OVERVIEW ON FIELDS RELATED TO RENEWABLE ENERGIES RELEVANT FOR NORTH-SOUTH COLLABORATIONS

New perspectives of co-development

P. Saint-Grégoire

The University of Nîmes
Department of Physics
30021 NIMES cedex 01, FRANCE
Telephone: +33 675 64 02 29; e-mail: pstgregoire@gmail.com

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In the perspective of a considerable expansion of research and use of renewable energies in near future, we present here an overview on fields and subjects that should be important in the frame of north-south collaborations, having particularly in mind the euro-african zone. This paper aims at favouring the creation of research networks in related topics and attracting attention on promising possibilities to develop southern countries and to setup a sustainable development.

Keywords: solar powerplants; energy of biomass; economical analysis in renewable energy; ecology of air atmosphere and space; philosophy problems

Pierre Saint-Grégoire

Organization: University professor, The University of Nîmes (France)
Education: Doctorat d'Etat (~habilitation), University Montpellier 2, 1985; PhD, University Montpellier 2, 1981, both in solid state physics.
Experience: CNRS researcher (1981-1997); University professor in Yaoundé (Cameroon) and Lomé (Togo) universities (1990-1992); University professor in Toulon university (1997-2008); General chairman of the international symposium ISFD7 and member of the international advisory committee; Adviser of the Minister of Education in Central African Republic for high education and research (2002-2006); Deputy Editor-in-Chief and member of experts board of the ISJAEE.
Main range of scientific interests: physics of solid state phase transitions, ferroelectrics, incommensurate phases, renewable energies, physics and sciences for the development.
Publications: about 100 papers in international scientific journals, 50 communications in scientific meetings, edition of 4 volumes of scientific journals.

Introduction

The fields related to renewable energies that are relevant for north-south (and south-north) collaborations are numerous, and it is out of the scope of this paper to give details in all of them. I shall nevertheless give a non-exhaustive overview on what seems to me the most important ones. I would like to mention also that this paper is written in an unusual way concerning references: instead of giving in bibliography the references of original papers that would not be accessible to most of southern scientists, I have preferred to list also internet addresses and references of papers in open access journals. This is for a practical reason, namely to provide in direction of the south, informations that may be used actually. I apologize with respect to authors who should be citated and are not because their paper is published in expensive journals, out of the means of universities of southern countries. Another objective of this paper is to attract attention on topics that seems to me important for the development of southern countries, and for the sustainable development of north; it is why this paper contains also a call for the constitution of research networks in the different topics.

Among different topics, I shall not neglect those based on very simple technology, even if they are not fashionable, because they may be important for the scientific activities in the south, and because they are in favour of an environmental reequilibrium of the corresponding regions. As an example, we can mention solar cookers, and, at a higher level, small or medium solar furnaces. The production of electricity using photovoltaic effect will also be discussed, together with the thermal powerplants and biodiesels.

Universities of the southern countries cannot compete with those of the most developed countries, but they have an important role to play in the development of renewable energies, in particular in fields that are not considered by northern research groups. One of the objectives of this paper is to attract attention on actions that may be pursued only by universities of southern countries, and on fields that may be developed in close contact and collaborations between institutes on both sites of Mediterranean Sea.

The present situation

A trivial constat is that in the euro-african zone, the solar resources are in the southern countries (Fig. 1), and the strongest needs and technology are in northern ones. However, in such poorly illuminated countries as Germany, there are at present time more solar powerplants than in the south (even if this will certainly change in future, with the development of powerplants in Spain, Portugal, Italy, etc), and the use of photovoltaic devices and solar thermal devices is the most developed. Such a situation is more due to a political decision than to a market mechanism: in Germany, the price of photovoltaic solar electricity is fixed at 0.50 € for 1 kW·h, which allows to planify the construction of photovoltaic solar powerplants at relatively high latitude. From financial point of view, the installation cost of PV powerplants is nevertheless still too high to attract massively investors, with a payback around 10 years and an environmental payback around half that time. The main challenge is therefore to decrease the cost of the "solar kW·h" in order to allow the spontaneous expansion of this production mode.
There is now a quasi consensus to attribute the cause of climate global change to the greenhouse gases emissions [1], mainly from industrial countries, and this led the EU to drastic decisions, namely to decrease the greenhouse gases emissions by 80 % before 2050, and to increase the part of renewable energies to 20 % by 2020 [2, 3]. In future, such political decisions could even be stronger if, as predicted, the global warming is more pronounced and climate changes are more evident. Environmental problems are now already considered by all political parties and play an important role in the public opinion, as observed recently in France with "*Grenelle de l'Environnement*" [4], an open meeting organized by the french government on environmental problems.
In the south, under-industrialized, environmental questions are not yet a priority, and the use of renewable energies, in spite of its obvious interest due to the strong solar radiation, remains marginal. In most african countries, the main source of electricity production is still based on fossil fuel. Poverty, finance problems, and external constraints hinder generally the southern countries to invest in the sector of energy. In many countries, extreme poverty is such that more than 95 % of the population do not have access at all to electricity, and the unique accessible energy source is the wood, thus leading to deforestation and to a considerable environment degradation. This has also as consequence, that mainly among the young generation, a lot have a strong will to emigrate, first within the country to big towns, and secondly to the north.
In a paradoxical way, the south may be a considerable source of energy for the future, obtained from solar powerplants, and from the potential exploitation of biofuels, both having positive impacts for at least two reasons: (i) they would tend to reequilibriate the planet with an energy harvesting without greenhouse gases and any environmental induced problem, (ii) they would considerably improve the economies and standard of life in southern countries.
In order to establish a new, more equitable, and sustainable order at a global level, the exploitation of solar resources and the exportation of energy from Africa, should reasonably be organized in future.
In the following, we mention the pharaonic projects that should be implemented in next years/decades, as a result of heavy financial investments, but we pay also attention to the projects that may be developed at a more modest scale, involving universities, non governmental organizations, researchers, and that may nevertheless have a strong environmental and economical impact. The next paragraph lists the different fields to be considered.

