis, from areas where the sun is still shining to areas where it has set.

With the new HVDC lines transmission losses are already less than 0.4 per cent per one hundred kilometres (SORENSEN, 2007), and the average cost is sometimes less than with ordinary AC lines (ABB, 2007). First commercial HVDC line ("Gotland 1") was constructed already in 1954 in Sweden, and since then a huge number of different types of HVDC lines have been installed. According to a World Bank Technology Review Paper a 300-kilometre-long AC line with a capacity of 2,000 megawatts has a cost of USD 200 million and a comparable DC line involves an expenditure of USD 300 million. However, when the 2,000-megawatt line becomes 650 kilometres long, the costs of AC and DC transmission become roughly equal, about USD 400 million. With a 1,500-kilometre-long line the costs of HVAC are USD 800 million and the costs of HVDC only USD 600 million

(RUDDERVALL, CHARPENTIER AND SHARMA, undated). The increasing price tag of AC results from higher transmission losses. Because the transmission losses increase steeply with AC when the line becomes longer, more transmission capacity is needed to deliver the same amount of electricity.

Some solar power plants – like solar chimneys and solar trough plants equipped with an energy storage – can also produce electricity during the night. Hydropower can be used as a backup. Heat can be stored and cold can be stored, in numerous different ways.

It has also been proposed, numerous times, that the extra electricity could be used to produce hydrogen fuel by breaking water to hydrogen and oxygen. In other words, part of the energy could be stored in the form of hydrogen, which could then be burned in fuel cells to power cars or to produce electricity.

This would be a very inefficient and expensive way of storing energy, because the electrolysis would probably only have an efficiency of 60 to 70 per cent and because the storing of hydrogen also consumes a lot of energy. Above all, such a system will not be acceptable in a world which is already now threatened by a man-made climatic catastrophe. Hydrogen atoms are very small, they can escape from tiniest holes or cracks in tanks or pipes, and the escaped hydrogen would, in most cases, rise on top of the atmosphere before reacting with oxygen and again forming water. Thus it would produce very high and very long-lasting artificial cirrus clouds, which would have a very strong heating impact on our planet.

The lithium-iron-phosphate batteries of modern electric cars could also act as a back-up system, feeding power into the national grid, local grids or for the electric equipment in a single household. After the efficiency of the batteries drops so much, after a few hundreds of thousands of kilometres, that it is no longer rational to use them in cars, they can still function for a couple of decades in a shed or in a cellar to provide back up power for a household or for a small company, before they are recycled. Still another possibility is to use larger flow battery systems (THWAITES, 2007). David Faiman, Dov Raviv and their co-workers have estimated, that it would cost about USD 285 million to equip a 1,000-megawatt solar power plant with Vanadium Redox flow batteries that could provide auxiliary power for six hours (FAIMAN et al, 2005).

Besides this, wind power, solar power, geothermal energy and hydropower can complement each other. The portion of wind power in an electric grid can be increased to a rather high level, if the wind-generated electricity comes from many separate areas whose winds operate in a different rhythm. In other words, if wind power is being produced at the North Sea, at the Baltic Sea, at the Norwegian Sea and at the Barents Sea (on the Kola Peninsula), and not only at the Baltic and North Seas, a much larger percentage of all electricity can be wind power. The mentioned four seas are never still at the same time! However, when solar power and wind power can be combined, and some hydropower can be used as a back-up, the situation becomes even easier.

It would be important to negotiate with Russia about the establishment of large wind parks on the Kola Peninsula. The Kola Peninsula is one of the world's best sites for producing windpower. It is the windiest part of Russia's northern coast. The winds are very strong and there are not many calm days. A study financed by the Norwegian environmental organization Bellona estimated, some years ago, that the theoretical annual wind power potential of the Kola Peninsula might amount to the almost incredible 21,000,000 gigawatt-hours (7,000 gigawatts!). A more recent study (MININ and DIMITRIEV, 2007) estimated that that even the technical and economic potential would be around 360,000 gigawatt-hours (120,000 megawatts).

The first large wind-park that is to be constructed to Kola Peninsula is expected to have a pay-back time of only three and a half years (HALL; 2008). It is interesting to compare this for example with the time that has already went to constructing the Olkiluoto three nuclear power plant in Finland, not to say anything about the expected pay-back time for the investment!

Because the present windmills are larger - and still growing bigger - both the theoretical and the technical potential is still increasing together with the improvements in the technology.

If a mutually beneficial deal can be negotiated with Russia, it would make a lot of sense to construct a lot of wind power on the Kola Peninsula. The area is not very far from West Europe or from Moscow.

Certain types of solar power plants can also produce power at night, especially the solar trough plants (if equipped with large heat storages) and the solar chimneys. With solar chimneys it is even possible to concentrate the production into the night time, but the efficiency (production of power) of the system is then somewhat reduced.

Thus the problem with the backup power will not be able to prevent the solar energy revolution. Solar power is coming, and it is now coming with a much faster speed than most people have yet realized.

2. THE NEW RADIO ECONOMY AND THE NEW SOLAR ECONOMY

Still in the 1970's it was easy to divide the various mass media into two simple, clear-cut categories. On the other hand we had the printed media: newspapers, magazines and books. And then we had the electronic media based on radio waves: radio and television. Besides electronic media and printed media we, of course, had all kinds of communication networks based on interpersonal communication, from political parties, trade unions, religious mass movements and agricultural extension services to institutionalized theatre, village and street theatre. Libraries could be seen as an extension of the printed media, and cinema as an extension of the electronic media, because the same films would often later be shown in television, as well. But the two major streams of mass communication were still very simple and clear-cut categories.

Since then technological change has made the picture much more complicated (see for example GODDARD, 2008; QUINT, 2001). We now have also the cable television, the satellite television, the VHS and DVD home videos, the personal computers and the internet. We have mobile phones that can be linked to the internet and used to watching videos or the television. At the same time the software and hardware required for recording music or making movies and videos or special effects for them is no longer a secluded monopoly of a few major film studios. Both the hardware and software required for such activities have become or are becoming affordable to most western consumers.

Television is clearly starting to lose its formerly dominant status. In the USA, 23 per cent of the viewers were watching television shows online in March 2007, but in October 2007 the figure had already grown to 38 per cent. Similarly, while 64 per cent of the US video viewers were using television and VHS/DVD to watch videos in October 2007, 37 per cent were using a computer, 20 per cent were using a cellphone and 10 per cent ipod (DELOTTE, 2007).

Moreover, there is a growing amount of different combinations of these technologies. A steadily growing proportion of the newspapers and magazines are also available through the internet. Movies or TV programmes can be down-loaded directly through video-on-demand-services, and there are thousands of online TV channels which can be viewed by a personal computer. Crocery shops are selling an increasing amount of very cheap DVD videos with the same philosophy as cheap paper-back books. The small television screens on long-distance flights, busses and trains are becoming an important mass media. Electric books – or, to be more precise, improved electronical reading devices – are starting to compete with the traditional printed books, at least partly because of the lack of space for more books in small and crowded urban homes.

TV channels have developed different interactive programme formats which fuse the old media (television broadcasts) together with some of the new media, like mobile phones and internet (NÄRÄNEN, 1999).

The way the cellphone networks are now experimenting with mobile television may change many things, on a longer run. In February 2008 a consortium of operators initiated a new trial on mobile television in London. Through it the customers of the operators could watch 24 television channels through their mobile phones. Phone manufacturers have reached an agreement about an international digital video standard for handsets (DVB-H). Thanks to the arrangement the same transmitters that broadcast terrestrial digital television can also broadcast the same programmes to an unlimited number of mobile phones, so that the mobile television programmes do not have to be sent through the mobile phone networks, which might lead to an overload in the system (GRAHAM-ROVE, 2008). Several companies, including Microvision, based on Richmond, Washington, are also working with handset manufacturers to develop phones capable of projecting movies or images on to a wall by a built-in laser projector.

An even more important change is the way millions of people have suddenly become publishers or TV- and movie producers. The change has been so rapid and dramatic that many communication researchers have not yet realized what has actually happened. In March 2007 already 34 per cent of consumers were creating content for others to see or to listen, like blogs, websites, or videos and music put on YouTube or on other systems through which such material can be shared, in theory, with all the other users of the internet. In October the percentage had risen to 45 per cent. In March 2007 52 per cent of the consumers were viewing citizen media content, in October 2007 the figure was 69 per cent. Roughly one third of all media consumers already see themselves as publishers or broadcasters (DELOTTE, 2007). 57 per cent of US teen-agers were “producing content” for the internet (KLUTH, 2006).

Probably the most important single citizen’s media are the blogs, the personal online journals. The system was initiated in 2003, and started to grow in an almost exponential way. In early 2006 there were already 10 million individual blogs, in March 2008 there are about 113 million and the number of new blogs emerging daily was then roughly 120,000 (GILLMOR, 2008). The quality and reliability of all these productions, of course, varies a lot.

At the same time internet has also democratized the access to information, at least to an extent. Almost every scientific journal now deposits at least the summaries of all its articles in the internet so that they are freely available to everybody. The main problem is that in most cases you have to pay a lot to gain access to the actual article, and the mere summaries are not often very useful. However, a growing number of scientists who have been concerned about this problem have adopted a policy of making their whole articles freely available through the internet. Many universities and other public institutions have adopted similar policies. This means that the internet already now contains an unprecedented amount of relevant information that is freely available to everybody, and which covers almost every imaginable subject. You only have to know the precise key terms and concepts to find the relevant scientific articles among the mass of other material.

These trends offer genuine possibilities for citizen’s journalism and for the democratization and diversification of the various human societies. (GLASSER and CRAFT, 1997; ANDERSON, 2006). On the other hand, they also bring with them a number of new problems. The behavioural codes in the internet are less developed than in the other fields of human communication, either inter-personal or mass communication. In the internet “anything goes”, and people often feel free to write extremely hostile and injurious language (SIEGEL, 2007).

Also, all the key technologies related to the new media are in practise controlled by a small number of large and influential transnational companies. A small group of corporations produces most of the world’s mobile phones, with the Finnish giant Nokia alone having a 40 per cent share of the world market. A single company, Intel, has almost a monopoly in the field of micro-processors used in personal computers and servers. Another company, Microsoft, is single-handedly dominating the software markets and a handful of companies, like Yahoo and Google, control the routes through which the majority of the people access the internet. Even though the new media have become a genuinely decentralizing and democratizing influence on people's possibilities to publish content which could theoretically be read or watched by a billion other people, the ownership of the key technologies has simultaneously become more concentrated than before.

Another problem is that computers and internet connections have still been far too expensive for the majority of the world's people. This, however, might change much sooner than anybody might have predicted, a decade ago. The cheapest available computers in Finland now cost only a little bit more than euro 200, and they are powerful machines with a lot of data storage and computing capacity, in-built wireless internet connections etc. It would now be easy to mass-produce somewhat less complicated computers with a very affordable price, indeed. Numerous different initiatives and individual companies are already speaking about manufacturing computers which would only cost less than USD 100, but in fact it would even now be theoretically possible to drop the prices even far below this level, if the mass-production would, for example, be done by a non-profit corporation aiming at democratizing the access to information.

Contrary to earlier expectations, communication systems based on radio waves are now spreading faster than the systems based on fast cable networks or satellites (see for instance CLARKE, 1978). The manufacturers of mobile phone networks have been able to stretch the technology much farther than anyone could have believed. At the moment there are almost four thousand million mobile phones in the world, and it seems that the wireless technology will also reach the two billion people living outside the central electricity grids faster than either the electric grid or the fast telephone lines or cable or satellite networks.

How does the emergence of the modern solar economy affect these trends? Does it have any significance, from this viewpoint?

The most important aspect might be that the construction of the mobile phone networks and the constitution of a modern solar economy are most probably going to proceed hand in hand. It is likely, that both processes will actually assist and speed up each other.

The mobile phone network operators now desperately want to reach the two billion people living outside the national power grids already before the grid reaches them. The expansion of the grid to remote, sparsely inhabited and poor regions is often very slow. This means that the network operators have to build between 100,000 and 1,000,000 mobile phone link stations to areas which are presently outside the national power grids, even if they would aim at building a very sparsely dotted network. In Britain, with a denser network, it was estimated that the 3G network would require at least 100,000 new antenna masts (FOX, 2001).

In a sparse cellphone network the link stations require a relatively large amounts of electric power, typically something between 10 kilowatts and 100 kilowatts per station. This can be produced by an aggregate run by diesel oil, but the power produced by such a system is very expensive and will become even more expensive with every new raise in the oil prices.

The cheapest, but still rather expensive, alternative has often been, already now, to use a combination of different renewable energy sources, wind and solar, and a battery producing the power during the nights when there is no wind (see EWING, 2008).

When the thin-film and concentrator photovoltaic systems reach the level of mass production, their prices will be much reduced, which would greatly benefit also the companies that are constructing the mobile phone networks. On the other hand, if the mobile phone networks are constructed so that they will use the new solar power technologies whose prices are declining rapidly, the construction of the mobile phone networks might in turn accelerate the solar revolution. Because the mobile phone networks anyway need to buy a lot of solar panels, they could make very large orders for the manufacturers of the most promising cpv technologies. This might reduce the time before the manufacturers of the key technologies reach the gigawatt-level in their production, and the time before the prices collapse far beyond the prices of other, non-renewable sources of energy.

People will of course have to recharge their mobile phones. If there are no other sources of power available, besides the power produced for the mobile phone link stations, the natural solution would be to install a few more photovoltaic panels and produce a little bit more extra power so that the people could come to the link stations to recharge their cell phones. This would not require a very large effort, because the valuable photovoltaic panels must, anyway, be guarded by someone.

However, people living outside the grid have, already now, also other devices which need to be recharged like battery radios, karaoke devices, solar lanterns and torches. They would, most probably, also like to recharge them at the same stations. In the future electric cars, motorbikes and bikes equipped with tiny electric motors will become more common, and they will also have to be charged, somewhere. So the mobile phone link stations might actually, little by little, grow to a kind of electric service stations in which all kinds of batteries could be recharged, from mobile phones to electric cars. It would also be natural to equip the stations with restaurants, cafes and small shops.

This would most probably speed up the spreading of radio receivers and small televisions in the rural areas which are not yet covered by the national power grids.

From the viewpoint of renewable energy such a scenario, mobile phone link stations becoming a kind of electric service stations, would be highly desirable, because it would mean that the electric grids on the remote areas would not be created only by expanding the present national grids based on fossil fuels and nuclear power plants.

Actually, rural power grids could grow in a decentralized way from a hundred thousand or from a million small, solar and wind powered power stations which would at first only power mobile phone link stations and provide some minor recharging services for the people, but which could later become the nodes for whole, local, “island” power grids. Such renewable energy power grids could finally grow together. After that they would be likely to eat away the power sources of the now existing national grids, because their operations would be based on systems that can already in the relatively near future produce massive amounts of electric power with a much lower unit price than nuclear power, oil, natural gas or coal.

Individual households could, and should, also have their own concentrator photovoltaic systems. The most simple such system would be an ordinary parabolic solar cooker, which would be equipped with a small power-producing element, either a small concentrator photovoltaic cell or a modern thermoelectric cell. Such a household-based system would be able to produce small amounts of electricity with a very affordable price, because the reflector would already be there and only a small power-producing element should be added, or installed into the focal point whenever there is a need for some electricity. When there would be no need for power, the same reflector could be used to cooking or preprocessing the food, for sterilizing the drinking water (with concentrated ultraviolet radiation) or for heating water for washing or house-warming purposes.

