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# TOTAL AND GREEN TECHNOLOGY : LARGE AND SMALL ARE MORE BEAUTIFUL TOGETHER

by

**Vincent Schächter**
Director, R&D, Total Gas and New Energies (GEN)

June 22nd, 2011
Report by Élisabeth Bourguinat
Translation by Rachel Marlin

## Overview

In a still unstable industrial and economic context, new energy technologies are growing especially in start-ups which are able to convey scientific progress more rapidly by breakthroughs than large groups. Total Gas and New Energies (Total GEN) aims to be a technology integrator and leader both in the solar photovoltaic sector and in white biotechnology (biotechnology applied to industrial processes). To achieve this, it draws on a network of partners who have been carefully selected from university laboratories and start-ups, and with which it forms joint research teams in order to develop technologies which are of interest to both parties. Total GEN only takes a minority share in the partner start-ups. The start-ups therefore remain independent thereby guaranteeing that they are free to innovate. Building and preserving this balance requires constant attention from both parties with respect to the compatibility of their strategies and to the mutual benefit of the partnership.

# TALK : Vincent Schächter

The Total group is the fifth largest oil company in the world. It operates in 130 countries and employs approximately 100,000 people. The group has four branches ; two upstream (Exploration & Production, Gas & New Energies) and two downstream (Refinery & Marketing, Chemicals), as well as its Trading & Shipping activity.

At the end of 2007, Total took the strategic decision to develop industrial activities in the new energies sector. This decision was not a publicity ploy or a question of economic responsibility, but a desire to prepare for the industrial future of the group appropriately. The Gas & Electricity branch changed its name to Gas & New Energies (GEN) and was given the task of carrying out this new strategy.

Before joining Total in 2009, I had carried out mathematical research, taken part in the creation of a biotechnology company, been IT director at the French Centre for Sequencing (Centre national de séquençage) at Évry, and had been responsible for a laboratory of basic research in life sciences at the French Alternative Energies and Atomic Energy Commission (CEA : Commissariat à l'énergie atomique). I had heard that Total wanted to start a white biotechnology activity and I knew that some of my research on synthetic biology could be applied to bio-fuels and chemical molecules. I made sure that these subjects were strategically important for Total and I decided to 'take the plunge' and applied for a job at Total.

## A strategic subject

There are currently two main reasons why one should be interested in new energies.

The best known reason is the need to combat climate change and to control the greenhouse effect. The International Energy Agency (IEA) drew up several scenarios regarding changes in the emission of greenhouse gases. The difference between the 'business as usual' scenario and the scenario where the emission rate would fall to 450 ppm of $CO_2$ between now and 2030 is 15 gigatonnes of $CO_2$. The IEA estimates that in order to be able to reduce these emissions to this extent, 50 % of our efforts should be directed towards energy efficiency, 17 % towards the carbon capture and sequestration, 9 % towards strengthening nuclear energy and 24 % towards the development of renewable energies and bio-fuels.

However, for an energy company such as Total, there is an even more important reason to be interested in new energies. In spite of very optimistic hypotheses about the exceptional growth of these energies, it will be very difficult to satisfy the global energy demand between 2030 and 2050, not to mention the impact which the Fukushima accident may well have on the future of nuclear energy on a world scale. Despite the expected impending energy shortage, under no circumstances will renewable energies be likely to replace fossil hydrocarbons. It is therefore appropriate for our group to explore new forms of energy while at the same time continuing to use hydrocarbons.

## Integration and differentiation

Having studied various options in the renewable energy field and in the nuclear sector, we decided to concentrate on two strategic areas : energy released from biomass by white biotechnologies, and the solar photovoltaic sector. We also adopted two fundamental principles.

*Integration of the entire value chain*

For each of these two areas, the first principle is integration of the entire value chain starting with the production of the raw materials (biomass in one case, silicon in the other) and finishing with the delivery to the end client (purchasers of bio-fuels or chemical molecules ; purchasers of solar panels or complete solar systems such as solar farms). We think that the margins associated with each of the links in the chain will vary hugely in the coming years depending on development in these fields, which is why it is important to be there from start to finish. Furthermore, with regard to the biomass, access to the resource will be crucial.

*Technological differentiation*

Our second important principle is technological differentiation. In these two areas, technologies change extremely quickly, more in the biomass sector than in the solar field, and this change is likely to transform the value chain. This is why we think that it is essential to build our competitive advantage based on technology.

## The choice of development

The group's aim to be the technological leader in white biotechnologies and in the photovoltaic sector has important implications for research and development (R&D).