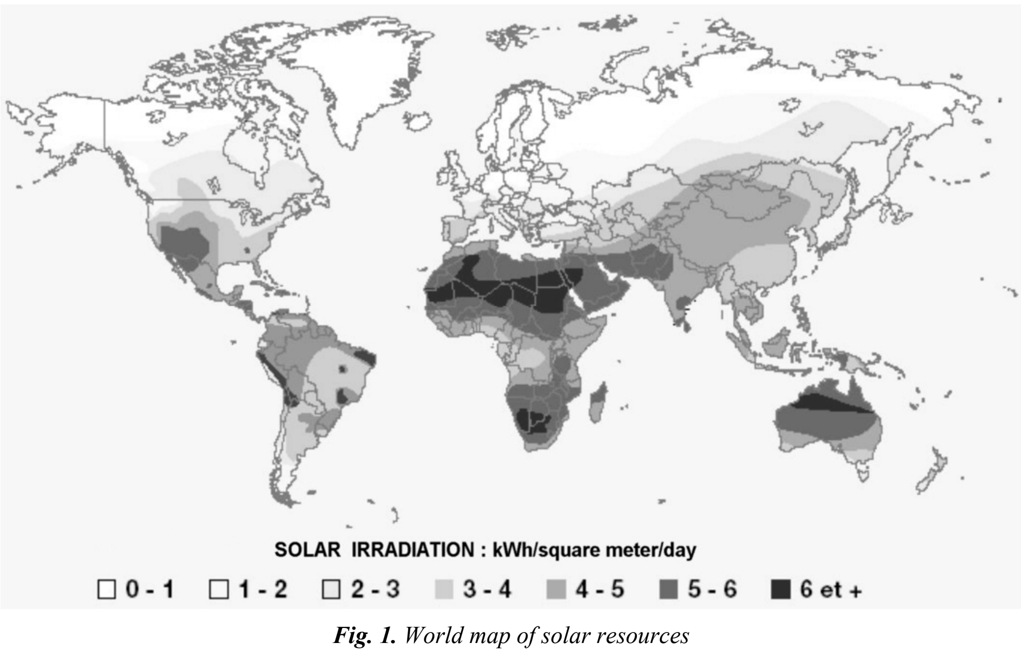


Fig. 1. *World map of solar resources*

Solar energy

Solar thermal devices

Solar concentration

Solar concentration is performed through an optical device, for collecting thermal energy at the level of a receiver. The concentration of the system is defined as the ratio between the area of the projected (collecting) surface of the optical device (in principle a lens, a mirror, or sets of lenses or mirrors) and the area of the receiver. In most cases, the optical device is nowadays constituted of mirrors. The thermal efficiency (the ratio between harvested thermal energy and incoming energy) is rather high in such systems, around 70 %. Losses are conductive, convective and radiative, and depend on the different geometries that are used, mainly for the receiver.