A parabolic reflector which can focus solar radiation can, of course, also focus radio waves. Thus the same device could also be used to focus and amplify radio, television or mobile phone signals, assuming that the user would know, exactly, in which direction the nearest television or radio transmitter or mobile phone link station is. It would be easy to mark the direction of the transmitting or link stations with two sticks of varying lengths (the line between the tops of the sticks pointing towards the station), so that the reflectors could be accurately pointed towards the right direction even during the night.

Besides these obvious possibilities, there is a somewhat more futuristic non-concentrating solar power concept that might be of interest in this context. If this concept, the solar chimney or the solar windmill, will be adopted, this will result in the construction of extremely tall structures that could also act as vast communication towers. The perspectives related to solar chimneys are discussed in more detail in the third chapter of this thesis.

However, there is one more issue that should be investigated in this chapter. As mentioned before, the search robot giant Google has invested heavily in renewable energy technologies. Besides this, Google has made large investments in two electric car companies: the Norwegian ThinkIt (originally a project of Ford) and the US Tesla Motors. Google has also initiated a number of projects which have to do with recharging the electric cars with renewable energy. It is also collecting new ideas about electric cars and renewable recharging through its Recharge It-webpage, and it promises to arrange funding for the promising ideas. Tesla Motors plans to offer optional solar-photoelectric systems for its clients with a price of a few thousand dollars, only. According to the plan Tesla's clients would be provided by solar "carports", in which the car batteries could be recharged with solar energy. This would make it possible to drive the maximum of 80 kilometres per day with the solar electricity provided by such a home recharging station.

Has Google made these moves because of the generous idealism of Google's main owners, or are they about something else?

The reality is seldom simple nor black-and-white, and the motives of Google's leaders are probably a combination of genuine idealism and hard business logic. However, Google's moves are probably at least partly related to the fact that even in the West, not to say anything about the South, the consuming power of the households is always limited.

The car manufacturers and oil companies are most interested in hybrid cars or fuel cell powered hydrogen cars, because they would be more expensive than the present diesel or internal combustion engine cars. Moreover, the fuel costs of a hybrid are a little bit less than with a diesel car, but not very much, and the fuel costs of a fuel cell car would be much higher than with the present cars. Electric cars, on the other hand, would be an economic disaster both for the oil companies and for the car manufacturers that have, at present, a dominant status at the world markets (see for instance CARSON and VAITHEESWARAN, 2008). Electric cars are so simple and have so few moving parts, that mass-produced electric cars would be very cheap, and they would last much longer than a gasoline or diesel car. Above all, their fuel costs would be 5 to 10 times less. Therefore most of the oil and car companies have done their best to keep the electric cars out of our roads.

This is a pity because from the environmental viewpoint the electric cars would be the best choice: they do not produce any nitrogen oxides (part of which can be converted to tropospheric ozone when exposed to direct and intensive sunlight), nitrous oxides or soot, and if their batteries are recharged with renewable energy they do not produce carbon dioxide, either (except the emissions caused by the original manufacturing process of the cars). Besides, as I have mentioned above, a shift to electric cars would also provide a partial solution to the back-up problems of solar and wind power.

One possibility would also be to design small and slow light-weight vehicles that would mostly be powered by flexible thin-film solar cells on their roofs. It is normally assumed, that this is not an option, and that solar cells could only provide power for an electric car’s air conditioning system. However, such thinking is based on the notion that an electric car should be able to cover a distance of 200 to 400 kilometres with is batteries without a recharge, and that it needs to have a maximum speed of at least 80 or 100 kilometres per hour. If the car can achieve a speed of 100 kilometres per hour, it cannot be very light, because the structures have to withstand, at least to an extent, car crashes happening at such speeds. And if the car weighs hundreds of kilograms or a ton, a relatively heavy battery, weighing hundreds of kilograms, is required to make it possible to drive at least 200 kilometres without a recharge.

But if we start from the other end, from looking how much power the solar cells could provide and what kind of a vehicle could be powered by this amount, the situation and the design parameters change, in a profound way. In the tropics four square metres of solar panels could provide a kilowatt of power during the daytime, roughly one old-fashioned horse-power. Even a horse can carry or draw rather large loads, even though it does not have wheels and even though it has not been made of light-weight glass-fibre composites. If the solar-powered vehicles would be designed so, that their maximum speed does not exceed 20 or 30 kilometres per hour, and so that they would only have a very limited drive-span after the sunset, it would be possible to construct them so that they would only weigh 50 or 100 kilograms, one third or one half of which would probably consist of the weight of the battery. Most medium-sized and large cities in the tropical and subtropical regions are already now very crowded and the traffic seriously congested, and these problems are likely to get worse while the overall number of cars and other motorized vehicles keeps on growing. So if the cars will not, in any case, be able to drive more than five, ten or twenty kilometres per hour, why should the cars meant to be used in urban areas be designed so that they can attain a much higher speed?

As the US energy and technological visionary Amory Lovins has observed, less than one per cent and sometimes only 0.3 per cent of the energy in a car’s fuel is now used to move the driver in a forward direction (CARSON and VAITHEESWARAN, 2008). With a combination of very light materials (like bamboo, magnesium or carbon-fibre), thin-film solar panels, modern electric engines and only a small battery (weighing a couple of tens of kilograms and enabling an hours’ drive without a recharge) it might be possible to improve this equation, and achieve an overall efficiency of 50 per cent or more.

In any case, compared to the old oil and car giants, companies like Google – or the manufacturers of mobile phones and mobile phone networks – have an opposite vested interest. If the consumers will, in the future, spend an even larger part of their money in purchasing fuel cell cars and in purchasing hydrogen for them, they have less to spend in everything else.

On the other hand, if the consumers acquire electric cars that cost less and which have very low fuel costs, they will have more money to spend on mobile and internet services, on buying videos, electric books and electric magazines and newspapers. They also have more to spend on gadgets like mobile phones, computers and navigators. In an electric car the various gadgets installed in the car, like navigators and other kinds of wireless communication systems, could actually amount to a relatively large percentage of the whole retail price of the car, because an electric car is (in mass production) anyway going to be cheaper than an ordinary car, not to say anything about a fuel cell car or a hybrid.

In a hybrid car or a fuel cell car (or in an ordinary diesel or gasoline car) the combined price of navigators and gadgets connecting the car to the internet (etc) cannot be very high. Because of the competition the overall price of the vehicle cannot be raised too much, and therefore there is actually very little freedom of movement left.

For these reasons it is plausible, that the new solar technologies, the other means of producing renewable electricity, the various wireless (radio) communication technologies and the electric cars, motorbikes, busses, lorries, trains and boats will soon become a whole new chain of technologies, or, to be more precise, a complex web of technology chains, that will play a major role in the effort to construct a more sustainable society.

3. A SOLAR CHIMNEY AS A COMMUNICATION TOWER

Solar chimney is a somewhat futuristic solar power plant concept. The first version of the idea has been discovered from the technical drawings of the Italian renaissance genius Leonardo da Vinci, but the modern version has been developed by professor Jörg Schlaich, a German structural engineering expert who has become widely acknowledged as one of the world´s most innovative civil engineers (STEWART, 2001; NOWAK, 2004; HATTERSLEY, 1999).

The concept of the solar chimney is very simple. There is a low, circular glass roof that is open at the periphery. In the middle of the glass roof there is a large vertical chimney with large air inlets at its base. The glass roof acts as a collector of solar heat. The hot air is lighter and rises up in the chimney. This creates an updraught that powers the wind turbines placed inside the chimney. Water-filled tubes under the glass roof store heat during daytime and release it at night. This makes it possible for the plant to operate 24 hours per day without dramatic fluctuations in its power output. It is actually possible to concentrate a solar chimney's power production to night time by keeping the chimney "shut" during the days. This is a benefit because night-time electricity is a valuable commodity in a solar-dominated energy system. Of course, concentrating the power production to nights increases the heat loss during the day and thus reduces, to an extent, the overall amount of power production. Another benefit is that the collector can utilized all kinds of solar radiation, both direct and diffused. Most other solar power concepts can only use direct sunlight, which lessens their energy production potential in regions with frequent cloud cover (SCHLAICH, 1995; SCHLAICH, 2002).

People often find it hard to believe that it would be possible to produce serious amounts of power by creating a strong upward draft of air. However, it should be remembered that even natural conditions can produce vertical winds blowing upwards with a speed of 160 kilometres per hour or more.

The amount of power that can be created by a solar chimney depends on the amount of solar radiation, the size of the collector and the height of the chimney. In a very well irradiated region a 200-megawatt plant would have a chimney that is 1,000 metres high and 170 or 200 metres in diameter, and a heat collector seven kilometres wide (or a four-kilometre-wide collector and a 1,500-metre-high chimney). The wall of the chimney tube would have a thickness of one metre at the bottom, half a metre at 250 metres and 25 centimetres at 600 metres (SCHLAICH, 1995).

This far only one larger pilot plant has been built. It was constructed in Manzanares, Spain. The plant, the world's first solar chimney, had a 195-metre chimney and a collector with a diameter of 240 metres, and produced 50 kilowatts of power. The collector of the Manzanares pilot plant warmed the air by about 17 degrees Celsius, and generated an updraught of 12 metres per second.

A collector seven kilometres across and a chimney three kilometres high could theoretically produce 600 megawatts of power, but it would be very expensive to construct something that has a height of 3,000 metres. However, Schlaich says that 1,000 metres should not be a major problem. The tallest existing man-made building, the CN Tower in Toronto, is 553 metres high, and the Japanese are seriously considering the construction of some 2,000-metre-high skyscrapers (HARVIE, 2004).

The economic feasibility of solar chimneys in the production of electricity is a hotly debated issue.

Many experts say, that solar chimneys are still very far away from being able to sell electricity at a profit.

The solar chimney that is being planned to Mildura, Australia, is expected to cost about USD 720 million, and produce 200 megawatts of energy, 650 gigawatt-hours (650 million kilowatt-hours) per year. Typical construction costs of a nuclear power plant would only be about USD 400 million for 200 megawatts of power generating capacity. With solar chimneys the fuel is free and the process does not generate any dangerous, radioactive waste matter. However, according to many experts, electricity from a solar chimney would definitely be a little bit more expensive than the electricity from a nuclear power plant (TAGGART, 2001).

However, the issue is not a very clear-cut one.

According to calculations made by the large German power utility company Energie in Baden-Wurttemberg a solar chimney commissioned in 2001 would have produced electricity with a 20 per cent higher price than a coal-powered plant if the original investment costs would have a total interest rate of 11 per cent. But if the interest rate would be 8 per cent, the electricity produced by the solar chimney would be cheaper than coal plant electricity. These figures are based on the present standard business managerial calculations, using the normal 20-year costing period (SCHLAICH, 1995).

In these calculations the construction period of the solar chimney would be four years, during which the investment costs increase by 30 per cent because of the high interest rate. If it is possible to speed up the construction process, investment costs can be reduced.

Above all: both the chimney and the greenhouse should have a much longer life span than the ordinary coal or gas or nuclear powered plants. Therefore, it would make sense to cost the project over a longer period of time. This changes the end result of the calculations in a dramatic way.

According to the calculations made by Energie in Baden-Wurttemberg the power produced by a 100-megawatt solar chimney cost Euro 0.09 per kilowatt-hour with a 20 year depreciation period. However, with a 40 year depreciation period the cost was only Euro 0.045 per kilowatt-hour and with a 80 year depreciation period only Euro 0.03 per kilowatt-hour. In other words, if you calculate the costs in a way that also takes into account the much longer life-span of the plant, you will get a very different result than if you want to recover all your costs in 20 years (SCHLAICH, 1995).

Also, Southern contractors would probably be able to build the solar chimneys with a much lower cost than the Australian or German companies. For instance Indian contractors offered to build a solar chimney and the related greenhouse with 56 per cent of the expenditure that the project would have cost in Germany. The cost level in Australia should be closer to that in Germany than to that in India.

According to Wolf-Walter Stinnes, who has been investigating future power choices for the Northern Cape government in South Africa, electricity produced by a solar chimney will become very profitable if the cost calculations are extended over a period of 80 years. Because two and a half coal-powered plants should be constructed during an 80-year period, this kind of formula produces a very different result than the standard calculation.

According to Stinnes´ calculations, it would cost about Rand 2,500 million (slightly more than Euro 300 million) to construct a 200- megawatt solar chimney in South Africa (HATTERSLEY, 1999).

Because solar chimney is an extremely simple power plant with a minimal number of moving parts and hi-tech, it should be a very reliable producer of electricity. It can be built of ordinary reinforced concrete and glass, which are locally available practically everywhere. The only hi-tech parts are the large wind turbines, and even they could easily be manufactured locally in most Third World countries.

What comes to the actual chimney, the actual bulk price of the concrete is not a major factor in the economic calculations, because concrete is a very cheap construction material. It might even be possible to use geopolymer cements in the construction of solar chimneys. This could be an interesting option, because geopolymer cements should be both stronger and cheaper than the conventional Portland cement, and they should only cause 10 or 20 per cent of the carbon dioxide emissions produced by the manufacturing of the Portland cement (NOWAK, 2008). The greatest expenditure is raising the concrete into the required heights, because this requires complex arrangements which cost a lot of money (HATTERSLEY, 1999). It might perhaps be possible to reduce these costs by designing airships that could act as "floating cranes" or air-cranes. This would probably be a much cheaper way of raising large quantities of material to great heights than the construction of conventional ramps. However, to my knowledge nobody has this far produced economic calculations related to this possibility.

The calculations related to a solar chimney's power output are based on already existing and easily available models of horizontal axis turbines arranged concentrically at the periphery of the tower. Schlaich says that vertical axis turbines in groups of six would be a better solution. At the moment nobody is producing suitable vertical axis windmills and turbines, so this option has not been used in the calculations. If large enough vertical axis windmills become available, the power output of the solar chimneys can be increased further.

This far nobody has yet built a full-scale solar chimney, although it now seems possible that the Australian company Environmission will actually build one. India was seriously considering a solar chimney project in the late 90’s in the Thar Desert, in the State of Rajasthan, but the growing tension between Pakistan and India led to the cancellation of the project. The government of Northern Cape in South Africa has also been seriously interested, as well as the governments of Egypt and Morocco. This far everybody has been deterred by the relatively high initial outlay of capital required by a project that might also involve some serious political credibility issues. Introducing major new concepts has never been easy, and the manufacturers of the coal, gas and nuclear-powered plants have traditionally formed very, very strong lobbies fiercely resisting the adoption of all new energy technologies.

However, both the greenhouse of a solar chimney and the actual chimney can be used to other purposes, as well, besides generating electric power. If the solar chimneys would be developed as the basis of a more complex set of different commercial enterprises, the financial returns from the investments could become very high, with a different order of magnitude than investments in any other currently existing energy production technology.

The roof of the greenhouse could also be used to rainwater harvesting with marginal additional costs. With 400 millimetres of annual rainfall, the 50 million square metres of a full-sized solar chimney could harvest 20 million cubic metres of rainwater per day. In dry countries, which often have to use desalinating plants, this is an interesting aspect. Desalinating one cubic metre of sea water with the most cost-effective presently existing method (reverse osmosis) costs about USD 1.