We should identify the technological elements which are likely to be 'differentiating' and develop them. However, involving just Total teams to do so would be difficult, and would take too long because there are not many researchers 'at the cutting edge' in the relevant areas, and acquiring technologies which are currently the most promising would not be the best solution because research changes very quickly. Furthermore, the value of start-ups is not only dependent on the technology which has already been developed, but is also linked to the fact that they are led by teams made up of high-quality individuals who are capable of innovating very quickly. However, these teams are more efficient and motivated in a start-up than in a large group. Buying these companies is therefore not a good idea if one does not want to run the risk of a brain-drain in the company.

This is why we prefer the solution of jointly developing technological elements which interest us, by having our teams work with those of our partners on R&D programmes which we devise together. These programmes are often centered at the core of the partner's technology, and therefore require a certain amount of negotiation.

## Aligning interests

Our network of partners has a mixture of start-ups and university laboratories with expertise in four areas : white biotechnologies ; solar photovoltaics ; stationary batteries (which are an important issue for renewable energies) ; and lastly, carbon chemistry (which is linked to the carbon capture and sequestration, and the transformation of $CO_2$).

In choosing our partners, we select segments from different fields which we think are essential and we draw up a map of the other companies currently involved in these areas. We select the best and decide which of them are likely to agree to join us in a constructive partnership. We then have discussions with them to make sure we have mutual interests because our partners must be highly motivated to work with us.

Even a relatively rich start-up has finite resources which limit it to a certain number of research ideas. It cannot necessarily create safety nets by developing further technologies or alternative resources itself. Yet, even though its chances of success on its chosen research paths are higher than for other start-ups, success is never guaranteed. In terms of risk management as opposed to changes in technology, a start-up working alone is therefore not the best configuration. It is better for a lone start-up to have the support of a large group especially if this group does not simply play the role of investor, but can also bring other skills.

On the other hand, there is the very delicate question of intellectual property which often features in discussions. In the case of Amyris (which I will discuss later), we wanted to preserve a degree of flexibility regarding the content of our joint projects, and we only negotiated a framework agreement. Discussions about intellectual property and sharing value are still a part of each of our projects, but this is the price we have to pay for remaining flexible.

## Bioenergies

If Total 'believes' in bio-fuels in the short and medium term, it is largely due to European and American regulations which make it compulsory to incorporate them into fuels. In the long term, bio-fuels also have the advantage of being transportable and therefore can be used in the transport sector, especially for heavy vehicles and aeroplanes which do not function well on electricity.

*Diversification of sources*

The main types of biomass which can be used for the production of energy today are cereal plants, sugar-based plants (such as sugar cane and sorghum) and oleaginous plants, and tomorrow perhaps, depending on technological progress, lignocellulosic fractions of numerous plant species, agricultural and forestry residues, urban waste and microalgae.

Following the sharp rise in food prices in 2007, there was a marked increase in research conducted into the deconstruction of lignocellulose, a so-called 'second generation' biomass, (compared to food plants such as cereals or sugar-based plants which make first generation biofuels). The aim is to break down hemicellulose and cellulose (which are complex and resistant sugar polymers) which ensure the structural composition of plants according to processes which are viable both economically and environmentally.

The field of microalgae and other phototrophs is five to ten years behind research conducted using soil-based plants, but it is very promising because energy production by surface unit is potentially much greater and does not have the added problem in terms of competition for the use of arable land and drinking water.

Currently, however, there is only one type of plant resource in the world which unites the three conditions of enabling an economically viable production of bioenergy, presenting reasonable growth prospects in terms of volume, and being judged acceptable from an environmental point of view in terms of $CO_2$ emissions. This plant is sugar cane, grown in Brazil. This is why we have chosen to 'test ourselves' in Brazil, a decision will prevent us from carrying out development subsequently elsewhere into lignocellulose or microalgae.

*Common bases*

In the first place, the use of white biotechnologies does not change the separation between upstream and downstream which exists in the fossil hydrocarbon industry. The initial resource becomes diversified, but the molecules produced from the upstream phase should be integrated into existing downstream industrial processes, in other words in refineries and petrochemical factories.

*When upstream and downstream become blurred*

The distinction between upstream and downstream activities is in a state of flux. It seems wiser to break down the complex carbon molecules produced from biological matter only partially rather than to dissociate them into simple molecules which will be reassembled into complex molecules later. Today, one can change living organisms so that they create chemical processes for us, and sometimes they can do so in a more efficient way. Usingsugars produced from the biomass, one can also produce molecules or intermediaries directly by fermentation without necessarily using molecules which normally enter into the downstream processes.