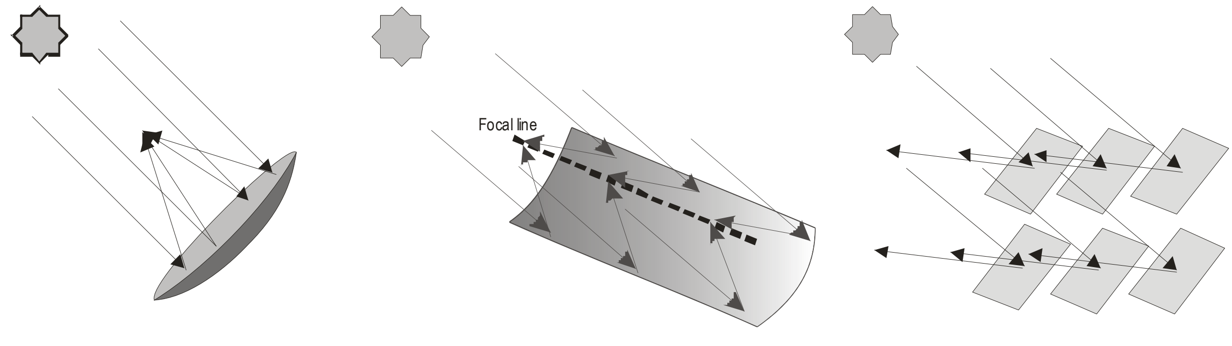
Different systems may be used in solar concentration [5]: the "parabolic-dish" reflectors (Fig. 2, *a*), the "parabolic-trough" (Fig. 2, *b*) and the sets of heliostats (Fig. 2, *c*).

The "parabolic dish" is based on a revolution paraboloid, which is well known for giving a perfect image of a point object situated at infinity on the axis. This system that needs a device for tracking the sun, achieves a high concentration, of several thousands, that may in principle be higher that 10^4. In practice, taking account the imperfections of the reflecting surface, the concentration ranges between 3000 and 5000.

In the parabolic-trough, a section of the mirror is parabolic, and in the perpendicular direction, it is linear: the focus of this device is therefore linear, which reduces the concentration to a value in practice close to one hundred. The system may be oriented in two manners: either north-south, with a continuous tracking of the sun during the day, or east-west with only a slight regular readjustment of the orientation.

Finally, in other technical solutions for achieving solar concentration, several mirrors (heliostats) can be used to focus continuously the light of the sun on a central point. Each mirror must track the sun in such a way that the image remains in a given direction. A compromise has to be found for the size of mirrors, since large mirrors need expensive bases and tracking devices, whereas smaller mirrors need simpler and hence cheaper devices, but should be more numerous.

Heliostats can be oriented either towards a receiver or towards a mirror, generally vertical and of paraboloid shape.



a *b* *c*

Fig. 2. *Different systems used for solar concentration: a – parabolic-dish, b – parabolic-trough, c – set of heliostats*

Thermal powerplants

Thermal powerplants designed for the production of electricity are based on one of the three concentrating systems presented above for collecting thermal energy, and on its transformation into mechanical energy and then to electricity.

Fig. 3. *The parabolic dish reflector in Odeillo (CNRS laboratory, South of France), equipped with a Stirling engine at the focus*

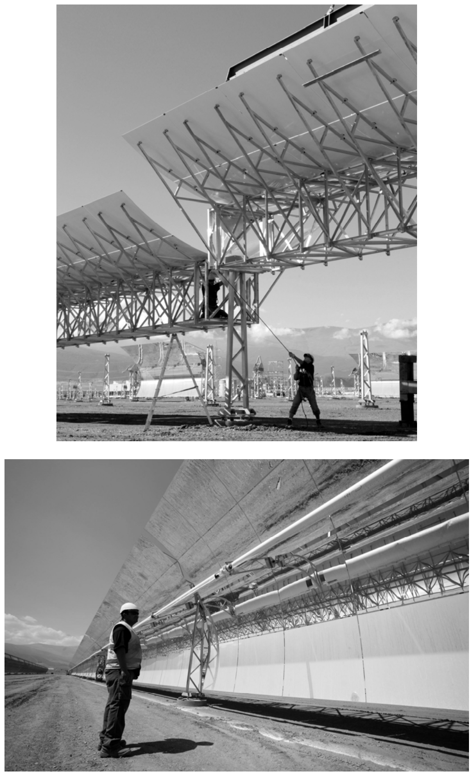
The idea to obtain mechanical energy from the sun was first made real by Auguste Mouchot who placed a steam engine at the focus of a parabolic mirror. He presented his invention at the Universal Exposition in Paris in 1878. In 1907, the trough parabolic collector was shown to be able to produce steam (a patent of Maier and Remshalden), and five years later, a plant was built in Meadi in Egypt.

Thereafter, it is only around 1970s that solar thermal projects began to be undertaken again, using the different concentration geometries.

Up to now, the best overall efficiency is obtained with parabolic-dish concentration, with a Stirling engine at the focus (see for instance Fig. 3). Efficiencies between 20 and 30 % were reported [6], but the weakness of this system lies in the Stirling engine that has still nowadays a limited operation time. Moreover, for obvious reasons, the size of the system is limited and devices are generally of few square meters; collecting more energy is then achieved by putting together several parabolic-