Moreover, it should be remembered that a large nuclear power plant or coal power plant annually consumes 20-30 million cubic cubic metres of freshwater.

Many of the tallest buildings in the world – including the tallest, the CN Tower in Toronto - have been built primarily to act as communication towers. Their primary purpose has been to broadcast TV and radio programmes in the form of narrow, focused beams to faraway link stations, which will then broadcast the programmes further into the nearby areas. The strategy minimizes the costs and power requirements of relaying the radio and television programmes over very large land areas. It is interesting to note, that it has been commercially feasible and reasonable to construct even 553-metre-high and very expensive buildings (much more expensive than a solar chimney) for this purpose, alone.

The main issue is very simple. When the distance increases 10-fold, the radio signal becomes one hundred times weaker and one hundred times more difficult to detect. However, it is easy to focus short radio waves by parabolic reflectors to very narrow beams that can have a very high apparent strength in the direction towards which they are sent. Thus it makes more sense to send focused beams to a large number of link stations instead of sending the broadcasts to all possible directions at once from a central communication tower.

When the transmissions are relayed further as focused beams, they can bridge very long distances without any problems. Therefore it makes sense to construct high communication towers and to install high antennas on top of tall buildings constructed for other purposes. The higher the building, the farther away its focused beams can reach in a direct line.

Because there are no relay stations on the oceans, the data must be sent over them either with the assistance of satellites or via communication cables laid at the bottom of the sea.

The demand for high communication towers has recently increased further due to the needs of the mobile phone networks and fixed wireless systems. The situation is further complicated by the fact that there are, in many countries, many different mobile network operators fiercely competing with each other. Each of these operators needs its own network of link stations and high transmission towers.

Solar chimneys would be the highest man-made structures in the world. It is not economically sensible to construct chimneys that are lower than one thousand metres, and it may be that some of them would be even higher than this, perhaps even 1,500 or 2,000 metres. This means that the solar chimneys, or at least many of them, might also have a role as communication towers. In many arid and sparsely populated countries they might even become the key element in developing improved communication systems. There are no calculations about this, but the use of solar chimneys as very high communication towers might provide considerable savings in the construction of TV, radio and mobile phone networks. This could be a major benefit, because modern communication networks tend to be notoriously expensive.

The large corporations have started to favour, in their internal communication, the relatively new fixed wireless technology. In a fixed wireless system huge masses of information – voice, data and video signals – are sent in the form of focused, precisely targeted transmissions from a building's parabolic antenna to another parabolic antenna on the roof of another building. The received material is then forwarded to internet, to the building's internal communication network or to voice networks. The system is attractive because the old-fashioned wires cannot transmit large floods of data and because the more effective fibre-optic cables are very expensive (FOX, 2001b). However, the technology can only be used when there is a direct and free line-of-sight for the transmissions.

Solar chimneys could be used as relay stations between a large number of local “communication islands” (villages, small towns, company headquarters etc) with their own cable or wireless communication networks.

In many countries this might be the cheapest and easiest way to provide remote rural villages with an access to telephone networks, internet, radio and television: instead of very expensive fibre-optic cables linking each village into a national network each village might have its own, local island network which would be linked to the national system via a fixed wireless link in a solar chimney.

Solar chimneys built inside or relatively near to large cities would, of course, be the most valuable for communication towers serving fixed wireless links.

Because a solar chimney would be at least 1,000 metres high and about 200 metres in diameter, there would, in theory, be space for a very large number of different fixed wireless links in each tower. The uppermost one hundred meters, alone, would have a combined surface area of 50,000 square metres. Each of these links could be pointed, accurately, towards another fixed parabolic antenna, for example the central antenna of a village.

Somewhat similar services can, of course, be provided by the communication satellites. However, the satellites are relatively expensive and their vulnerability to terrorist attacks is a growing concern. Even a very small 10-kiloton nuclear detonation in the height of 125 to 300 kilometres would permanently disable all the low-Earth-orbit satellites which have not been specially protected to withstand the radiation caused by such an event. At least 90 per cent of the currently existing 250 low-Earth-orbit satellites have not been protected like this (DUPONT, 2004). Another way to damage or disable the communication satellites might be to detonate a very simple microwave bomb (flux compressor) inside a parabolic reflector that would concentrate the electromagnetic pulse into a focused beam.

It is possible to harden the satellites against the radiation from nuclear blasts, but the extra costs would amount to 20 to 50 per cent of the present price of a communication satellite.

Also, the functional bandwidth of the components able to withstand the radiation would be only 10 per cent of that of the currently used processors. The combination of these two factors greatly reduces the chances that the communication satellites would ever be protected against hypothetical nuclear or E-bomb strikes: from a business viewpoint a remote danger is always better than a certain bankruptcy.

Even land-based communication systems can, of course, be seriously damaged by weapons that produce strong electromagnetic pulses. However, destroying whole land-based communications systems requires a much larger and much more complicated effort. Because the whole global satellite-based communication system can be completely wrecked by one relatively simple strike (for example North Korea might do something like this to revenge a military attack by the USA) it might be a good idea to reduce, and not increase, our dependency on low-Earth-orbit satellites.

It has also been suggested that an aeroplane or an airship anchored on a certain place with long cables could act as an atmospheric, "low-flying", satellite, replacing much more expensive orbital or geosynchronic satellites (IANNOTTA, 2000; LEHTO, 2006).

It should perhaps be investigated, whether it would be a good idea to anchor such atmospheric satellites on top of a large solar chimney. In a solar chimney all the warm air from a very large area would be drawn into the greenhouse and channelled into the chimney. This should create an abnormally high and narrow convective cell into the atmosphere, a kind of a bump in the air. Thus it might be that it would be easier for an airship to reach a very high altitude if it would be anchored straight above a solar chimney.

It might be possible to calculate with a computer, whether this assumption is likely to hold water. If the computer models would show that it might be a real possibility, the idea might merit an experiment with an airship. The main drawback, here, is that not a single full-scale solar windmill has ever been built.

4. A BRIEF HISTORY OF RADIOASTRONOMY AND *SETI*

The emerging solar revolution might also benefit radio astronomy and its different fields, including a controversial area known as SETI, or Search for Extraterrestrial Intelligence.

Modern radio astronomy was born in 1930, when Karl Jansky, working for the Bell phone laboratory in the USA, accidentally discovered strong radio impulses which were coming from the center of our galaxy. Jansky was investigating the disturbance caused by distant storm centers on long-distance radio signals with the help of a large radio antenna, using the wavelength of 14.6 metres. He first thought that the disturbance was coming from the Sun, but the source was not moving together with it (LEHTO, 2006).

The US radio engineer Grote Reber became interested in Jansky's observation. Reber deciced to construct a ten-metre-wide parabolic antenna to his backyard in order to focus the incoming radio waves, and started to investigate the sky with the radio wavelengths. During the 1940's several universities started to construct parabolic radio telescopes and in a few decades radio astronomy became one of the most important areas of astronomy. Since then many important discoveries have been made by the radio telescopes, including neutron stars and pulsars, quasars and the first objects which almost certainly were black holes, strange entities predicted by the general theory of relativity.

Radio telescope can collect the more energy and observe the weaker signals the larger surface it has. When the diameter of a parabolic reflector increases ten-fold, the amount of energy it collects increases 100-fold and it can detect weaker signals.

The resolution of a radio telescope, its ability to discern smaller details, can be increased by erecting two radio telescopes or a larger group of them as far from each other as possible, and linking them to each other so that the information they collect can be combined into a single image with the help of a computer. The method is called aperture synthesis or radio interferometry. Aperture synthesis is particularly important in radio astronomy, because radio waves are very long, roughly 100,000 times longer than the waves of visible light. Therefore a very large area is needed for seeing any details. The method was originally developed by Sir Martin Ryle in the University of Cambridge. Ryle received the 1974 Nobel price for physics for his invention (MATTILA et al, 1983).

However, the amount of energy collected is still directly comparable to the combined area of the radio telescopes linked together. Therefore the radio astronomers would like to have as large telescopes or telescope fields as possible. At the moment the largest radio telescope in the world is still the Arecibo at the Puerto Rico, with a diameter of 305 metres, but the astronomers are dreaming of a "square kilometre array", an antenna field consisting of a large number of separate radio telescopes linked to each other, and with a combined surface area of a square kilometre, or one million square metres.

Since 1960, the search for possibly existing extraterrestrial civilizations – other technological civilizations using radio waves in their communication but living on the planets of other solar systems – has become one of the most well-known sectors of radio astronomy. Many radio astronomers still consider SETI as only a curiosity, but the concept has captured the imagination of the public and is probably better known among the general population than any of the other current investigations in radio astronomy.

Human beings have, for a long time, believed in the existence of extraterrestrial civilizations, intelligent beings living on other planets of our own solar system, or on the planets orbiting faraway stars. In the South Asian culture such a notion has always been an integral part of the religious and philosophical belief systems (TERESI, 2003). In the West the notion seems to appear a little bit later, during the fourth century before Christ (DRAKE and SOBEL, 1993).

We now know that there are no intelligent beings on the other planets of our solar system. However, there are hundreds of billions of galaxies in our Universe, and each galaxy contains, on average, a few hundred billion stars. So there might be something like a hundred thousand million million million stars in the Universe (DRAKE AND SOBEL, 1993).

Frank Drake, the "father of SETI" developed, in 1961, a formula which is now widely known as the Drake equation. Drake's formula is a simple way to express all the known factors which should influence the number of extraterrestrial civilizations in a mathematical form. Drake himself commented, that the formula is a good way of "organizing our ignorance" (DRAKE and SOBEL, 1993).

The Drake equation reads as:

N = R x Fs x Fp x Ne x Fl x Fi x Fc x L

N is the approximate amount of technological civilizations, in the galaxy (or in the Universe), which are currently broadcasting detectable radio or optical signals.

R refers to the rate of star formation in the galaxy (or in the Universe).

Fs means the percentage of stars which are suitable for the development of planetary systems.

Fp means the fraction of the suitable stars which actually are surrounded by planetary systems.

Ne is the number of possible Earth-like worlds surrounding the stars which have some kind of planetary systems.

Fl is is the fraction of those Earth-like worlds where life could possibly develop.

Fi is the percentage of those life-bearing worlds where life, at some point, could evolve to produce intelligent species.

Fc is the fraction of those worlds where intelligent species may have evolved and developed complex technological civilizations capable of interstellar communication.

L is the average lifetime of communicating technological civilizations.

There are a number of other factors which might also influence the number of technological civilizations practising interstellar communication. Such factors may or may not be included in the equation. We might, for example, want to add a separate factor for the percentage of technological civilizations which exist and which are technically capable of interstellar communication but which have chosen not to become involved with such activities.

We have a pretty good idea of the rate of star formation in our own Galaxy: there are 10 or 20 new stars born in the Milky Way, annually (McCONNELL, 2001). Thus we can give a relatively precise value for the factor R. R = 10-20 stars/year. But what comes to the next four factors, Fs, Fp, Ne and Fl, uncertainties already become much more profound.

For example the famous US astronomer Otto Struve thought that most stars are surrounded by planetary systems (DRAKE and SOBEL, 1993), but there really wasn’t any way of being certain of this. The search for exoplanets, planets orbiting stars other than our own Sun, has become technically possible only recently.

In the beginning of 2008 astronomers had discovered almost 300 planets orbiting nearby or relatively nearby stars. Most of them were Jupiter-like gas giants and only a dozen or so were Neptune-like ice worlds or rocky planets like the Earth. Even these observation already proved that planetary systems are not uncommon, but it was likely that the astronomers had only seen a small percentage of the planets which were orbiting around the observed stars. Also, the large gas giants are obviously easier to find than the much smaller rocky planets. However, in May 2008 the researchers of the High Accuracy Radial Velocity Planet Searcher (HARPS) survey, based in the European Southern Observatory in La Silla, Chile, announced the discovery of 45 new exoplanets, all of which were at least ten times smaller than Jupiter. The new HARPS data suggests that small planets are very abundant and that they are perhaps three times more common in our own galaxy than Jupiter-sized gas giants (SEMENIUK, 2008). It might – relatively soon – be possible to compile the first really serious estimates about the number of different kinds of planetary systems in our Galaxy.

The number of planetary systems where life could possibly develop, is a very complex and hotly debated issue.

According to computer simulations, sunlike stars should typically be surrounded by relatively narrow habitable zones. The planets circling a star on such a zone would not be too hot nor too cold for life. The planetary scientist Carl Sagan estimated, that there could be something like one billion habitable solar systems in our Galaxy, one for eighty sunlike stars, allthough this was, in reality, only a guess which was not based on any real data.

Sagan thought that planetary systems surrounding very large stars or very small stars, so called red dwarfs, cannot give birth to life. The main problem with the red dwarfs seemed to be, that their planets should be very close to the mother star in order to receive enough warmth to keep the average temperatures above the freezing point of water. Such planets would become tidally locked, the same side of the planet would always face the star. On the other side of the planet the temperatures would be permanently below the freezing point, and on the other side permanently above the boiling point of water. Sagan also excluded stars which belonged to binary systems, because they have very unstable orbits, and stars that belong to very old star populations, because their planets do not have heavier elements but consist of hydrogen and helium (SAGAN, 1973a; ASIMOV, 1979).

Serge Tabachnik and Kristen Menou of Princeton University, New Jersey, created computer simulations about the 85 solar systems around sunlike stars that were known in August 2002. According to their analysis up to 40 per cent of all sunlike stars might have terrestrial planets orbiting inside the potentially habitable zone of the solar system. Other scientists have proposed that large planets like Jupiter might often have their own habitable zones containing several habitable large moons.

In the beginning of 1990´s Manoj Joshi and Robert Haberle of NASA's Ames Research Center claimed that even the planets around red dwarfs might harbour life. They calculated that the planets only need a little bit of atmosphere and some oceans to circulate enough heat from the daylight to the dark side (JOSHI et al, 1997; HEATH et al, 1999). The notion caused some controversy among the astronomers, but in 2007 it started to look that Joshi and Haberle had been right. The astronomers found a relatively small planet orbiting around the red dwarf star Gliese 581, which is only 20.5 light years from Earth. The planet was at least five times more massive as our own home planet, but its average surface temperature seems to be somewhere between minus 3 and plus 40 Celsius (TÄHTINEN, 2008).

Red dwarfs are much more numerous than sunlike stars. There are at least 200 billion (and possibly 2,000 billion) such stars in our galaxy, alone, and many of them will have a life-span of more than one million million years. Thus the number of life-bearing planets could actually be much larger than what has previously been thought.

Other scientists have presented much bleaker views, some have even said that we may be alone in the Galaxy (WEBB, 2006). The truth is that we do not know, yet. We can only say that in our own solar system complex life has developed on one planet and that there may have been primitive life on another planet (Mars). For example the famous Antarctic meteorite ALH 84001 contains anomalies which might or might not be traces of ancient biological life (McKAY et al, 1996).

Space probes sent by NASA ("Terrestrial Planet Finder") and ESA ("Darwin") might soon be mapping hundreds of thousands of different solar systems, looking for biosignatures, signs of living biospheres, from planetary atmospheres. If these projects will be realized, we might soon know much more about the frequency at least single-cellular life tends to arise in our Galaxy.