*A disrupted value chain*

If reliable industrial processes are implemented for these different activities, the value chain will be completely disrupted. This is why we want to be involved in the entire field. However, this change will take time. New industrial processes will have to be optimised because the target products are commodities and should therefore be made in large quantities and at very low cost.

*Transformation of sugars*

The three main intermediary products which one can make from different types of biomass are sugars, fatty acids and syngases (synthetic gases). In view of the many transformation paths possible between the different sources, the various intermediary products and the target molecules, we decided to concentrate on the transformation of sugars in molecules other than ethanol. Once this 'common base' is controlled, it is possible, at quite a low marginal cost, to develop paths towards different target molecules. For example, until now, one used cereals or sugar-based plants to make ethanol and oleaginous plants to make bio-fuels. One direction we would like to follow is the transformation of sugar into bio-diesel.

## Amyris

Having defined our strategy in terms of bioenergies, we divided up the various organisations involved in biotechnologies (including university laboratories and start-ups) according to their technological skills and the quality of their management. Amyris is one of the companies which we identified as being well placed. Negotiations with Amyris lasted 18 months before we reached a framework agreement which was signed in June 2010.

*The beginnings of Amyris*

Amyris was created in 2003 and drew its inspiration from the works of a Berkeley professor, Jay Keasling. He was the first person to show that one could produce a molecule less expensively by placing a bacterium (whose metabolism has been genetically modified) in a fermentation vat than by traditional methods. Jay Keasling used this technique when developing artemisinin, a treatment to combat malaria.

Amyris' first three research years were financed by the Bill and Melinda Gates Foundation which donated 45 million dollars for the development of a technological platform, an entire group of tools for genetic modification, and high-output screening of different modified strains. This platform helped to obtain yeast strains capable of producing artemisinin and other molecules. The advantage of working with living chemistry is that one merely needs to change an enzyme in order to obtain end results which are quite different.

At a roundtable organised in 2006, well-known venture capitalists such as Kleiner Perkins Caufield & Byers and Khosla Ventures decided to invest in Amyris. As well as artemisinin which will be manufactured and distributed by Sanofi as of next year, these investors targeted the chemistry and fuel markets.

When we invested in the company in June 2010, there were 400 employees, and 250 million dollars had been raised. Our investment increased our shareholding to 22 % and made us the majority shareholder.

*Collaboration between Total and Amyris*

As well as our financial stake, our aim was to create real collaboration between Amyris and Total especially regarding the five main links in the value chain.

Total and Amyris' intentions are clearly aligned as far as research and securing the biomass resource are concerned. These are areas where we can pool our efforts.

The second link is synthetic biology which is Amyris' core business. It is slightly embarrassing when it is the start-up which tells you about the possibility of synergy in your own area of expertise. In fact, there is no equivalent of Amyris' fast-track platform for genetic modification anywhere else in the world. However, because of our own resources and network of R&D partnerships, we can bring supplementary technologies, for example those regarding lignocellulose, or we can be on active standby concerning specific questions. Agreement on such points is easier to reach as a result of scientific and technological respect between the teams rather than through negotiation.

The third link is large-scale fermentation. Both Total and Amyris have everything to learn in this sector.

The fourth is the chemical transformation of the molecule obtained by fermentation. In this field, Total has a great deal of experience. This is also true of the fifth and last link, access to fuel or chemical markets.

*The beginnings of the partnership*

The contract was signed in June 2010, and from now until the end of 2011, about ten of our researchers will be working for Amyris. They are more qualified on average than people who work in R&D departments of other large industrial groups. The framework agreement states that the list of subjects on which we are going to concentrate is not limited as we all realise that technologies and target molecules can change very quickly.

## The solar photovoltaic sector

The discussion about solar energy has been slightly prejudiced in France because 80 % of electricity used in France is nuclear. This is why it is difficult for solar energy to be profitable in France. Even though Total is French, we operate throughout the world, and therefore we regard solar energy as a very advantageous source of renewable energy.

We think that the use of this form of energy should increase by about 20 to 25 % per year on average until 2020. It currently represents 0.2 % of global electricity production, but should reach 5 % in 2030, and 11 % in 2050. For the time being, Europe accounts for 75% of the market, but demand from North and South America and Asia is growing. These three markets should all be equal by 2020. As far as supply is concerned, the production of photovoltaic cells and modules, which was mainly based in Europe five years ago, has shifted massively towards Asia.

*Crystalline silicon*

There are three important solar photovoltaic technologies. The most well-known product is crystalline silicon where cells exist in conventional solar panels which are fixed on rooftops. This technology accounts for 80 % of the market at the current time.