dish devices. This technical solution may be interesting in future for producing small to large quantities of electricity, but it will remain as a project as far as Stirling engines will not be more reliable. Another weakness of that system, is that it does not allow any storage of thermal energy, so that it is able to work only during directly illuminated day time. This may nevertheless be interesting in warm countries where the peak of electricity consumption is due to air conditioning and occurs precisely at about the same moments.
The concentration using heliostats has led to an architecture of solar powerplants where energy is focused onto a receiver located at the top of a tower. This was the case of the early powerplants CRS and CESA in Spain, Sunshine in Japan, Aurelios in Italy, Solar One, MSEE in USA, Themis in France, and C3C in Soviet Union (nowadays in Ukraina). All these powerplants were built between 1981 and 1985. The concentration for these powerplants are of several hundreds, from approximately 250 (Solar One, circular field of heliostats) to 700 for Themis (field of heliostats in the north of the tower).
Different materials were thus tested for the heat transfer and heat storage: water-steam, sodium, and molten salts. Each technology has its interests and difficulties. Molten salts, in solid state at ambient temperature, need to be heated well above 100 °C (140 for Themis, 220 for Solar Two) in the whole circuit, which may appear as a delicate task. This needs external energy, and also energy is consumed to insure the motion of the salts in the circuits. At the opposite, molten salts are well suited for the thermal storage at high temperature (between 550 and 1000 °C). The thermal efficiency of this type of system is around 73 %, and the maximal global efficiency (conversion solar energy into electricity) is about 23 %. Activities of research and development continue for this technology, see for instance the paper by Ferrière in this volume.
Finally, the most modest, with respect to expected efficiencies and technology, but also the most robust models, commercially available, are based on parabolic-trough reflectors. Solar powerplants of this type are exploited in USA in the desert of Mojave, till the mid 80s and have an overall power of 354 MW_e, divided in blocks between 30 to 80 MW_e. Nowadays, this technology is the cheapest one. It was first produced in series in the mid 1980s by the company Luz International which installed the mentioned powerplants in USA. Thereafter, this company disappeared, and more recently, the activity was pursued by Solar Millenium [7] and few others.
In this type of powerplant, the receiver lies in a glass tube in which vacuum is achieved in order to make the thermal losses at minimum. The thermal transfer fluid is here heated between 300 and 550 °C, it may be a synthetic oil, molten salts, or water. Such systems can still work in absence of radiation, due to thermal storage devices allowing autonomy and possibility to continue delivering electricity during periods depending on the storage capacity.

The mirrows for the plants come from Flabeg, manufacturer of technical glass. The concave mirrors are made from silver-coated white glass which is about 4 to 5 mm thick. The elementary mirrors are 2 to 2.8 square meters in size. Over 98 % of the solar radiation that arrives at the mirrors is reflected onto the absorber pipe along the focal line of the collectors. For further information see www.flabeg.com
The cost of this technology, expressed with respect to the electric power, depends naturally on the location of the power plant and the integration of thermal storages. Taking as an example one of the Andasol powerplants (South of Spain) which are currently being built, the capital expenditure is of about 300 millions €, and the electricity output will be of about 180 GW·h per year (Fig. 4).



Courtesy of Gollmer/Solar Millennium

Fig. 4. *Andasol powerplant in the south of Spain: mounting collectors*

Solar Millennium projects a decrease of prices in future, due to economies of scale. Moreover, investments in research and development, made by Solar Millennium (Fig. 5), are intended to reduce the costs of solar thermal power generation considerably during the next years. This can be achieved by the optimization of parabolic trough collectors by the use of direct steam generation. Water is to be directly vaporized in the absorber pipes located in the focal line of the collectors. Up to now a synthetic, liquid heat transfer medium is conducted through the absorber pipes and this medium emits its heat via heat exchangers to a steam cycle. If direct steam generation proves to be a reasonable alternative, the cycle with the heat transfer medium liquid and the heat

exchangers will no longer be needed. This will increase the yield of parabolic trough powerplants.
Another way to increase efficiency of solar thermal power plants is to improve the collector design as a whole. Therefore, Solar Millenium has developed a new generation of parabolic trough collectors. A series of innovations means that the investment costs for solar collectors will be reduced by 15 to 20 percent in the future (for details, see the press release [8]).
In future, the concentrated solar power (CSP) should therefore occupy a bigger place in the production of electricity.