What comes to the probability of the development of intelligent life, we can only say for sure that on the one planet which has given birth to a complex ecosystem and which is known to us, life has tended to develop towards more intelligent forms equipped with larger brains. Besides humans, there have been a number of other land animals, related to us, with only slightly less complex brains and at least one species with an even larger brain, the Neanderthal Man. Also, in our seas there are dozens of cetacean species with very large and complex brains. The sperm whale has, by far, the largest brain on the planet, weighing up to seven kilograms, and for instance pilot whales, beluga whales, orcas (killer whales) and many species of dolphins have huge and enormously complex brains compared with the size of their bodies. Even chimpanzees, gorillas and elephants are intelligent enough to recognize their own image from a mirror.

What we know seems to support the idea that life tends to develop towards intelligent forms. And if it turns out that there has really been primitive life on Mars, the outlook for life in the Universe starts to look very promising, indeed. If life would have developed on two separate planets in the same solar system, it would start to seem likely that it would also have developed in numerous other solar systems.

During the 1800's scientists proposed a number of ways to communicate with intelligent beings living on the other planets of our own solar system. These early proposals usually dealt with conveying messages to Mars, which was then thought to be a habitable planet and a home of an ancient civilization.

The German mathematician Karl Gauss wanted, in 1820's, to cut huge patterns, large enough for the extraterrestrials to see, into the vast Siberian forest. The Viennese astronomer Joseph von Littrow planned, in 1840, to dig trenches, twenty kilometres in diameter, in Sahara and fill them with kerosene. When the kerosene would be lit, the flaming patterns created by the trenches would be visible to powerful telescopes pointed to our direction in Mars or Venus. The French physicist Charles Cross proposed, in 1869, a giant array of mirrors that would have reflected sunlight to Mars (DRAKE and SOBEL, 1993).

One of the first and possibly the very first person to propose the use of electric gadgets in communication with extraterrestrial civilizations was the Finnish military officer and mathematician Edward Elgerbert Neovius. He published, in 1875, a small book called The

Most Important Task of our Time. The book proposed the use of 22,500 electric lamps and a large array of simple generators, so called Galvanic pairs, to send messages to Mars (LEHTI, 1993).

All these early communication efforts had been based on optical wavelengths. In 1887 the German scientist Heinrich Hertz discovered that there are also another kinds of electromagnetic waves, which had much longer wavelengths than visible light (DRAKE and SOBEL, 1993). The very long electromagnetic waves discovered by Hertz soon became known as radio waves. It soon turned out, that it was very easy to create radio waves, because they had so long wavelengths that they contained extremely low amounts of energy. Receiving radio waves was also easy. Because radio messages sent with a tiny power output of five watts (!) simultaneously to all directions could be captured with simple amateur antennas on the other side of the world, why could the humans not talk to Mars or even to other solar systems with slightly more powerful transmitters? It would be much easier and cheaper than orchestrating vast displays of visible light.

The first person who tried to use radio waves in interplanetary communication was the Serbian-Croatian electric engineer Nikola Tesla, who single-handedly invented most of the key technologies related to electric power and radio technology. Tesla built, in 1899, a huge coil of wire, 22 metres high, and used it to beam radio signals to the sky. Tesla also used his device for listening, which made him the first person ever to look for artificial radio signals coming from the space. He actually heard strange, regular noises which he interpreted as signals sent by an alien civilization. However, in reality he most probably intercepted natural radio signals caused by lightning strikes. Guglielmo Marconi, one of the inventors and developers of commercialized radio equipment, also thought that he had, in 1922, captured signals sent by extraterrestrial beings. It is likely that he received similar lightning-induced whispers that Tesla heard (DRAKE and SOBEL, 1993; CHENEY, 2001).

The first person who used, in 1960, a modern parabolic radio telescope to search extraterrestrial intelligences from other solar systems was the US astronomer Frank Drake. The scale of Drake’s project Ozma was rather modest: it only covered two nearby stars. However, project Ozma became the starting point for the first really serious efforts in interstellar communication.

In the year 1961 scientists in the USA and Soviet Union initiated an important new round of discussions about our possibilities to find alien civilizations from other solar systems, and about communicating with them. The concept became known with the acronym CETI, meaning Communication with Extraterrestrial Intelligences. But because no traces of alien civilizations had been found, and because all the efforts actually concentrated in searching for alien civilizations – and not for conveying our greetings or messages to them – the first letter of the acronym was soon changed. The present, more modest, form is SETI, Search for Extraterrestrial Intelligences (see for example COCCONI and MORRISON, 1959; KUIPER and MORRIS, 1977; WILSON, 2001; PONNAMPERUNA and CAMERON, 1974; ROOD and TREFIL, 1981; SHKLOVSKY, 1991; SHKLOVSKY and SAGAN, 1966; ASHPOLE, 1989; OJA 1994).

It was now realized, that with large parabolic radio telescopes it might be possible to receive messages coming from incredibly distant sources. Radio signals are very fast, they travel with the speed of 300,000 kilometres per second, more than a billion kilometres per hour, five million times faster than a Formula-1 car. Also, they are not easily stopped by interstellar gas and dust clouds. The short radio waves – the so called microwaves – looked particularly attractive. Microwaves are not blanked out or distorted by background radiation, and different frequencies are easy to separate from each other. In most parts of the sky there is very little microwave radiation and most stars do not produce much of it. Moreover, different molecules emit and absorb their own, specific wave lengths. Therefore large areas of the microwave spectrum are almost empty of background radiation and it would not require a great effort to send a message in a frequency in which it was much, much stronger than the background radiation.

In 1964 the Mariner 4 probe sent pictures from Mars to Earth, from a distance of 220 million kilometres, even though it had only 10.5 watts of power, only part of which could be used in the transmission, and only a tiny antenna (WASHBURN, 1977). With larger parabolic radio antennas the signals can be focused much more, so that the same amount of power will carry the signals much farther.

In 2006 the largest radio telescope on Earth was the 305-metre-wide giant at Arecibo, Puerto Rico. Arecibo’s maximum transmission power is about half a megawatt, but its vast parabolic reflector can be used to broadcast a focused radio beam whose power is, in one direction, equivalent to omnidirectional antenna that would be blasting with a power of 20 million megawatts to all directions. When Arecibo is transmitting such a focused beam in its standard radar frequency, its apparent brightness in the region towards which the beam is directed is twenty million times more than that of the Sun, but only on a very narrow band of frequencies (DRAKE and SOBEL, 1993).

A focused beam from Arecibo would, in theory, be detectable by a similar instrument at the other edge of the Milky Way, almost 400,000 light-years from Earth (DRAKE and SOBEL, 1993). This sounds very impressive, indeed, but there is a catch. The receiving, Arecibo-sized instruments can only detect our message if they are listening to exactly the same band of frequencies (and if they are looking directly towards us).

This makes things more complicated, because there is an infinite number of different radio frequencies. According to Frank Drake (DRAKE and SOBEL, 1993) even the part of the radio spectrum where the Universe is the darkest and the most quiet and where the disturbances by the atmosphere and by the Milky Way are almost non-existing, can be divided to about one hundred billion different channels consisting of a frequency band about 100 cycles per second (100 hertz) wide.

If the receivers are not listening to the same channel (frequency band) in which the sender is transmitting, they will not detect the signal. The messages could naturally be sent in a very large number of different frequencies, but this increases the need for transmission power. It is relatively easy to send a very strong focused message in only one, narrow band of frequencies, but if we want to send the same message in a million different channels, we need a million times more power.

Also, a telescope can broadcast to all directions at once, so that the transmission ”covers” the whole celestial space. But the signal will then not be detectable over great distances. On the other hand, if Arecibo’s beam is focused to one direction it becomes from one million to one hundred million times (depending on the wavelength) more powerful in this direction, but it only covers from one millionth to one hundred millionth of the sky at any given time. Thus the chance that a certain extraterrestrial civilization in our Galaxy would detect our beam becomes very small, indeed. Even if it were listening for the right frequency and looking straight at us, it might still have only one chance in a hundred million to discover our beam, because our beam would most probably be directed towards another direction.

Many different frequencies or bands of frequencies have been proposed as strategic frequencies which should receive particular attention in the SETI programmes because concentrating on them might increase our chances of succeeding (see for instance VAKOCH, 1999; PAPAGIANNIS, 1980; KARDASHEV, 1979). A search for messages sent in optical frequencies (visible laser light) has also been proposed (SCHWARTZ and TOWNES, 1961) but such messages would disperse relatively quickly and disappear into the background noise.

The third problem is the temporal factor, the time. Young extraterrestrial civilizations are not likely to be separated from us only by vast distances of space, also the distances in time could be of equivalent magnitude. Our Universe has probably existed for 13.7 billion years. However, the average lifetime of a technological civilization may be very short. In 2006 we have, ourselves, been around for about 100,000 years as a species but only about one hundred years as a proper technological civilization. We have been able to broadcast messages with radio equipment for a little bit more than one hundred years, and we have possessed nuclear technologies for less than seventy years.

During these sixty plus years there have already been a number of situations which might have led, with worse luck, to the complete destruction of our whole civilization. During the cold war the USA and the USSR came, a couple of times, very close to a nuclear war. Even a limited nuclear war would have been much more destructive than anybody then understood. According to Paul Crutzen, who won a Nobel price for explaining how the ozone-depleting stratospheric chemical reactions actually happen, practically the whole ozone layer might have been destroyed if the DuPont chemists had adopted bromide compounds instead of chlorine compounds when they were developing new coolants for fridges (PEARCE, 2007).

Enrico Fermi, the Italian physicist who developed the world’s first nuclear reactor, is also known from a famous question which is widely known as the Fermi’s Paradox. If technological civilizations are so common in the Universe, why haven’t we not met them, yet, or at least seen any signs of their existence? Where is everybody? (COOPER, 2008d).

Since then, many different kinds of solutions to the Fermi’s Paradox have been proposed (see for example HART, 1975; WEBB, 2006).

One of the simplest, most logical and most self-evident answers to Fermi´s Paradox is that young technocultures do not live long but quickly destroy themselves when they start experimenting with nuclear reactors and nuclear bombs, or when their production of greenhouse gases results in a runaway greenhouse effect. Because we have already almost destroyed ourselves, a number of times, in mere sixty years after inventing nuclear power, this does not feel like a far-fetched solution to the dilemma. Perhaps the typical lifespan of a technoculture, counted in years, is in the low hundreds, or even less than this.

Even if we assume, very optimistically, that a technological civilization would have an average life-span of 1,000,000 years, this would still be 13,700 times less than the present age of our Universe. Even though rocky planets and complex life can only have emerged after numerous supernova explosions had created large enough quantities of heavier elements, the figure is still sobering. In practise it means that even if the Galaxy had, during its history, given birth to billions of different civilizations, the number of currently existing technocultures is likely to be much smaller. It seems probable, that even our nearest neighbours might be quite far away.

To improve the odds of finding something, we have to increase our listening power. We need more antennas and we need more computing power so that we can listen to a larger spectrum of frequencies.

Fortunately, computing power has become much cheaper than what it was a few decades ago. Individual households can nowadays have a thousand times more computing power than the whole Apollo programme of manned space flights to Moon did have, in the late 1960’s and early 1970’s.

For example the so called SERENDIP project, whose headquarters are at the University of California’s Berkeley Campus, has already been scanning the skies in 168 million different frequency bands. Another SETI project called BETA (Billion Channel Extraterrestrial Assay) is using the Harvard-Smithsonian 26-metre-wide radio antenna for listening 640 million channels, and its sister institution in Argentina is covering 100 million other frequency bands. Project Phoenix, sponsored by the privately funded SETI Institute, is following one thousand nearby sunlike stars in two billion frequency bands (McCONNELL, 2001, see also the webpages of SETI@home).

The most powerful search, however, is done jointly by four or five million individual personal computers that participate in the University of Berkeley's SETI@home project. David Anderson, Dan Werthimer and a team of other Berkeley scientists developed a way to distribute the task of analysing radio signals collected by Arecibo for numerous personal computers in small parcels, via the internet. SETI@home is actually following ”only” 33.5 million channels, but it is also looking for signals which might have drifted over a larger spectrum of frequencies during their journey. In terms of computing power the search SETI@home is carrying out is equivalent to listening to 436 billion frequency bands without paying attention to the issue of drifting. In other words, with SETI@home the power of the search has increased approximately one hundred million million times since the year 1960. SETI@home has also made SETI a major people's movement (McCONNELL, 2001).

Unfortunately the advances in computing power have not been accompanied by larger and more efficient radio telescopes. In 1971 a NASA research team including Barney Oliver, the vice president for research and development of the Hewlett-Packard corporation, proposed the construction of a very large array of radio telescopes devoted to SETI. Oliver named the project Cyclops after the mythical Greek giant with only one eye in the middle of the forehead. Cyclops would have consisted of one thousand five hundred 90-metre-wide radio telescopes (SETI INSTITUTE, 1971). But the cost of the project was considered so high that the array was never built.

Besides Arecibo, the most powerful radio telescope array in the world, in 2006, was the Very Large Array (VLA), a group of 27 interlinked, 25-metre-wide radio telescopes in New Mexico. VLA uses a method called aperture synthesis or radio interferometry, in which the information collected by a number of separate telescopes is combined into a single image with a help of a powerful computer. The inventor of the method, the English astronomer Martin Ryle, shared the Nobel price for physics in 1974 because of this achievement (VALTONEN, 1983). VLA played a prominent role also in the science fiction movie Contact, in which a scientist played by Jodie Foster discovers an artificial radio signal coming from the outer space.

The SETI League, a non-governmental initiative, has proposed that hundreds of thousands of individual people should be mobilized to participate in the search of extraterrestrial intelligences with small radiotelescopes built by using commercially available satellite receiver systems. SETI League has developed intelligent ways to cut the price of the required equipment. It is possible to get a feedhorn by only USD 50, and a simplified microwave receiver, a microwave ”down-converter”, only costs about USD 200. Second-hand computers and second-hand satellite dishes also cost very little. However, small satellite dishes can only detect very powerful signals (CHOWN, 1997).

Paul Allen, the other one of the two founders of the Microsoft Company, and Nathan Myrhvold, another millionaire, recently donated USD 12 million for the SETI Foundation for establishing a one-hectare-wide array of relatively small radiotelescopes that, together, will form the equivalent of a single large dish. The installation, known as the Paul Allen Telescope Array (ATA), will be the world’s first large radio telescope concentrating in the Search of Extraterrestrial Intelligences, only.

The Allen telescope has an unusual design known as the Gregorian antenna. The main antennas are equipped with a secondary dish which reduce unwanted noise from the ground. The Allen Telescope Array will also do many other things, besides its SETI search. It will classify a quarter of a million extragalactic radio sources as either quasars or starbursting galaxies. It will search for gravitational lenses. It will measure the galactic magnetic field, as well as the magnetic fields in the Local Group of galaxies, to understand how these magnetic fields effect star and galaxy formation. It will map the neutral hydrogen content of the galaxy for three quarters of the sky. It will also study black holes, their aggregation discs and the gamma-ray burst afterglows, and it will investigate star formation and the properties of molecular hydrogen clouds, using new molecular tracers to analyse the distribution of heavy elements in the Galaxy (COOPER, 2008a).