In this process, silicon is refined in order to produce granules of polysilicon. These granules are then transformed into ingots by crystallisation and cut up into thin slices called wafers. These wafers are then assembled in layers with other materials which act as semiconductors in order to constitute microelectronic cells (which themselves are organised into modules and coupled with an electric circuit) in order to generate power and eventually a battery. The current yield of crystalline silicon is 15 to 22 % and the target yield for the next three years is 20 to 25 %.

*Thin layers*

The second technology is linked to thin layers. It consists of depositing thin layers of semiconductor materials on a substrate (such as glass). Because these materials have properties which are slightly different from those of silicon, they do not need to be very thick. The manufacturing model is more straightforward than for silicon. On the other hand, the yield is smaller : it is currently between 6 and 12 % and the aim is to reach 12 to 18 % over the next three years.

*Organic photovoltaics*

The third technology is not linked to mineral chemistry, but to organic chemistry. The modules are manufactured from semiconducting polymers which are an advantage for a number of reasons. Firstly, the raw material is abundant, non-toxic and cheap ; secondly, the product is very thin and may even be transparent or at least translucent and may also be coloured ; and thirdly, it is flexible which means it can be placed on various objects such as handbags or camping tents. However, it has a very low yield. At the present time, it is between 3 and 5 % and we hope that it will be between 8 and 12 % over the next three years.

## Total's partners in the solar sector

In keeping with our policy, we hope to have a presence throughout the whole value chain of the solar photovoltaic sector (such as in R&D and pre-industrialisation pilots, production, access to the market), by choosing 'differentiating' technologies.

In the field of crystalline silicon, we are working on the upstream activity with AE Polysilicon Corporation, a start-up based in the United States and Taiwan which refines silicon to produce low-price, good quality polysilicon ingots. This partnership, which started a year ago, corresponds to the model which I described earlier, namely investment and joint development.

As far as photovoltaic cells and modules are concerned, we have a partnership with the IMEC (Institute for Micro-Electronics and Composants in Louvain, Belgium) and we have just bought 60 % of SunPower, one of the top ten global solar companies. With SunPower, we have chosen the best cells in the world in terms of yield, and we aim to reduce the costs later. We think that it is the only chance for European or American companies to compete with Asian companies which adopt low-cost technologies with average yields. SunPower also supplies us with market access.

Photovoltech, located in Belgium, is one of our older acquisitions. We are joint owners with GDF Suez. This company makes photovoltaic cells with quite a limited capacity (150 MW). We also bought out Tenesol, a French company which we used to own jointly with EDF and which manufactures modules and systems, and installs panels on roofs, mainly in France.

As far as the thin layers are concerned, we created a laboratory with the École polytechnique called Nano PV which employs ten people. Some of the technologies developed by this laboratory can also be applied to crystalline silicon.

We own 20 % of the capital of Konarka, a start-up created in 2001 by an entrepreneur and Nobel prize-winner and located in the industrial suburbs of Boston. Our partnership with this company, which is a leader in the organic photovoltaic sector, was signed two-and-half years ago. We agreed that the Total teams work with the Konarka teams, but at that time, our philosophy was not the same as it is today, and we did not adequately discuss our access to the core technology which makes our collaborative work a little complex. Some specialised chemical subsidiaries at Total supply polymers to Konarka. We have also launched a joint programme with MIT (Massachusetts Institute of Technology) to overcome one of the main problems of this technology, notably the short lifespan of organic polymers.

Finally, for systems construction which can be applied to all three sorts of technology, we have a partnership with the LAAS (Laboratoire d'Analyse et d'Architecture des Systèmes) in Toulouse.

## DISCUSSION

### The NIH

**Question :** *Do these various partnerships not provoke a NIH* (Not Invented Here) *syndrome within the Total Gas & New Energies department ?*

**Vincent Schächter :** This risk is reduced by the fact that all the innovations are jointly developed by our teams and our partners' teams. Furthermore, the people we recruit in order to send them to work in start-ups are new to Total, apart from a few researchers in the carbochemistry department. Their main interest is to lead projects at the cutting edge on a scientific or technological level with real industrial prospects. This is the case both in solar and biomass projects.

### Industrial property

**Q. :** *You have shown that with your financial strength, industrialisation capacity and legitimacy as an' intermediary' is what you bring to start-ups. On the other hand, since Total does not buy companies, how is the intellectual property (IP) divided up ?*

**V. S. :** We at Total have had to learn a great deal in this area, because for an energy group like ours, it is not familiar territory. On the other hand, as far as start-ups are concerned, intellectual property is extremely important, especially in biotechnologies, and we regularly have difficult negotiations in this area.