Courtesy of Solar Millennium AG

***Fig. 5.** Parabolic-trough collectors in working orientation*

In various countries, interest for such an electricity production is renewed in reason of the recent oil price increase and perspectives of further increase in future. In France, a small company, SOLAR EUROMED, has started building a prototype of solar powerplant with parabolic trough concentrators in a moderately illuminated region (the south of France), on the basis of experience elaborated at Themis.
The building of such powerplants in southern countries has started. First, of course, with Andasol in Spain, but also on the african continent. Solar Millennium will build in Kuraymat, approximately 95 kilometers south of Cairo (Egypt), a hybrid powerplant using both natural gas and solar power to produce a total output of 150 MW, with solar field of parabolic troughs with a total mirror surface area of approximately 130,000 square meters. Other countries of Maghreb, Algeria and Morocco in particular, will also build such powerplants.
The overall efficiency of such powerplants is now significantly above 20 %, with a net annual efficiency around 14 %.
Taking into account the high direct radiation received in some african regions, around 2900 kW·h/m^2 per year, it may be extrapolated that the production costs will be in the medium term around 0.6-0.7 €/kW·h and that at the same time the desertic regions of Africa should reasonably be used for electricity production, since it is now possible, using High Voltage Direct Current lines (HVDC) to carry energy over large distances without big losses. This production may then be purely solar, and not hybrid as in less favourable regions.
Energy may also be exported as hydrogen produced from solar energy. The water electrolysis using electricity produced from the sun will compete with the production via water decomposition at high temperature (in solar furnace) using different thermochemical cycles [9]. This still needs research. The interest of such projects will depend particularly on the progresses of fuel cells technology in future.
The quantity of electricity produced in this way will be determined not by natural constraints since Sahara could allow the production of much more than the present world consumption of electricity, but by political decisions and by financial volumes that may be dedicated to such projects. A relatively small ratio of the Saharian area, if covered with thermal powerplants, would produce the total energy consumption of Europe including Russia.
We only stress that such a production of electricity would avoid the emission of huge quantities of greenhouse gases, and that installation of powerplants in Africa would reduce the big gap of standards of life between northern and southern countries, that may be in future at the origin of big political instabilities in wide zones, and of uncontrolled migrations.
Till now, the construction of powerplants is due to decisions of particular countries, and projections in future on this basis led Greenpeace to predict that CSP could allow to furnish 5 % of the world production of electricity by 2040 (see the whole document of Greenpeace on the Concentrated Solar Thermal [10]); however, in future it would be highly desirable that countries associate efforts and cooperate around such a clean production of electricity and hydrogen, in order to achieve the largest possible production. Electricity production at zero emission of greenhouse gases is indeed possible with CSP, and at the same time may be a considerable factor of global economical growth since in african countries the (economic) marginal propensity is very high.
Besides such pharaonic projects, universities of southern countries should pay attention to research and development on CSP for rural production of electricity. This supposes in particular to design and test smaller size systems, and to look for solutions with minimal costs, even if efficiency is consequently reduced.

Solar furnaces

The first model of solar furnace for scientific purposes was built in Mont-Louis in the south of France in 1949 by Prof. Louis Trombe. This furnace, of more than 50 kW_{th} is still active and is used for scientific culture and applications [11]. Later on, between 1963 and 1969, a larger furnace was built close to this one, in Odeillo (Fig. 6), under the responsibility of CNRS [12]. The former is composed of a vertical parabolic mirror and one heliostat, whereas the latter, much larger, is composed of a large parabolic reflector composed itself of 9500 mirrors fixed to the frontage of a building facing a field of 63 heliostats of 45 square meters each. The power of this furnace reaches 1 GW_{th} and the working temperature at the focus may be above 3500 °C.

Both furnaces have widely demonstrated the possibility to use solar energy in material science and for applied purposes. Mention in particular applications in the synthesis of nanomaterials, in metallurgy, in burning, high temperature tests of materials, etc.

It is out of present possibilities of southern countries to build such a large furnace as that of Odeillo. However, furnaces of approximately the size of Mont-Louis furnace, with more modest costs may be planned. We would like to mention a very interesting project that follows convincing tests performed at Mont-Louis, namely the construction of a furnace in Morocco for burning traditional ceramics. Tests of burning ceramics using solar energy appeared positive, with practically no loss of items, and with very good esthetic qualities of the burned ceramics (see in [11]).

Universities of southern countries should perform research on the construction of solar furnaces for local purposes (metallurgy, burning ceramics, bricks, etc) following two directions: (i) design geometries eventually more proper to intertropical situations, (ii) reduce the costs, for instance by using local materials and cheap materials for mirrors – aluminum foils, plastic mirrors, etc.

The widespread use of such furnaces could indeed considerably reduce the environmental pressure, as will be seen in **Environmental impacts**.

Solar cookers and solar dryers

Solar cookers are examples of very simple devices [13] that could have a very strong impact on environment. Several models exist, either using the solar concentration on cooking recipients using a reflector, or using greenhouse effect in a box closed with glass and internally covered with a reflector (the cooking recipient absorbs light in both cases). Research in southern universities could be performed with the aims to increase the performances of these devices, to reduce the costs (for instance by using local materials in the conception), and to study carefully the appropriation by population and the preservation of woods that follows the use of these devices. In such studies, it is important to approach the situation with different points of view, and in particular from those of physics, anthropology, biology, economy.