There have been some intriguing candidates for artificial signals from outer space, like the famous ”wow” signal that was detected in 1977. For example the META I and META II searches found sixty potential candidates for signals sent by intelligent extraterrestrials. SETI@home has analysed more than a billion signals, among which there are some very interesting ones. However, even the most promising candidates have been short fragments none of which has been clearly artificial.

Frank Drake has said that it is possible that innumerable artificial signals are falling on our planet all the time, every second, like raindrops, or like electromagnetic rain covering every square centimetre of the whole planet. It may be that among the noise we are hearing in our instruments there are signals from countless millions of other civilizations in our own Galaxy and in the neighbouring galaxies, but our instruments are still too weak to separate these signals from each other (DRAKE and SOBEL, 1993). This is a genuine, and most exciting possibility. However, it is also possible that some of the candidate signals are echoes of our own transmissions, radio signals that have just been reflected back by faraway asteroids containing large amounts of metals.

We simply do not know, and we may never know unless we construct more powerful instruments for our SETI programmes. Luckily, the situation might change, in a most profound way, with the coming of the modern solar economy.

5. THE MODERN SOLAR ECONOMY, RADIOASTRONOMY AND *SETI*

In the first chapter it was argued, that concentrator photovoltaic systems may soon become the dominant form of power generation on Earth, and that at the moment one of the most promising designs is a large, parabolic dish and a much smaller photovoltaic panel placed into its focal area.

What if we had, by the year 2100, something like 50,000 gigawatts of this kind concentrator photovoltaic systems, erected in the world's deserts and drylands?

It is likely that several different types of solar energy systems will be produced and installed. However, as mentioned above, on a long run the cheapest solar electricity might come from relatively large, parabolic, light-weight structures, manufactured from plastics with a thin metal surface and protected by windbreaks.

We do not know how much electricity will, in the future, be produced with larger reflectors and how much with modular solar panels consisting of several smaller Fresnel lenses or parabolic reflectors, and the solar cells attached to them.

However, we could assume here, as a thought experiment, that the world would have for example 500 million 25-metre-wide parabolic reflectors by the year 2100. The combined collector area of all these reflectors would be about 200,000 square kilometres, or 20 million hectares. This would be equivalent to 0.04 per cent of the surface of the planet and 0.12 per cent of its land area.

However, such a surface area would also be equivalent to 20 million Allen Telescope Arrays or Very Large Arrays, or more than two million Arecibos. It would be 30,000 times more than the vast telescope array imagined by Barney Oliver and the other visionaries behind the Cyclops project.

All these solar dishes could, at least in theory, also be used as radio telescopes, individually or together, in different combinations, with only minor modifications and marginal additional investment.

During nights the photovoltaic panels could be shifted into another position, so that the radio signals collected by the reflector will reach a feedhorn placed behind the solar cells. Or, alternatively, the solar dishes could be transformed to radio telescopes when they become too old, dirty and scratched to reflect sunlight efficiently enough. Reflecting radio waves is much less demanding.

If used individually, for example in cooperation with a vastly expanded SETI League, 500 million 25-metre-wide solar dishes could be used to monitor practically every spot on the sky, instead of a limited number of carefully selected targets. A 25-metre-wide antenna is about one hundred times more effective than the much smaller radio telescopes currently used by the SETI League members.

When all the telescopes were used together, they could detect almost unimaginably weak radio signals, two million times weaker than the signals detectable by the giant Arecibo radio telescope.

The same array could probably detect a message sent towards us by an Alien Arecibo with half a megawatt of power from galaxies hundreds of millions of light-years away. Thus we could, theoretically, start searching Alien Arecibos from a billion different galaxies and a 2,000-megawatt focused beam would become detectable from a distance of ten billion light years. Within this distance there are already hundreds of billions of galaxies.

Between these two extremes there is an endless number of different possibilities. In any case, the use of such vast arrays of solar dishes for SETI would increase the power of the search and the chances of success enormously, by six or seven full orders of magnitude, by millions or tens of millions of times.

Such a programme would completely dwarf all the earlier visions and dreams of the SETI activists and researchers. But something like this might actually happen, because all these telescopes and their tracking systems will primarily not be built for astronomical purposes, but for producing electric current to satisfy the growing energy needs of the humanity. Astronomical research has always been a relatively low-budget activity. An instrument that costs USD 100 million is already a very big astronomical project. But what comes to energy, this is peanuts. The world will, in any case, invest a few hundred thousand billion dollars or euros in the energy sector during the next one hundred years.

But… how about the 22nd century? And the following centuries? The price of solar dishes and other concentrator photovoltaic equipment should fall down the more solar power will be installed. It has been calculated, that the first 100 megawatts of Sede Boqer-type solar power plants will cost USD 2,500 per kilowatt, but this will drop to USD 850 per kilowatt if 1,000 megawatts of capacity will be produced, even if the production would take place in Europe (FAIMAN et al, 2005). If solar dishes would later be mass produced in very long series, by millions per year, they would become very, very cheap indeed.

When solar dishes become cheaper they will also become more popular. Many more will be bought by the people. Production series will become still longer and the price will drop further. After one hundred years or less, it may be that a concentrator photovoltaic system including a 25-metre-wide solar dish and producing 200 kilowatts of power might not be seen as a major investment by even the low-income households.

It is not impossible that the logic of industrial mass production would finally lead to a situation, in which practically every rural household who can spare the space will have a relatively large solar dish of its own. If such a scenario would become the reality, the humanity´s energy producing capacity might increase by a factor of two hundred, lets say to 2,000,000 gigawatts.

This already sounds a little bit frightening, because such a number of large solar dishes required about six hundred million hectares of land, one fifth of the area of Africa, or actually two times this amount, if also the land separating the dishes from each other is counted.

However, parabolic solar dishes could also be used for rainwater harvesting, besides which the reflectors made of metal might also be able to condense smaller amounts of moisture directly from the air. Besides this, very large parabolic reflector arrays should be able to reduce the local soil temperatures in a significant way, because they channel or reflect away roughly one half of the sunlight in the area that is used for intensive solar power production. Such a shading effect should be very valuable for food plants in hot regions. If the effect reduced the average temperature by 10 degrees Celsius, the water harvested or condensed by the reflectors could produce several times more food than an equivalent amount of water in normal, hotter conditions (PEARCE, 2002). Therefore, it might be a good idea to place at least some of the solar dish arrays on cultivated lands in the tropics.

The combined area and efficiency of billions of dishes like this would be comparable to four hundred million Very Large Arrays, forty million Arecibos or 600,000 Cyclops arrays. Such an array would be an enormously powerful listening tool. However, as a vision about the future of man kind, it might already be closer to a nightmare than to a utopia.

6. SENDING MESSAGES TO THE STARS: FROM *SETI* TO *CETI*

Preceding chapters have argued, that the new solar economy is likely to improve, in a dramatic way, our ability to search for artificial radio signals from the space. But could we also send messages to the stars, besides listening for them? This far the assumption has been, that it does not make any sense to send messages to the stars before we have actually found other technological civilizations and know exactly where the radio beams should be directed. If the signals have to be sent to all possible directions at once, the energy consumption will be enormous.

However, what if all the other technological civilizations in the Universe have arrived to the same, logical conclusion? What if everybody is just listening and nobody wants to waste energy to sending any messages before they know that there are other civilizations which would listen to the transmissions? (see WEBB, 2006; MERALI, 2008).

Should we, after all, also send messages to space, besides listening for them? And how much energy such a programme would require?

The shift from fossil fuels and nuclear power to modern solar economy would create new resources that could also be used in CETI programmes. For example, it would be possible to use the solar dishes for sending focused radio beams towards distant targets, just like they can also be used to searching for artificial radio signals.

Moreover, it is probably not possible to design an energy system based on solar power so, that there would not be any major discrepancies between the availability of solar power and the need for electricity. This means that a lot of extra capacity has to be built in the system, and that there will be periods of time during which a lot of extra solar power will be available, electricity for which there are no obvious uses.

Many solar power plants cannot produce energy during nights and they do not produce much when it rains. In Northern areas solar power plants would produce a lot of energy during the summer and very little during the winter, because the summer days are much longer and the sun rises higher in the sky. In the Arctic areas the Sun does not set at all during the summer months, so a lot of electricity can be produced even at midnight. In mid-winter it is not possible to produce any solar power in the Arctic because the sun does not rise up for some months, but there is a peak in the need for heating energy, then. In South and South-East Asia the consumption of electricity will most probably reach its annual peak during the hot summer months, when air-conditioning requires a lot of power. But the monsoon rains fall during the same period of time, and they may cover most of the sky over the whole region under heavy clouds. When there is an economic boom the various industries consume a lot of energy. When there is a recession their consumption is a small fraction of this peak.

As mentioned above, the most obvious partial solution to such problems is to construct longer high-voltage direct current transmission lines and to transport large quantities of electricity from East to West and vice versa. In Eurasia and Africa most of the problem can be solved this way, because Eurasia stretches over full 180 degrees of longitude, half the way around the Earth. When the sun sets in the westernmost parts of the giant continent, it is already rising in East Eurasia. With the present alternating current transmission lines the loss of electricity increases with the distance. In the high-voltage direct current lines the initial loss when the power is fed into the line is greater, but after that the loss does not increase much with the distance.

In spite of these possibilities it is not possible to construct a solar economy without installing a lot of extra capacity into many parts of the energy producing system, because the capacity of the whole global energy system must be large enough to satisfy the needs of the industries even during their most active production periods.

This means that an energy system based on solar power can often produce much more electricity than what is actually needed. On days with clear summer skies over vast areas of Eurasia during a major economic recession the surplus production of power might actually reach gigantic proportions. In solar power plants the fuel is free, it falls down from the sky not depending on whether it is needed or not. This surplus energy, or parts of it, could perhaps be used in sending messages to the stars. Such energy could, occasionally, be given for the CETI programmes by the publicly or cooperatively or privately owned power producing companies free of charge or with a very low, nominal price.

Moreover, the vast vanadium, lithium or lithium-iron-phosphate battery systems that would most probably be used by some of the solar power plants could also be used to produce very strong pulses of power which might be detectable by single Arecibo-sized telescopes from billions of light years. This power, however, would not be free because the flow batteries or other large-scale energy storage systems all have a limited life-span.

How far would these resources go? We have to keep in mind that the Universe is very large, indeed.

In 1964 the Russian astronomer Nikolai Kardashev published an imaginary classification of potentially existing, ancient supercivilizations and their capabilities for interstellar communication. Kardashev classified aliens who are able to capture and utilise all the energy resources of their own planet for such communication as Type I civilizations. In Kardashev´s vision Type II civilizations can control and use the whole energy output of their home star, and Type III civilizations are able to utilise the power output of the whole galaxy for interstellar communication purposes. Kardashev said that the transmissions of a Type II civilization would be visible everywhere in the same galaxy, while the transmissions of Type III civilizations could easily be seen everywhere in the Universe (SAGAN 1973a and SAGAN, 1973b). According to this classification our own civilization is still closer to an ordinary anthill than a Type I Civilization, because our combined use of energy amounts to less than 0.01 per cent of the solar radiation falling on Earth, and because we have only invested a minuscule amount of our energy production in CETI programmes.

However, it may not be necessary to use such enormous amounts of energy and money to send messages to faraway galaxies.

In the following pages I will outline an alternative approach for a CETI programme. I will first analyze the theoretical possibilities to convey messages to young technological civilizations which are roughly at the same level as we are now, meaning civilizations which still satisfy their energy needs by fossil fuels, biofuels, hydropower and nuclear power, and which are in possession of only one, roughly Arecibo-sized radio telescope. After this I will, very briefly, discuss the possibilities of reaching civilizations whose economies are largely based on solar energy.

As mentioned before, there is an enormous number of different radio frequencies. Even the so called cosmic water hole, the range of frequencies in which the background noise in the Universe is at its the lowest level, contains approximately one hundred thousand million channels or narrow bands of frequencies. It has often been assumed, that SETI and CETI efforts all over the Universe would concentrate on this range of frequencies because it is, by far, the most quiet part of the electromagnetic spectrum.

But even one hundred billion channels is a lot. If we broadcast with all of them, we need one hundred billion times more power to reach a certain distance. But if we only broadcast with one frequency, the aliens in another solar system will not hear us unless their receiver happens to be tuned to the same band of frequencies we are using in our broadcasts.

However, it may be that this is not, after all, a very big problem. Because of the improvements of our computer technology even we are already able to listen to billions of different channels at the same time, and it only requires a small additional increase in our computing power before we can cover all the one hundred billion channels in the “cosmic water hole”. So, it seems that if we want to send a message to the stars, the best option is to concentrate on only one narrow band of frequencies within the cosmic waterhole and assume that the receiving antenna will be covering all the channels in this range.

To improve the odds further, we could of course choose a frequency that should have a spesific significance for mathematically and astronomically oriented civilizations. All mathematically oriented civilizations should have divided the length of a circle´s arch with its radius, and thus calculated the value of pi. Therefore, for example the hydrogen frequency (21 centimeters) divided with the value of pi might be a good choice. However, the spectrum of the signal will, in any case, spread and change if it will travel very far, so it doesn’t really pay to hunt for the magic frequency if the signal is coming from a distant galaxy.

If we only concentrate on sending with one, narrow band of frequencies, no matter what the channel will be, we will reduce our energy bill by at least one hundred billion times.

Instead of sending our messages randomly to a hundred million different directions, we should probably concentrate on carefully selected target areas.

Because the number of young technological civilizations which exist in the Universe at any given time may be low, even if most of the habitable solar systems would finally develop their own intelligent species, it might be a good idea to beam the messages to a very large number of solar systems at the same time. The larger the number of solar systems covered, the larger the chances that we will reach at least some extraterrestrial civilizations. Or, in other words, the lower the density of the civilizations, the farther the messages should be aimed at, in order to reach somebody.

The intensity of a radio beam falls off with a square root of the distance. When the distance increases 10-fold, the power of the beam has to increase 100-fold. The standard conclusion from this has been, that it is the most cost-effective to concentrate on targets that are relatively near. For example Brian McConnell concludes in his book Beyond Contact that: ”If you increase the transmitter´s power, the reception range for the signal will increase in proportion to the square root of the increase in power. So, if you quadruple your transmission power, you´ll double the effective reception range for the signal. If you increase the transmitter power 100 times, you´ll increase the reception range by 10 times. What this trend implies is that increasing transmitter power produces diminishing returns since a million-fold increase in transmitter power produces only a thousand-fold increase in detection range (all things remaining equal on the receiving side)” (McCONNELL, 2001).

But there is another way to look at this equation. When the distance increases 10-fold, the volume of space becomes 1,000 times larger, and the number of solar systems that can be reached also increases, approximately, 1,000-fold. This means that the most cost-effective strategy, in terms of the number of civilizations reached, may actually be to send very powerful beams towards targets that are very, very far away.

To reach a distance of a billion light years requires one hundred million times more energy than to reach a distance of one hundred thousand light years. However, the volume of space covered will be approximately one million million (or one thousand billion) times larger.