In the case of Amyris, for example, our contact is an extremely intelligent young woman who has a PhD and is also a lawyer. She is the only person in the company who dares contradict the CEO. Since bluffing one's way plays a large part in these kinds of negotiations about IP, and as the CEO himself has no way of knowing whether what this woman says is right or not, he prefers to keep quiet rather than to challenge her. He may even leave the negotiation room to talk with her in private before putting forward a proposition.

At first our legal director thought that it would be enough to involve specialists and ask them for due diligence in IP in order to know the real value of the portfolios of start-ups with whom we were in negotiation. However, at this level of technology, there are only ten people in the world who are capable of understanding what it is about, and it is likely that these ten people would have at least three different opinions.

Additionally, it is important to choose the consultants according to the final, desired result. Some are capable of devising agreements, while others are more talented at handling hard negotiations. Initially, we thought that the second type of person was more relevant to us. Because our contacts adopted positions which we found very arrogant, our consultant tended to be very aggressive and thought that they were bluffing. At the end of two weeks, we had not moved forward and the approach to reach a strategic partnership did not seem very appropriate.

Finally, we had to ask for help from three partners from a well-known American law firm who almost slept in our offices for three weeks, and in the end we managed to conclude our negotiations successfully.

## Public financing

**Q. :** *How do you see the role of public financing for the development of solar energy ?*

**V. S. :** Even though the French and European circumstances are not very favourable for the industrial production of solar cells and modules, it nevertheless enables R&D to be conducted in satisfactory conditions.

In France, we find the ability of such financing in order to create collaborations and a structural environment for other people involved more interesting than the amount of the financing itself. This is the case, for example, in our IEED (Institut d'Excellence en Énergies Décarbonées) project for the plateau de Saclay (a research station near Paris), which we created with EDF, the École polytechnique and the CNRS (National Centre for Scientific Research). In this sort of project, strictly speaking the grant is not the determining factor for us, but it is crucial for the École Polytechnique and the CNRS.

On the other hand, when my colleagues ask me if they should submit a project for a particular tender, I ask them to calculate the costs and profits of the operation first of all. Currently, the Ministry for Sustainable Development is inviting offers to tender for bio-fuels, but this sector is not sufficiently interesting for a group like Total to spend months putting together a dossier in order to obtain a refundable advance on projects which are not large-scale.

On a European level, the approach could be interesting if it were to catalyse the creation of a high-quality consortium, on the understanding that the administrative and reporting work remains reasonable.

**Q. :** *What is your position with regards to the crédit impôt recherche (a French government financial aid to encourage the development of R&D in companies) ? Does it encourage you to carry out more research ?*

**V. S. :** If the aim of the CIR is to modify the strategy or the choices of partnerships of companies and important groups, then, for the time being, it is a failure for a very simple reason. The possibility of having a CIR does not enter into the decision-making process at the right time. At the time of year when I negotiate my budget with general management, I have no idea about the impact that the CIR might have. It is only a great deal later that I discover in which fields we have benefited from the CIR, and I have to find out this specific information specifically.

In addition, I asked my secretary general to draw up a spreadsheet which would enable me to highlight to the management committee the fact that we had been granted CIRs for various partnerships with French companies, but I know in advance that the committee will say 'OK, but is the laboratory in question any good ?'

In the end, the CIR does not really permit one to express a preference for a specific research area.

## Batteries and intelligent networks

**Q. :** *One of the limiting factors of renewable energies is their random character in time, and therefore the proportion of renewable energy should not be greater than 30 % of total electricity production. Would not a better solution be to develop batteries with a very large capacity ?*

**V. S. :** The solution would be the development of both storage technologies and intelligent network technologies. We keep a close eye on these two aspects. Because of the explosion of the mobile telephone market, the very rapid development in lithium-ion batteries in the 1990s makes me quite confident that methods of storage adapted to new needs, notably stationary batteries adapted to intermittent energies, will probably be found. Furthermore, the enormous amount of financial aid granted by the Chinese government for research on batteries (as indeed for research in the solar sector and the biomass) makes one very optimistic about the future progress of these technologies.

Presentation of the speaker :

Vincent Schächter : R&D director at Total Gas & New Energies. He joined Total in 2009 and started the group's R&D activities in biotechnologies. Previously he took part in the creation of Hybrigenics (a biotechnology start-up) ; was the Bio-IT director at the Centre National de Séquençage ; and managed a laboratory at the CEA (Commissariat à l'énergie atomique) which was an interface between mathematics and molecular biology. He is a graduate of the École normale supérieure (Paris) and has a PhD in information technology.

Translation by Rachel Marlin (rjmarlin@gmail.com)