Fig. 6. *The solar furnace of CNRS in Odeillo (South of France).*
A large parabolic reflector constituted of 9500 mirrors is facing a field of heliostats on the right, seen from the back

Photovoltaic cells, and photovoltageïc powerplants

If more and more photovoltaic powerplants and houses are built in Europe in reason of state helps, this type of project has not yet been reached Africa where its future will depend on the cost of such devices, at present much too high to be widespread. Mainly foreigners or international organizations do install such devices, for the electrical supply of isolated sites or for avoiding problems of supply interruptions. The Rwanda government has nevertheless shown interest for such installations, by taking the decision of building solar photovoltaic powerplants,

starting in the neighbourhood of the capital Kigali, at 2500 m high. This country, where 99.3 % of the population do not have access to electricity, is the first for developing such an approach, in the frame of the Germany-Rwanda cooperation (more precisely with Pallatinat) [14].
The challenge with photovoltaic cells is nowadays to attain a steep decrease of costs.

Locks with silicon cells

The technology of silicon cells is robust and reliable, with durability of cells around 25 to 30 years, and efficiencies that do not decrease too strongly all along the life of cells. The costs are nevertheless too high to be widespread and to answer to the needs in the south, or to market mechanisms in the north. It is well known that about 70 % of the cost of a silicon solar cell is the material itself, so that these cells are strongly dependent on the price of Si, the remaining part being related to the production process. To overcome these inconvenients, other photovoltaic devices have been designed, and exploration of new technologies has begun [15].

Second and third generation cells

In the second generation cells the problem of cost of basic materials has been overcome since these devices are based on thin films. Nowadays, there are several technologies and materials used in the production of these cells: mainly amorphous and microcrystalline silicon, CdTe, CIS ($CuInSe_2$ and related compounds) [16, 17].
The third generation cells [18, 19] are based on research in two opposite directions: (i) reducing price of cells with respect to the nominal power by increasing the efficiency at nearly constant cost, (ii) reducing considerably the costs even if efficiency is lowered.
Increasing the efficiency above the Schockley-Queisser limit (~ 30 %) can be realized with high technology devices: quantum wells (quantum dots, quantum ropes, etc) devices and tandem cells (multilayers), both based on the absorption of light in a wide spectrum [20]. In the tandem cell for instance, a photon that is not absorbed in a first layer is absorbed in the following or in one of the next ones (multispectrum cells). Reported efficiencies of existing devices are now above 40 %, a value that lets hope that the compatibility of these cells with solar concentration will be soon possible. These cells will certainly remain expensive in future.
In the opposite direction, the costs are strongly lowered because the technologies are no more based on classical semiconductor processes, but are very simple. This is achieved with polymer solar cells, nanocrystal solar cells, Dye-sensitized solar cells ("DSSC") [21], and photoelectrochemical cells [22]. Efficiencies around 10 % begin to be reached for such cells, with expected costs much lower than for the silicon technologies.

Interesting perspectives

African, and even many european universities cannot compete in the field of high technology third generation cells that may be designed and realized only in few centers. However, some perspectives seem interesting in the frame of cooperations.
A simple research direction is to increase the actual efficiency by tracking the sun [22, 23]: the solar pannels are then always oriented in an optimal direction, which may increase by 20 to 30 % the global efficiency of the device. Another simple idea is to conjugate the device with a concentration of the incoming light on the photovoltaic pannel, and thus harvest more electrical power. However, in "low efficiency cells", the energy that is not converted into electricity is transformed into heat, and the cells will rapidly reach too high temperatures, in particular in Africa where the ambient temperature is often above 30 °C during the day. Such devices should thus include displays to dissipate the heat that is necessarily generated, which could be performed by a simultaneous water heating. Universities of southern countries should perform such studies that are not so pertinent in other places and that would be fruitful for lowering the costs of PV pannels in Africa.
Another important direction, concerns the DSSC: these cells can be realized without major technological investment, and should be studied in laboratories of southern countries in the frame of international collaborations. Even at low efficiencies (for instance around 8 %), these cells of very low cost, that could be produced in southern countries, could very advantageously be used in Africa where the solar irradiation is strong and where space is generally available.
Research studies on the conception of such cells in the local conditions, and of their durability in real conditions should be performed. This may also be an interesting research direction in the frame of international cooperation between southern and northern countries.

Possible biodiesel production

Biofuels are the object of controversial papers, because their environmental bilan is not clearly positive. In northern countries where agriculture is highly productive because it consumes a lot of energy, it is relevant to keep in mind the cost in term of CO_2 emission, for evaluating the interest of producing biofuels. In southern countries, classical biofuels as those derived from sugars have clear negative consequences on environment: destruction of vast quantities of forests to replace the removed trees by cultures, and rarefaction of food in reason of the deviation towards energy production. Prices of such basic products as sugar, and various cereals, are strongly sensitive on the politics of energy, and it may be dangerous to develop such biofuels as those mentioned without an extreme caution.
However, all biofuels do not seem to be dangerous for the environment and for the economical equilibrium of the society. In particular, a very interesting plant can grow in tropical and subtropical regions, is robust, and its seeds may produce an oil that can be used as biodiesel. This plant, named "*jatropha curcas*", belongs to the family of euphorbiaceae [25], and though being