If the solar systems were evenly distributed in space, the ”contact price” per solar system would then be ten thousand times less. In reality the distribution of matter in the Universe seems to be fractal (BARYSHEV and TEERIKORPI, 2003; EINASTO, 2006), which means that the reality is quite a bit more complex. However, as a general thumb rule the equation is still relevant.

To reach solar systems that are only one hundred light-years away, very little power is required, but the contact price per solar system is, statistically, roughly ten million times more than if the beam is sent to a target one billion light years away. And it may be that there are no technological civilizations within one hundred light-years, in which case the whole effort will be in vain.

Moreover, if we beam our messages to faraway targets, like whole distant galaxies, there is a better chance that the listening telescopes will be directed towards our transmissions. Two Arecibo-sized telescopes searching for each other in the same galaxy are very unlikely to ever find each other, but an Alien Arecibo searching for more powerful transmissions from distant galaxies will find them because there is only one direction per galaxy where to look at.

Beaming the signals to all the solar systems in very large faraway targets would be the most efficient strategy: if both the listening capacity and transmission power are concentrated for example in one thousand or one million nearby galaxies, the number of targets becomes relatively small. This is in a way so obvious that it may be that most of the intelligent civilizations finally arrive to the same conclusion, after a few decades or centuries of fruitless efforts to find transmissions from nearby stars. This, of course, means that the cherished dream about continuous two-way-communication with nearby aliens has to be abandoned, or at least dropped from the very center of the effort.

If the radio signals are beamed to lets say one thousand clearly defined, faraway targets, for instance to one thousand particularly promising galaxies, instead of a hundred million different directions, and if we will only use one frequency instead of a hundred billion, we have already reduced our power requirements by a factor of ten thousand million million.

There could be still more ways to reduce our electricity bill. It has been proposed, that most solar systems harbouring living planets probably exist on habitable zones which circle the galactic planes like a few thousand light-years-wide, relatively narrow rings. When a galaxy is not positioned edge-on towards us but so that we can see the whole vortex of stars from ”above” (or from ”below”) we could concentrate our transmissions on this habitable ring. This would reduce the area which ought to be covered in that galaxy by at least a hundred and possibly by a few hundred times.

Our beam could sweep round this ring over an over again, like a beam of a lighthouse. We could use a similar sweeping light-house beam also in our transmissions to the other solar systems of our own Galaxy. We cannot direct our messages so that they would only cover the habitable ring around the center of our Galaxy, because we see the Milky Way edge-on. But we could send a lighthouse-beam that would sweep along the relatively thin disk, or plain, of our galaxy (RIDPATH, 1978).

The use of gravitational lenses for intergalactic communication purposes is also an interesting option. The idea of gravitational lenses was first put forward by Albert Einstein. It has been proposed, that the gravitational lenses could also be used as interstellar or intergalactic communication devices (ESHELMAN, 1979).

Stars and galaxies focus all kinds of electromagnetic radiation by bending space. For example the Sun is able to concentrate radio waves and other electromagnetic radiation by one hundred million times into a focal point which is approximately 550 astronomical units (roughly 80,000 million kilometres) away from the Earth. With optical lenses light diverges after the focal point, but a gravitational lens operates in a notably different way. Rays that are passing by farther away will not be bent at all. Rays that pass by very close from the object will be focused in a similar way than the rays that pass through an ordinary optical lens: they will be concentrated into the focal point, after which they will again disperse. However, there is also a narrow zone on which the focal length of the gravitational lens is infinitely long. Radiation passing through this zone remains along the focal axis, for ever (MATTLOFF, 2000). In other words, the gravitational lens is a spherical zone, a thin surface of a spherical bubble, surrounding a large concentration of mass. From any given direction this spherical zone will look like a narrow ring, and the gravitational lens will only focus radiation that passes through the ring.

Because of the phenomenon of gravitational lensing, astronomers have been able to observe exoplanets rotating around stars tens of thousands of light-years from the Earth. Without the gravitational lensing events, these objects would have been detectable with the same telescopes only from a distance of a few or a few dozen light years.

There are a lot of stars around us, and there are a lot of galaxies in the Universe. In all the cases where a certain star and a certain galaxy behind it are on a direct line, we should be able, at least in theory, to use the star as a gravitational lens that would focus our signal by one hundred million times on its way towards the distant galaxy. This could bring many faraway galaxies very close to us in terms of power that is required to transmit messages to them.

At the wall of my working chamber there is a poster about the spiral galaxy in Antlia, NGC 2997. The stars which exist directly between us and this faraway target are clearly visible against the spiral arms of the galaxy as large, white spots. There are dozens of stars that could most probably be used as gravitational lenses focusing and concentrating our signals to different parts of the spiral arms of NGC 2997. If a star is one thousand light-years away from us but there is a galaxy directly behind it in a distance of lets say one hundred million light-years, it might be possible to reach this galaxy with a very modest output of transmitting power. According to a rough back-of-the-envelope-type calculation even 10 kilowatts might be enough. Such an amount of power can easily be taken by any household from the normal electric grid. So in practise anyone who has a large parabolic reflector and the suitable radio transmission equipment, might be able to send a radio message to a faraway galaxy, utilising a nearby star as a gravitational lens.

In some cases it might also be possible to use whole galaxies as gravitational lenses that would boost the signal sent to another, more distant galaxy straight behind them. It seems that the clusters and superclusters of galaxies form even longer filaments and vast sheets which can be hundreds of millions or even a billion light-years long, and which are separated by vast voids of empty space. If this is the case, it may be that most galaxies in the Universe can be reached with relatively small amounts of power by using either stars or other galaxies as gravitational lenses.

However, the potential of the approach is reduced by a number of factors.

First, only the rays that will pass by from a relatively close distance will be bent and focused. This means that a major part of the power would probably be lost. Second, the rays passing by the zone on which the focal length is infinite, would remain focused for a very long time, but it would be almost impossible to know whether they would ever encounter an inhabited planet. Such an intensely focused transmission would travel through the space like a very narrow tip of a needle, it would, so to speak, only make a very, very narrow hole in the space because it would not disperse over a larger area. Because the relative positions of stars and even galaxies keep on changing and there is a chaotic element in such movements, it is not possible to calculate precisely where a certain faraway star will be after a hundred million years.

These are, in practise, serious limitations but gravitational lenses might still turn out to be useful communication tools.

It might even be possible to utilise black holes and different kinds of clusters of dark matter as gravitational lenses. Such possibilities of course depend on the exact nature of the dark matter. The issue is still hotly debated by the astronomers. At the moment there is almost a consensus that most of the missing mass in the Universe consists of “dark energy” and exotic dark matter, and only a minor part is made of ordinary, baryonic dark matter (mostly hydrogen atoms).

However, the whole assumption about the existence of dark energy is largely based on theoretical calculations and only on a single piece of empirical evidence: on the fact that certain type of supernovas which have exploded billions of light-years away look a little bit dimmer than what they should (PERLMUTTER et al, 1998; RIESS et al, 1998). The community of physicists has decided that the only way to interpret this observation is that most of everything consists of strange dark energy which is accelerating the expansion of the Universe.

But there is also another, much simpler explanation, which may have been discarded too lightly. What if there is so much unevenly spread ordinary dark matter in our Universe that space is a little bit more curved than what the cosmologists have calculated?

If this is the case light would simply have been forced to travel a slightly longer distance in the slightly smaller Universe which was there a few billion years ago. Thus no dark energy would be needed to explain the supernova observations, and most of the dark matter could simply consist of hydrogen and helium atoms in very dense and cold gas and ice planets or in brown drawfs, small and cold protostars inside which the fusion-powered fires have never ignited. We know that most of the dark matter in our galaxy lies in the corona, the huge invisible sphere surrounding the galactic disk. It could be that very different kinds of celestial objects exist in the corona than in the galactic disk

In the galactic disk the average density of matter and the average temperatures are much higher than in the corona. Also, there are more heavy elements – including radioactive elements – because of the numerous supernova explosions which have taken place in this region.

The physicist J. Martin Herndon (HERNDON, 1994a) has suggested that the very small stars can perhaps only ignite with some help from the heavy radioactive elements. This is, of course, still a very hypothetical notion and most astronomers currently disagree with the idea. When astronomers have tried to calculate what is the lowest amount of mass necessary for a star to ignite, they have ended with a figure of 0.08 solar masses, which almost precisely corresponds with what can be observed at the sky. If the smallest actually existing stars are of the same size as what they should be, according to the theoretical calculations, there seems not to be any major problems, here, and Herndon's hypothesis about the smallest stars being able to ignite only with the help of radioactive elements probably doesn't correspond with the reality.

However, without the impact of solar radiation for example Jupiter and Saturn might look very different from the relatively large, brown and bloated gas balloons known to us. Even the outermost layers of Jupiter, Saturn, Uranus and Neptune are still relatively warm. The surface temperature of Jupiter is 123 K, and the corresponding values for Saturn, Uranus and Neptune are 93 K, 63 K and 53 K (MOORE, 1991). Without any solar or star radiation these planets would be much colder, smaller and darker.

Herndon and some other physicists (see HERNDON, 1994b; RAO, 2002) have proposed that the radioactive compounds decaying at the cores of different kinds of planets should contribute something to their current temperatures and sizes. Only a very small part of for example Jupiter's and Saturn's mass consists of the heavier elements, including the radioactive substances. This means that radioactive substances are not likely to contribute significantly to their temperatures. However, in very cold regions of space – like the galactic coronas – where there are no stars, and where the temperatures would not be much above the temperature level provided by the cosmic background radiation (3 K), the (almost) complete lack of radioactive substances might be important. It might mean that even relatively small concentrations of hydrogen and helium, and minor amounts of other elements, might condense so much that they would reach the liquefaction temperatures of hydrogen and helium (20.4 K and 4.2 K in the pressure of one bar).

This is, admittedly, a very speculative line of thought, but according to the existing data – within the limits of our present ignorance – we cannot really exclude the possibility of very large numbers of celestial objects, with masses smaller than the mass of the smallest red dwarfs, littering the galactic coronas; compressed to very tight and dense, almost pitch-black balls of matter because of the lack of starlight and because of an almost complete lack of internal heat (radioactive elements).

What if the kind of stars and planets known to us mostly exist in the densely populated parts of the galaxies, with high amounts of radiation and heat? What if most of all the matter that exists consists of innumerable dark planets and dark stars, with temperatures very close to absolute zero, "black dwarfs" drifting around in the galactic coronas? Earth-sized objects with the mass of a Sun and Ceres-sized objects with the mass of Jupiter, and so on? There could also be smaller ice planets.

Such frozen worlds could mostly consist of: 1. frozen hydrogen and frozen helium 2. frozen hydrogen and liquid helium 3. frozen hydrogen and gaseous helium 4. liquid hydrogen and liquid helium, or 5. liquid hydrogen and gaseous helium.

These ideas go against the mainstream of present astronomical thinking and theoretical calculations seem to have proven that most of the missing mass could not consist of such conventional dark matter. However, models, assumptions and theoretical calculations are not empirical data, and they often have a nasty way of changing.

The above outlined hypothesis could, at least in theory, be verified or falsified through empirical observation. If we some day find, for example from the galactic corona, very cold celestial objects with an atmosphere consisting of helium, only (and no hydrogen!) we have almost proved that at least some of the above outlined hypothetical objects do exist. That would give us a serious reason for reconsidering the validity of the dark energy hypothesis.

Also, it is now known that dwarf galaxies like Ursa Major II, Willman I and Coma Berenices Dwarf appear to have a gravitational field equivalent to at least one million solar masses even though they only shine as bright as a thousand suns. It seems that such dwarf galaxies are very difficult to observe because their stars move very slowly and because their matter has been distributed so widely that only a small number of stars have been born (ANANTHASWAMY, 2008; NEW SCIENTIST, 2008b). These observations should perhaps also be regarded as empirical evidence supporting the notion that the missing mass might consist of ordinary, fractally distributed matter and that dark energy might still prove out to be only a mirage.

If 90 or 99 per cent of all the matter in the Universe – including at least 90 per cent of all matter in our own Galaxy – would consist of dense, unbelievably cold, dark worlds, we would be surrounded from all sides by innumerable dark matter objects which could be utilised as gravitational lenses. If there would be thousands of billions or perhaps even hundreds of thousands of billions of them in our own Galactic corona, we might be able to reach every galaxy in the Universe with a relatively small amount of transmitting power by using the dark matter objects as gravitational lenses. Such objects, of course, would be very small and very dark, so the first problem would be how to device instruments by which it would be possible locate and follow such objects.

7. CHOOSING THE CONTENT: WHAT SHOULD WE BROADCAST?

However, if we – the humanity – were to send radio messages to the stars, what exactly should we send?

It is very difficult to see how it could be possible to analyze such a question in a “scientific” way. Our ignorance about the possibly existing extraterrestrial civilizations and their various cultures is absolute, we do not yet even know whether any such civilizations actually exist.

Therefore, this chapter will, inevitably, be much more subjective and speculative than the preceding chapters. Especially the last pages are probably closer to science fiction than to serious science. The following pages should basically be regarded as only a personal vision on why it just might be a good idea to invest serious amounts of resources in a CETI programme. It is still impossible to say whether the main ideas presented at the end of this chapter might ever make any real sense, at all.

However, even though this concluding chapter is, in many ways, less analytical and scientifically on a much shakier ground than the preceding chapters, I still decided to include it, because it would feel stupid to discuss SETI and CETI without saying anything about the content of the messages which we might or might not one day send to the stars.

Many SETI and CETI visionaries have imagined capturing or sending galactic broadcasts with enormous amount of information, whole galactic encyclopedias containing all the combined wisdom and knowledge of a galactic club of supercivilizations. What comes to our own transmissions to the stars, the proposals have envisioned sending detailed descriptions about the whole ecosystem of the Earth, pictures of all its animal species, details of the planet’s geography and human history, selected presentations of our art, and much else. However, even sending a few good-quality, greyscale pictures involves sending quite a few bits of information. A typical photo with a resolution of 1,000 to 2,000 pixels on each side may require 8 to 32 million bits, if each pixel has 256 different brightness levels (McCONNELL; 2001). Sending coloured pictures requires still many more bits. So it quickly goes to billions and trillions of bits. If the messages become so complicated, we need a lot of energy for reaching a certain number of stars. Thus we can reach only a small number of potentially inhabited solar systems, and it becomes unlikely that our messages will ever reach anyone.

Therefore it might be the best to concentrate on sending only one or a few short and simple messages which we think are the most important things we could possibly say to other young techno-cultures.

If we forget the shades and colours and concentrate on very simple but clear black and white pictures much can be said with a very small number of bits. Frank Drake and Carl Sagan packed quite a lot of data into the 1,679-bit signal they sent, in 1974, from Arecibo towards the globular cluster M-13 (DRAKE and SOBEL, 1993; COOPER, 2008c).

The message stared with numbers from one to ten, expressed according to the binary counting system. After that there were diagrams for the molecules which are essential to life on Earth: hydrogen, carbon, oxygen, nitrogen and phosphorus, expressed with the same code of numbers by which the message had started. Drake also added the chemical formula of DNA, a graphic description of the shape of the DNA molecule, and an elongated block which aimed to say that humans have three billion pairs of DNA. Then there was a simplified picture of a human being, another block representing the number of humans living on the planet, a diagram of the solar system and a rough representation of the Arecibo telescope.