originary from Caribbean, it has been spred in nearly all tropical and subtropical regions: in Asia, Africa, America. It is currently advantageously used in hedges, and for stabilizing soils against erosion.
The oil, present in the seeds to an amount till 40 %, has proven to be successfully used in diesel engines without major problem. More and more tropical and subtropical countries have designed projects to grow this plant for the oil production (see for instance [26]).
Jatropha curcas grows rapidly, it may begin to produce seeds after about three years, adapts to different soils and climates (from North Africa – it grows in Egypt for instance, to subtropical and wet regions as Central Africa) and does not need a lot of water. Its productivity is nevertheless variable because it is generally found in a semi wild state and just begins to be domesticated. It ranges between 400 to 800 liters per hectare.
Environmentalists have promoted a project called "*green belt*", where jatropha curcas is apparently absent till now (see [27]). Though the environmental impact of this plant has not been the object of studies in long term, the observation of fields where jatropha curcas is present since many years, does not exhibit environmental problems and at the opposite, shows that it is very useful to protect the vegetation in semi arid places. In Africa, it has also been integrated with other plants, and is currently used as medicament, or for domestic purposes (soap production, oil for lamps...).
Jatropha curcas could change the rural situation in so called Third World by increasing steeply the standard of life at a moment when the price of such products as coffee, cacao, and coton are very low, provided its production be free. In Central America, India, and Mali, for instance, its culture has led to a considerable improvement of the life by giving access for the population, to electricity produced from generators working with biofuels and by giving supplements of incomes, especially as the extraction of oil does not need sophisticated technical means, and is accessible to modest categories of population.
The large scale culture of this plant all around Sahara to stabilize the desert (such a country as Senegal, for instance, looses 50 000 ha of land per year to the profit of desert) should be accompanied by scientific studies to precise the environmental, economical, and human (ethnological and anthropological) impacts. It would at the same time increase the income of the concerned regions: the expected production could amount to 50 billions liters of oil, which corresponds, taking into account the average sale price in internal markets (~ 1 €/l) to 50 billions €. Such a "jatropha green belt" around Sahara to stabilize the desert could concern Mauritania, Senegal, Mali, Burkina Faso, Niger, Chad, Suddan, Ethiopia, Egypt. Without taking into account the human factors, its extension to other countries or other regions more distant from the desert, is sustainable and could allow to reach a production representing a non negligible part of the present world consumption of diesel oil. Since nearly all african countries have soils able to grow jatropha curcas , and most of other intertropical countries also, this favourable situation could in a first period result in a decrease of the international tensions around energy, but at long term lead to a wild competition among producers, with price instabilities. This, especially as diesel production by algae, which is also a realistic perspective, has not been taken into consieration here.
In all cases, the development of such biofuel production, would involve several hundreds of thousands of jobs. This is of course very important for economy in countries where the rate of unemployment is high, and the number of workers in a state of poverty among the young generation has increased in last ten years to 87 %. It should result in a steep global economic growth. Again, as for solar thermal powerplants, the feasability of such a project depends on political decisions and an international project could be initiated in that sense.

Environmental impacts

In many places in Africa, an environmental degradation is reported in the last decades. Causes are of different origins, in some cases phenomena are related to global climate changes, in others they are clearly due to an environmental degradation related to a direct human intervention. Around capitals and big towns, for instance, a deforestation is generally observed, due to the use of wood, even in town, as main fuel for cooking. Bangui, the capital of Central African Republic, was completely surrounded by dense forests at the beginning of colonialism, whereas forests are nowadays divided and distant of the town by several tens of km.
In this respect, it is important to consider the preservation of vegetation that the use of solar energy can induce. It depends naturally on the density of vegetation.
Consider first solar cookers. Equiping a village of 1000 inhabitants with solar cookers leads each year to the preservation of vegetation over an area of more than 100 ha – (1 million square meters), for an initial cost smaller than 10 000 €, in regions between forest and savana with an intermediate density of trees. In such fragile environments as sahelian regions, this area may be much larger and be around 1000 ha.
In the example of burning ceramics using a solar furnace of 50 kW_{th}, it is estimated that approximately 600 cubic meters of ceramics can be burned in one year, which corresponds to the preservation of 2000 T of wood. Generalizing the use of such devices for metallurgy, bricks or ceramics burning, and cooking, would therefore lead to a considerable environment preservation, in regions often initially very fragil.
Concerning powerplants, it is important to have in mind their payoff. The financial payoff determines the spontaneous feasability by investors, and we shall rather consider here the "environmental payoff". For a silicon powerplant, the financial payoff is nowadays somewhat less than 10 years, whereas the environmental payoff is

about twice shorter. Producing Si indeed induces direct emission of CO_2 (carboreduction of SiO_2) and needs energy for processing the cells. It is estimated that the cell will compensate these environmental costs after operating approximately 5 years. In the case of thermal powerplants, the environmental payoff is considerably reduced since it is estimated to be around 5 months, and after that period, the gain is quasi total during the whole operating time, estimated around 20-30 years. Moreover, in comparison to a modern coal fired power plant, a 50 MW Andasol-type parabolic trough power plant saves 149,000 tons of CO_2 per year.

As far as integration of powerplants in their environment is concerned, mention the problem in saharian zones, where dust will deposit on mirrors and strong winds carrying sands will damage the optics. Solutions for protecting mirrors has to be found, otherwise powerplants should be more advantageously located in regions (sahelian) where the agressivity would be reduced whereas the irradiation is of the same order.

Thermal powerplants should therefore advantageously be developed in Africa. Moreover, in arid regions where plants do not survive easily in reason of a too strong solar irradiation, the shadow of reflectors would play a protection role and permit their growth and culture, especially as solar powerplants can be used also for the simultaneous desalination of water. Such possibilities are naturally important in such countries as South of Morocco, Mauritania, and Senegal or in those at the east side of Africa at the same latitude.

Finally, in the case of the considered possibility of biodiesel production from the jatropha curcas plants, mention that the environmental gain is also important in reason of the stabilization of soils that would follow from the culture of this species, and because these plants were already observed to have a protection role on other plants. Besides, carbon is naturally fixed in the leaves, the branches, and the roots of the plants, so that the carbon bilan of such a culture is favourable since the very beginning of the process. Moreover, biodiesel obtained from this plant is known to be much less aggressive and is exempt of some pollutants contained in petroleum derived diesels.

Risks, erroneous “good ideas”, needs for a respectous approach with different points of view

In the past, several “good ideas” or projects recommended by experts have appeared as disastrous in Africa, the reason being generally due to partial analyses of the situations and disregards of local opinions. Neglecting aspects related to education led also to failures.

As an example, mention what happened in some places with the solar pumping of water; after installation, population and herds have concentrated around equipped wells, which led to the degradation of vegetation all around, and to the abandonment of traditional wells working manually. When the pumping equipments did not work anymore, the vegetal degradation appeared irreversible, and the traditional wells were unable to work anymore.

Concerning any introduced device, a very cautious attitude should be adopted. A strategy that may appear good, though not sufficient by itself, is to involve students in the development of their own original human environment: they know the situation, and as such, can explain the interests of introduced devices. They also may give pertinent opinions. The distribution of solar cookers, for instance, in regions where people use to cook only inside the houses (this has happened actually, and cookers were of course not used) leads to a failure that may be predicted by persons knowing the habits.

Finally, the problem of maintenance is very important in geographical zones where the distances are large. It is crucial to analyse all the possible causes of failures in order to prepare missing items, to form local personal for simple maintenance, and to set up a hierarchy of maintenance personals as a function of the degree of complexity of the reparation to be performed on the site: simple reparations may thus be performed rapidly by local interveners, and more complex failures will need equipments and interveners from more distant places.

Conclusion

In future, the situation of Africa with respect to energy should be at the center of a sustainable development approach both for Africa and for Europe: in the south, the generalisation of such simple and cheap solar devices as solar cookers would strongly reduce the pressure on environment, of populations that otherwise use wood, and the use of solar furnaces (in particular concerning the burning of ceramics, bricks, etc) would also avoid the degradation of vegetation over large zones.

Both the implantation of solar powerplants and of fields of jatropha curcas would considerably increase the incomes of the african continent, and at the same time lead to a huge progress in diminishing the emission of greenhouse gases since Africa is able to furnish enough energy for Europe and for itself. This would be made possible by raising large quantities of capital at this purpose, but not doing it as soon as possible would certainly cost much more to the humanity. Moreover, at a moment when in the north the question of emigration is considered by some as a problem, creating a fund for setting up such projects would favour the economical development of southern countries, and lead to the reduction of the emigration pressure.

Such a scheme, where the production of solar electricity is performed in arid zones and where biodiesel plants are grown, can be developped in nearly all continents, and seems to be the unique possibility for avoiding the disaster of the global warming in future, precisely at the moment where the permafrost and antartic ices melting is confirmed and may accelerate the phenomena [27, 28].

International organizations, governments, and various partners should understand that the question of energy is crucial in the development of the african continent and for the world equilibrium from several viewpoints. Universities in Africa should be encouraged to perform research studies on the topics of energy in relation with the possible perspectives in their country, and should be encouraged also to form engineers able to work in the construction of the powerplants in future.

Concerning south-north cooperation in euro-african zone, it seems pertinent to constitute networks around the following topics: solar concentration, photovoltaics, and biofuels. Interested scientists wishing to take part to such networks are invited to manifest themselves at pstgregoire@gmail.com.

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