Drake and Sagan were thus able to pack a lot of information into their short 1,679-bit message. Of course, it is very difficult to say whether an alien civilization would really be able to interpret any parts of the message correctly, even if somebody would capture it. Somewhat more detailed pictures presented in binary code might be easier to interpret correctly (McCONNELL, 2003).

But what kind of information should we include into the messages?

There cannot be any “scientific” answers to such a question, and different people will have varying opinions on the subject.

One possibility would be to concentrate on those issues which we consider, at least for the time being, to be the most serious threats for our own, long-time survival. If these issues are the most acute and important issues for our own species, they might also have some relevance for some of the other young techno-cultures which might share the Universe with us.

There are, at the moment, at least four possible dangers which might destroy our species, wipe out every woman, man and child from our planet.

One of these factors is the possibility of an unlimited nuclear war. Nuclear weapons are much more destructive than we have thought. For example the US military, in spite of having spent USD 5,500 billion in the development of its nuclear weapons systems, has hugely underestimated their destructive potential (GREEN, 1999). In Hiroshima and Nagasaki nuclear detonations caused firestorms which burned everything and killed everybody inside the fire perimeter. However, the US military scientists considered fire damage so unpredictable, that for fifty years they only concentrated in analysing the impact of the blast. When the USA was afraid of a nuclear war between Pakistan and India, in 2002, it warned that a nuclear war in South Asia might kill twelve million people. The figure was absurdly low because it only took the impact of the nuclear blasts into consideration. According to more recent US research fire damage radii of nuclear blasts are 2 to 5 times larger than those determined for airblast effects, which in practise means that areas destroyed by fire are 4 to 25 times larger than areas damaged by blast, alone (EDEN, 2004).

Unfortunately, even this is not the full picture, yet. The firestorms in Dresden, Hamburg, Hiroshima and Nagasaki caused very strong rising air currents, which in turn created hurricane-speed winds, blowing with speeds exceeding 160 kilometres and possibly even 270 kilometres per hour. A nuclear explosion in a modern city would create a still much fiercer firestorm because modern cities contain huge quantities of oil and gasoline in the form of plastics, asphalt, gasoline, oil and gas. Such a firestorm would create phenomenal super-hurricane winds in an area dozens of times larger than the area covered by the actual firestorm. It has been estimated that even the explosion of a small, Hiroshima-size nuclear bomb in Manhattan would create winds blowing with the speed of 600 kilometres per hour (GOLDMAN, 2006). Such a super-hurricane wind would be strong enough to topple skyscrapers and to destroy most other human-made structures exposed to it (EDEN, 2004). The area devastated by the super-hurricane might be more than a thousand times larger than the area destroyed by the original blast.

The insurance companies have calculated that the destructive potential of wind increases by 650 per cent when the wind speed increases from 20-26 metres per second to 26-31 metres per second (FLANNERY, 2005). Wind speeds approaching 200 metres per second would be extremely destructive.

According to a recent study (MILLS et al, 2008) even a very small, one or two megaton nuclear war, involving the exploding of one hundred Hiroshima-sized nuclear bombs in northern subtropical cities, might destroy a major part of the global ozone layer, protecting us from the deadly short-wave ultraviolet or uv-c radiation.

Another thing that might kill us all is a war involving numerous military or terrorist strikes against nuclear power plants, either with nuclear warheads or with conventional weapons. We might easily think that this would not be bad enough to kill everybody, but we should remember that for instance in Chernobyl only about 50 million curies of radioactivity was released, according to the International Atomic Energy Association, roughly half a per cent of the radioactivity inside one nuclear reactor. There can be up to 150 tons of nuclear fuel inside a large nuclear reactor, and each ton can contain 300 million curies of radioactivity. So the nuclear fuel in one reactor, alone, can contain approximately 900 Chernobyls' worth of radioactivity.

Some of the planned new nuclear reactor types (like Finland's Olkiluoto Three Reactor) would be even larger than the present ones, and their fuel would be kept inside the reactor for a longer time. If all the fuel inside such a reactor would burn, it could, according to the worst-case-scenario, release 4,000 times more radioactivity than the accident in Chernobyl. This is because increasing the burn-up rate from 20 GWd/tU to 60 GWd/tU almost triples the amount of peak radioactivity in the used nuclear fuel, when counted in curies (EDWARDS, 2008).

We already have about 440 nuclear reactors on Earth, and many governments are now saying that we should combat global warming by replacing fossil fuels by nuclear power. We are, at the moment, producing less than three per cent of our energy and a somewhat larger percentage of electricity with nuclear power. If the nuclear power's share of the world's energy budget were increased to 50 per cent while the total consumption of energy tripled, we would have 60 or 70 times more nuclear power than at present. So a war that destroyed all of these facilities could cause a radioactive fallout equivalent to a hundred million Chernobyls, when counted in curies.

A third factor which might kill us all is a large tsunami wave hitting numerous coastal nuclear power plants, their cooling ponds and nuclear fuel recycling facilities at the same time. Strikes by asteroids (BLAKESLEE, 2006), underwater earthquakes and submarine landslides can create very large tsunamis. The collapse of an old volcano can also do that (MARSHALL, 2001). Even in the North Atlantic there has been roughly one 10 to 15-metre-high tsunami in a century. The most recent such events have taken place on years 1580, 1607, 1755 and 1929 (McGUIRE, 2005).

Moreover, the researchers of the Christian Albrecht University in Kiel, Germany, and of the Shirshov institute for Oceanographic research in Moscow have noted that global warming may cause megatsunamis by destabilizing the offshore methane clathrate deposits. Methane clathrates are ice-like solids in which methane molecules have been trapped inside cages that consist of ice. They are only stable in high-pressure conditions that exist under more than four hundred metres of water and in temperatures only a few degrees above the freezing point of water (SUESS et al, 1999). 7,900 years ago a large eruption of methane from the methane clathrate deposits off the coast of Norway triggered a vast submarine avalanche of mud and other loose sediments, known as the Storegga, or the Great Wall. The Storegga submarine landslide also caused a very large tsunami at the coastal areas of Britain and Norway (NISBETT and PIPER, 1998; PEARCE, 2007).

The disintegration of continental ice sheets can also cause giant tsunamis by a number of different ways. A continental glacier can weigh so much, that the Earth’s crust under it is often depressed by 800 or even 1,000 metres. When the glacier begins to melt it becomes lighter and the crust starts to bounce back. This can create very large rebounce earthquakes and related tsunamis (ARVIDSSON, 1996; JOHNSTON, 1996; MÖRNER, 2003; MÖRNER, 2006; MÖRNER, 2008, McGUIRE, 2006).

For instance on the coastal areas of Australia the scientists of the University of Wollongong have found traces of huge megatsunamis which have reached 35 kilometres inland and deposited car-sized boulders 130 metres above the present sea-level (JONES, 2002; BRYANT, 2001; BRYANT and NOTT, 2001). There have been so many different giant tidal waves that most of them have probably been caused by the melting of the Antarctic ice sheets at the end of the last Ice Age.

If a 10-metre tsunami – not to say anything about a 100-metre supergiant – hits a nuclear power plant it will destroy its cooling pipes and the power sources of the cooling systems. The same also happens for the cooling ponds and other containers storing large amounts of highly radioactive substances. At least in many cooling ponds the spent nuclear fuel would either melt or burn, in which case much of it would be released into the atmosphere in an aerosolic form (see for example BRWM, 2006). For example the five cooling ponds of La Hague, France's nuclear fuel recycling facility, contain about 7,500 tons of used nuclear fuel rods. There is so much fuel in each pond that the rods will be ignited if the cooling water evaporates and the pumps will not replace it. In Britain's Sellafield there is one building containing 70 tons of plutonium and another container, known as B219, which stores roughly one hundred times more cesium 137 than what was released in Chernobyl. The plutonium store will explode and the cesium in B219 will start boiling and evaporating into the atmosphere if the cooling systems will be disrupted (EDWARDS, 2001).

If the production of nuclear power is to be multiplied, most of the new reactors have to be fast breeder reactors, nuclear power plants which can produce more nuclear fuel than what they consume. The natural uranium deposits will not be able to satisfy the demand of many more nuclear power plants, but fast breeder reactors can convert the ordinary uranium 238 and even thorium into fissionable isotopes. However, this far the fast breeders have only achieved a breeding ratio of 1:1,2 (HYPERPHYSICS, 2006). This means that five fast breeders can only produce their own fuel plus fuel for one additional, conventional nuclear power plant.

Fast breeder reactors are very dangerous, for two different reasons. First, they use either liquid sodium or liquid lithium as their coolant. Both substances explode when they get in touch with water or air. This means that fast breeders are especially vulnerable to sabotage or accidents caused by floods, hurricanes or tsunamis. If a tsunami hits a fast breeder, only one small break in one cooling pipe is required and the whole cooling system will be destroyed in a series of explosions quickly spreading to all directions.

Second, while normal nuclear power plants use fuel in which the uranium 235 content has been enriched to 2 or to the maximum of 4 per cent, fast breeders use uranium 235 or plutonium enriched from 15 to 60 per cent. This means that their fuel can be used, without any further enrichment, to make nuclear bombs. Such bombs will only become slightly larger than the bombs made of the so called weapons-grade uranium, containing 93 per cent uranium 235. About 20 kilograms of weapons-grade uranium is required to make a Hiroshima bomb. With fast breeder reactor fuel containing 20 per cent of uranium 235 twenty times more material is needed, 400 kilograms. But this size is still not a serious constraint for terrorist groups or armies (GLASER and VON HIPPEL, 2006).

According to the recent German KiKK study (the German acronym for Childhood Cancer in the Vicinity of Nuclear Power Plants) there has been a 60 per cent increase in solid cancers and a 117 per cent increase in leukaemia among young children living near the 16 large German nuclear facilities between 1980 and 2003. Children living within five kilometres of the plants were more than twice as likely to contract cancer as the ones living further away (KAATSCH et al, 2007 and 2008; SPIX et al, 2007) .The methodology of the studies was rigorously designed, the studies were carefully made and their findings have now been accepted by the government of Germany (FAIRLIE, 2008). The worrying thing is that the radioactive emissions produced by a nuclear power plant in normal conditions are extremely low, billions of times less than what could be released in connection of a serious accident.

The most likely culprit is radioactive tritium which is routinely ventilated out from the reactor halls and just released into the environment. The amounts of radioactivity thus released are relatively small, for instance the Finnish nuclear power company TVO says that in 2006 its nuclear power plants released 2.46 terabecquerels or approximately 80 curies worth of tritium into the environment. This is 2.5 billion times less than the maximum amount of radioactivity that could be released from a large, modern nuclear reactor if its nuclear fuel would catch fire and all of it would burn.

Tritium is probably able to cause so much damage because it is extremely radioactive, and because it produces neutrons when it decays. Neutrons are, for living things like humans, the most dangerous form of radioactive radiation. However, if tiny annual releases – less than one billionth of the total amount of radioactivity inside each nuclear reactor – can already cause cancer epidemics which can be recognized, at least very near the nuclear power plants, as clear and high peaks among the background noise consisting of all the other cancers, it is safe to assume that massive simultaneous releases from numerous different nuclear power plants would probably do a lot of damage.

(Most of the extra cancer mortality caused by the tritium releases must actually occur much farther than five kilometres from the nuclear power plants, even though it is no longer possible to discern the effect from the background noise. Tritium has a half-life of 12.3 years so it has the time to travel relatively far in the environment. Theoretically the exposure at a distance of 500 kilometres should be – according to a very rough model – ten thousand times less than at a distance of 5 kilometres. However, for example in Central Europe there can be two hundred million people living in an area with a radius of 500 kilometres.)

It is very difficult to get reliable information on the health risks related to radioactive substances, because the issue is a political hot potato, because there are large economic vested interests involved and because the institutions and research groups involved with such studies often tend to be biased either against or for nuclear power. The above mentioned German KiKK study, however, is an obvious, rare and refreshing exception from this main rule.

In a way the most reliable source of information about the dangers related to radioactive substances might be the military academies and armed forces, because for them the cold and unbiased assessment of the relative importance of various risk factors is very crucial. According to a study conducted by three generals of the US Air Forces, a terrorist organization that would capture ten kilograms of used nuclear fuel which had just been taken out from a nuclear rector, could kill between 50 and 90 per cent of the unprotected population of Washington DC, New York, Philadelphia and Baltimore, if they would pulverize the fuel using a ton of conventional high explosives, during a moment when the winds were blowing towards these cities (NICHELSON, MEDLIN and STAFFORD, 1999).

The fourth factor which might kill us all is a runaway greenhouse effect leading to massive methane, carbon dioxide and carbon monoxide releases from permafrost, sea water, the organic sediment layers at the sea bottom and, above all, from the methane clathrate deposits on continental margins and under the permafrost. It seems that there have, every now and then, been huge eruptions of methane from such offshore sources. These eruptions have often killed a large percentage of all living species on our planet (see for example WARD, 2006b, 2006d and 2007; PEARCE, 2007, LYNAS 2008, FLANNERY, 2005).

It may be that the atmosphere has become poisonous for the larger animals. We do not know exactly how much methane clathrate there is, under the mud of the continental margins, but the published estimates have varied between 10,000 billion and 10,000,000 billion tons (KVENVOLDEN, 1988). Even a series of eruptions releasing 10,000 billion tons of methane might make the atmosphere poisonous to us, if the eruptions would take place within a relatively short period of time, and if a relatively large part of the methane would only be converted to carbon monoxide because of the lack of hydroxyl radicals (see ISOMÄKI, 2008). Carbon monoxide is highly poisonous to humans even in relatively small concentrations.

Moreover, it seems that the build-up of carbon dioxide into the atmosphere has, on several occasions, led to vast hydrogen sulphide emissions from the sea bottom. When massive amounts of methane and carbon dioxide have been released into the atmosphere, the strengthened greenhouse effect has caused a rapid global warming. The warmer ocean has been able to absorb less oxygen. The cumulative reduction in the ocean's oxygen content has destabilized the so called chemocline, a zone where oxygenated water has met deep water containing large amounts of the hydrogen sulphide produced by anaerobic bacteria living at the sea bottom. Because of this the chemocline has risen close to the surface and the hydrogen sulphide bacteria have conquered most of the ocean water. This has, finally, resulted in massive hydrogen sulphide emissions, perhaps 2,000 times larger than our present global sulphur emissions (WARD, 2006; WARD, 2007).

Could something like this happen again, if we keep on pumping more carbon dioxide and other greenhouse gases into the atmosphere? The present carbon dioxide content in the atmosphere is 385 parts per million (ppm), but it might reach 1,000 ppm within a hundred years, or much faster if there are major releases of methane and carbon dioxide from the permafrost and offshore methane clathrate deposits. For example the great Permian mass extinction took place when the carbon dioxide content of the atmosphere exceeded 3,000 ppm. However, the somewhat smaller mass extinction of species 55 million years ago was triggered by a carbon dioxide content of only slightly more than 1,000 ppm. So there might be a reason to worry, here (WARD, 2006).

If we come back to CETI, one option might be to concentrate in sending warnings, in the form of very simple digital black and white pictures, about these four threats. It is possible that also many other young techno-cultures which might exist or which might be born elsewhere in the Universe are or might at some point be in danger of destroying themselves. All the solar systems in the Universe share the same elements, isotopes and chemical compounds. There will be fossil fuels and methane clathrates on other living planets, as well. They will also have uranium 235 and thorium. The dangers related to nuclear technologies and greenhouse gases may be, more or less, universal. It might be possible to construct a series of pictures about these dangers, containing only a hundred thousand or a million bits.

However, even this may not be absolutely necessary. Actually, the cheapest way of influencing the fate of other young techno-cultures might be to just send to space an 18-bit-signal consisting of the five first prime numbers: 1, 2, 3, 5 and 7.

Such a very simple signal would contain only one piece of new information, but that single piece of knowledge would, in a way, be more important than anything else could ever be. The signal would be undeniably artificial. It would prove that there are other technological civilizations in the Universe, and that at least one of them is sending radio messages to the space.

Let's imagine that we would detect, with the Arecibo radio telescope, such a 18-bit signal coming from the Galaxy of Andromeda, or from a very faraway galaxy in the Coma cluster of galaxies. We would probably presume, that the 18-bit-signal is only a cosmic buoy, and that there is also another signal, containing much more information but sent with a lesser amount of power. We would probably construct a vast array of radio telescopes, a cosmic ear capable of detecting one thousand or one million times weaker signals than Arecibo, and we would direct all these telescopes towards the direction of the 18-bit-signal.

And we might, then, find a signal sent with a million times less power, and it might contain a lot of useful and exciting information for us, greetings that another, totally alien species had sent to the stars, millions of years earlier. But even if we were not to find anything at all, the effort would change our whole society in important ways.

First, the sky would, again, have ears and eyes. This would be a little bit like getting the Gods back. If we knew that there are other intelligent beings watching us, we might become inclined to behave in a little bit more intelligent and dignified and merciful and gentler way towards each other and towards the other species which share the planet with us.

Second, the technologies which can be used to amplify weak radio signals coming from distant space - large parabolic reflectors and Fresnel lenses - would become very important cultural icons, perhaps the most important cultural icons there are. At the moment parabolic reflectors are not a very central thing in our culture. Some people know that they exist inside reflecting optical telescopes. All of us have seen satellite dishes but we do not pay much attention to them. We have seen pictures of radio telescopes and solar cookers, but they do not mean much to most of us. What comes to Fresnel lenses they exist in numerous different places, for example in traffic lights, LED lights, lighthouses and car lights, but relatively few people know anything about them.

However, detecting a genuinely artificial radio signal coming from the outer space would change all this, at one stroke. The shape of the vast parabolic reflectors and/or Fresnel lenses that were built to detect the possible weaker signals would become a very, very familiar thing to every single human being on Earth. Everybody would understand how a parabolic reflector or a Fresnel lens works. Everybody would have this idea inside her head. Everybody would think in terms of parabolic reflectors and Fresnel lenses. Everybody would have parabolic reflectors and Fresnel lenses in his head.

And, as we have seen, parabolic reflectors, Fresnel lenses, astronomy and solar energy are intimately linked. The more attention paid to astronomy or/and parabolic reflectors and Fresnel lenses, the sooner nuclear power, fossil fuels, fuelwood and giant dams will be replaced with solar power: by simple parabolic solar cookers, by a little bit more complex multi-purpose parabolic reflectors, by large concentrating solar heat systems and by concentrating solar power plants producing electricity by steam engines, steam turbines, some kind of ”Stirling engines”, thermoelectric cells or by concentrator photovoltaics, or by other means that we have not yet thought of. The only problem in utilising solar energy is that it is a diffused form of energy that needs to be concentrated a bit to make it really useful, and the most obvious and efficient way of doing this is to use a parabolic reflector or a Fresnel lens.

In the preceding chapters I have argued that a shift to a solar economy might also lead to a much greater capacity to receive and send radio messages, as a by-product from the mass-production of large solar dishes.

The logic of industrial mass production also applies when the starting point is a SETI programme. If a technological species wants to have a serious, large-scale SETI or CETI programme, it needs to develop industrial mass production of the necessary equipment, including large parabolic reflectors or Fresnel lenses. If parabolic reflectors are mass produced for a SETI programme, the price of solar dish-type solar power systems will simultaneously be reduced into a very low level as an almost automatic by-product of the process.

This may sound a tall claim, but lets say that we would receive an 18-bit signal with Arecibo and then decided, at first, to build only 40 times more capacity for listening, to check whether there is another, weaker signal which can be captured with this amount of antennas. The cheapest way to construct 40 Arecibos probably is to launch a semi-serious serial production effort of ten thousand 25-metre-wide parabolic reflectors. Such a project could, in many cases, be financed by using the telescopic array also as power producing array of solar dishes. 40 Arecibos is still a very modest investment, and most civilizations were probably ready to go up to one thousand or even one million Arecibos if the weaker signals were not found with a smaller amount of antennas.

However, even 40 Arecibos already amounts to 1,000 gigawatts of solar power, if the solar dishes were also used to produce energy. And when the production of the solar dishes reaches this level, the price of solar energy most probably drops below of the price of coal power and nuclear energy even on planets which have abundant coal and uranium reserves.

In other words: an 18-bit-signal might be enough to save whole civilizations from the kind of ecological catastrophes which are now threatening our own survival.

And, almost needless to say, when a civilization becomes a solar economy, many other problems will also be solved at the same time. On our own planet, fifty or one hundred million people have been displaced by large dams. The small particle emissions from biofuels and fossil fuels are killing millions of people, every year. The sulphur emissions from fossil fuels are suffocating forests, damaging crops and killing people on every continent. The production of fuelwood and charcoal is destroying millions of hectares of natural forests, annually. The destruction of mountain forests, partly for fuelwood, is the most serious threat for the water supply of billions of people. Oil spills are contaminating groundwater and beaches. When we move to solar economy we will gradually get rid of all these problems, and the other civilizations on other planets would probably gain many of the same benefits if they made a similar shift.

If we only have to send 18 bits of data to achieve such results, the power requirements will, again, be much reduced.

If we send radio messages to the space, messages that may reach other solar systems and other civilizations even long after our planet had ceased to exist, we just might be able to help other young technocultures to survive their childhood diseases, the same dangers which are now threatening our own survival. And if this would encourage other civilizations to launch their own CETI programmes, this might (at least in theory, there is no way of calculating the probabilities of something like this actually happening) become a chain reaction that could go on almost for ever, perhaps for a million million years, for as long as new stars will be born in our Universe.

With 50,000 gigawatts of solar power we could carry out huge CETI programmes even without gravitational lenses. We could perhaps occasionally use the huge vanadium or lithium battery arsenals of our solar power plants to concentrate a few hours' worth of power production into 18 short, one-second-long radio pulses, which would again increase our maximum transmission power by a thousand times. If also the possibilities provided by the gravitational lenses are included in the calculations, we could most probably do even more. We probably could, within a few centuries, send Arecibo-detectable 18-bit-signals to billions of different galaxies.

And if our power producing capacity one day reaches, due to the logic of industrial mass production, a level at which most rural households would have their own, 200-kilowatt solar dishes, we could, at least in theory, send Arecibo-detectable beams to hundreds of billions of galaxies, to a hundred thousand million million million different solar systems.

However, I do not know whether such a scenario is ever likely to become realized. If we look at the logic of industrial mass production, it is true that something like this just might happen, but probably only if there are no major collapses during which the whole society and its technological infrastructures proceed through phases of chaotic change. Personally, I am not so sure whether a model of linear industrial development lasting for several centuries and resulting in an enormously expanded solar energy production capacity should be seen as a desirable utopia.

In any case, to reach hundreds of billions of different galaxies would of course be a vast operation, requiring a partly centralized and partly decentralized organization. To reach faraway clusters of galaxies huge combined power outputs and cooperation between millions of individual households would be needed. On the other hand, if there are, in our Universe, a hundred different galaxies and a hundred thousand billion solar systems to be covered for each human being currently living on this planet, the major part of the work could only be done in a decentralized way.

But how about the older civilizations which are no longer in danger of wiping themselves out from their own planets?

It is very likely that such civilizations are mostly using solar power. It is, of course, possible to speculate about other sources of energy, still unknown to us. Well-known scientists have calculated, that vacuum might contain so much energy that a space enough to fill a light-bulb could destroy a whole galaxy. Cosmic supercivilizations may possess technologies through which they can harness exotic energy sources that are incomprehensible for us. This is theoretically possible. But if there are advanced supercivilizations possessing such mind-boggling sources of energy, they seem not to be using them. If they were, we should see them doing it. We have not, this far, observed anything that would point to the existence of very major sources of energy still unknown to us. We can more or less explain and roughly understand everything that we can see at the sky.

So, on the basis of the existing evidence, it is reasonable to assume, that the more advanced civilizations, the cosmic sages, are largely using solar power. It is also likely that they are concentrating it by parabolic reflectors, solar troughs, Fresnel lenses or something like this. If they are using parabolic reflectors, they are most probably using them, or at least some of them, also as radio telescopes. This means that many of such civilizations might have very large ears, like what we will have after we have moved to solar economy. One million Arecibos, one hundred million Arecibos, or something like that. In other words, such civilizations can detect radio messages even if they are sent with relatively little power.

So we could divide our transmissions into two categories. We should beam the 18-bit-message (meant for the human-like morons still using nuclear power and fossil fuels) into space with enormous power. But we could also send a much more detailed and richer message, consisting of billions or trillions of bits, towards the distant galaxies with a million times less power. The 18-bit-message would act as a marker buoy also for the advanced solar civilizations.

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ANNEX

UNFOUNDED FEARS: WHY THE WAR OF THE WORLDS IS NOT AN ISSUE?

Hollywood movies like Independence Day and the War of the Worlds have conditioned us to fear extraterrestrial civilizations. What if they are hostile? What if they come and attack us or eat us if they find out that we are here?

Fortunately, these fears do not have much to do with reality. It is very difficult if not impossible to move, physically, from one solar system to another within a reasonable amount of time, not to say anything about intergalactic space travel.

Compared with space travel, identifying planets which harbour life is very easy indeed. We already possess technology by which we can soon identify all the living planets within the million or so nearest solar systems. The easiest way is to search for atmospheres which contain both methane and free oxygen. The simultaneous existence of both substances is almost certain proof about existence of life on the planet.

The European Space Agency (ESA) is supposed to launch, during the year 2016 or 2018, an optical space interferometer called Darwin. Darwin would consist of six small telescopes flying within a distance of one kilometre from each other. Linked to each other they would, together, form a telescope in some ways equivalent to a one-kilometre-wide parabolic mirror. If Darwin will be sent, it will be able to detect planetary systems at least 50 light-years away and analyze their chemical composition with a high-resolution spectrometer.

After one hundred years, we might be able to send a similar fleet of space probes separated with a distance of a thousand kilometres, instead of only a thousand metres. Such a thousand-kilometre-wide interferometer should already be able to locate, at least in theory, oxygen- and methane-containing atmospheres 50,000 light-years from our own solar system.

Or, if we find out that it is too difficult to operate a one thousand-kilometre-wide optical interferometer in space, we might send a Darwin-like-instrument to the solar focus, and let the Sun’s gravitational lens increase its power by a factor of one hundred million.

But by 2200 we might already have thousand-kilometre-wide interferometers at the Sun’s focal point, 80 billion kilometres from Earth. Such instruments might be able to detect life-bearing planets from a mind-boggling distance of 500,000,000 light-years. At least theoretically. Also, as we have seen, it is theoretically possible to intercept and eavesdrop even unintentional radio and television transmissions from vast distances.

The Earth has harboured life for at least 3,600 million years. For at least three billion years our planet has had both methane and free oxygen. For three billion years it has been broadcasting to space the signature of life, showing to everybody that we have a living, habitable planet in our solar system.

Three thousand million years is a very long time. During this time our solar system has completed fifteen full rounds around the Center of our Galaxy. If there are ancient civilizations in our Galaxy, they have known about the existence of Earth for a long time. We might ourselves be able to identify all the atmospheres of living planets in our Galaxy during the next one hundred years. So if there were advanced technological civilizations capable of easy interstellar travel, they would have reached our solar system, long time ago. This far none of them have come, which does not prove that there are no other technological civilizations in the Galaxy. It only confirms what we already know: interstellar flights are very difficult.

The US government funded, in 1957-65, a project called Orion, which was developing nuclear pulse propulsion for manned, interplanetary space flights to Mars and to the moons of Jupiter and Saturn. The project also designed, on paper, an interstellar version of the nuclear spaceship. However, the interstellar SuperOrion would have required 25 million megaton-class nuclear bombs to reach Alpha Centauri in 150 years, thousands of times more than the humanity's combined nuclear arsenal at the height of the Cold War. Also, SuperOrion would have went straight through the Alpha Centauri system. It would not have been able to stop, not to say anything about turning back (DYSON, 2002).

The radioactive fallout from the explosions that would have pushed the SuperOrion towards Alpha Centauri would have been ejected to the opposite direction, towards our own solar system. And the fallout would have been in the form of plasma, ions which would have been effectively captured by the magnetic field of our home planet.

In 1976 the British Interplanetary Society developed a slightly different version of the same idea, called Daedalus. Daedalus would have flown to Barnard's star in 49 years. It would have required 30,000 million small nuclear bombs. But it would have been an unmanned space probe and it would, also, have flown through the Barnard's star solar system in a few hours (RIDPATH, 1979). It can be asked, whether this would have been worth increasing the combined number of nuclear bombs that have ever been produced by a factor of one million.

Other scientists have proposed, that we could push a spaceship equipped with large solar sails to the stars with a large array of powerful lasers. However, to reach Alpha Centauri within forty years would require 75,000 terawatts of continuously operating lasers (FORWARD and DAVIS, 1990). This is 7,500 times more than the humanity's present energy consumption and 40,000 times our present production of electricity.

All this should be in the form of continuous laser light, and the lasers should be installed in space. Apollo flights delivered material to Moon with the marginal transportation cost of USD 2 million per kilogram and we can deliver mass to the lowest orbit, 200 kilometres above the Earth's surface, with USD 15,000 per kilogram. However, we do not yet know how to produce continuous laser light, we can only produce very short pulses of laser. At the moment we need roughly a Colosseum-sized array of lasers to produce the average power of one kilowatt of laser light. 75,000 billion Colosseum-sized laser arrays in space?

Even these figures are a bit optimistic, because they do not yet include all the important factors. In practise the space ships should be much heavier, because they require extensive radiation and meteorite shields. A space ship travelling with the speed of a million kilometres per hour, roughly one thousandth of the speed of light, would reach Proxima Centauri in 4,000 years. However, if it collided with a dust particle with a mass of one gram, the result would be an explosion comparable to the detonation of six kilograms of TNT. If we accelerated the speed so much that the ship would reach Proxima Centauri in mere 40 years, the same dust particle would explode like 60 kilotons of TNT. A small meteorite weighing one kilogram would cause a 60-megaton explosion.

Besides the dust there are also molecules and on average one hydrogen atom for each cubic centimetre in the interstellar space. Hydrogen atoms and molecules are much too little to cause any actual explosions, but their number is very large and they will have a strong eroding impact on vehicles travelling in the space with a great speed.

In other words, finding habitable planets is easy, but reaching them is not. Reaching a living planet requires not only billions but literally trillions of times more resources than merely finding it. So, in reality there is no reason to worry.