TECHNOLOGICAL STAKES AND CHALLENGES

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After the various oil crises, the scarcity of resources which could be used for the production of energy had the effect of steering research in two directions, to improve the performances of the bio-energy sector :

- optimizing the supply by lowering the cost of the biomass,
- optimizing the conversion technologies.

For the time being, there have been no practical results obtained from creating a low-cost forest resource by applying a system of short-rotation crops. But the bulk of the research work carried out in this area has been done : crop types have been established, logging equipment has been improved, and its development depends mainly on economic conditions and on the price of rival sources of energy. At the present time, and for the years to come, reducing the cost of timber implies the use of waste, which may sometimes have a negative value : industrial waste, agricultural waste, mixtures of waste and wood... The introduction of waste supply branches and the versatility of the installations are also priorities for the development of bio-energy.

Short rotation Ipil Ipil plantations in the Philippines

PRODUCING HEAT AND ELECTRICITY

The optimization of conversion branches has been the object of many projects since the 1970s. Here we shall try to present a summary of the bio-energy sector, specifying the challenges involved in optimizing these technologies.

MATURE TECHNOLOGIES

The markets for wood burning equipment have become quite differentiated over the past few years in the Northern and Southern countries. In the former, heat requirements for heating purposes have created new markets for thermal apparatus whereas, for the latter (apart from domestic fire-places) the demand for apparatus has remained traditional and limited to industrial sectors : process steam and electricity requirements...

In the Northern countries, two specific sectors have instigated the development of combustion technologies :

□ District heating

- The construction of district heating for supplying urban and rural heat systems has led to the introduction of dozens of installations producing between several hundred kW (mainly in Austria) and several MW, in Sweden, Finland and Denmark. For the largest stations, cogeneration units have usually been installed.

Note should be taken of several technical changes in this area :

- the development of peripheral equipment to store fuel, to transfer and to feed boilers ;
- the optimization of fuel cycles both to control combustion more effectively (which is also necessary for reducing the impact of boiler rooms on their immediate environment, which is generally highly urbanized) and to improve the use of calories by recovery, and then by the distribution of heat at low temperatures. The condensation of fumes, using an exchanger at the boiler outlet, helps to increase the useable output of the installation.

These technologies nevertheless appear to be quite difficult to transpose into the tropical countries where, as a general rule, heat requirements stop at the production of process steam and thermal fluid at high temperature.

The wood and pulping industries, and the various agro-industries are the traditional users of biomass combustion technologies. For primary and secondary processing industries, as well as for agro-industries, the quest for optimized systems has, in many cases, turned out not to be necessary, because the resource available on an industrial site usually exceeds requirements. A boiler with a poor performance thus makes it possible to incinerate surplus waste to good effect. In the past few years, however, boiler controls and automation have been improved.

□ Paper industries

It tends to be in the pulp and paper industries that technical changes are the most noticeable. Given the very high fuel consumption levels of these industries, they have in fact had to develop methods of producing electricity and cogeneration methods designed to match their needs (a few dozen megawatts) and tallying with the availability of waste (bark, black liquor, waste from wood and paper...). Combustion systems in fluidized beds – simple fluidized beds, recirculation beds – are now meeting these needs.

Wood combustion technologies will nevertheless probably reach their limits before very long. If, up until now, the evolution of combustion technologies for solid fuels was similar for wood, peat and coal, there is now a shift towards a separation of basic concepts. Large units using coal are turning towards combustion in supercritical conditions (high temperatures and pressure), but for several hundred megawatts. These operating conditions should help to achieve high outputs of electric power. For installations using the biomass, reaching this size is not easy to imagine, because the swift increase of the cost of the raw material linked up with the increase of the radius within which the supply is gathered hampers the economic planning of major projects.

The search for a certain flexibility in these installations in relation to the resource is one of the extremely topical themes of research in the area of combustion. This trend, which is aimed at using wood (waste) and coal or waste (urban, industrial and agricultural) and coal, or mixtures of urban and industrial waste, for one and same installation, got off the ground some years ago, with the rise in the cost of waste treatment and the growing pressure directed at getting rid of refuse dumps. What is more, this flexibility is a major advantage for the operators of energy-producing plants, for whom it will then be easier to manage the fluctuating costs of their fuels more efficiently. Tropical countries have been among the first to show an interest in this type of installation, in particular for the production of electricity using bagasse, during the milling season, and coal in between seasons (Bois Rouge and Gol installations in Réunion, established by the Babcock company and Les Charbonnages de France). This type of installation is of great interest for all agro-industries, because it helps to compensate for the seasonal problem and the availability of the biomass.

ELECTRICITY PRODUCTION BY GASIFICATION : A TECHNOLOGY OF THE FUTURE ?

The production of electricity by gasification has given rise to many studies and experiments. It is essentially, wood — generally used in the form of "chips" — that is the reference fuel, because it is suitable for the various gasification processes.

This technology is nevertheless having trouble realizing its full potential, both for economic reasons, because the initial units have an investment cost of about US$2,500/kW installed, and for technical reasons : poor reliability of gas filtering systems, corrosion or uncontrolled deposit on turbines and engines, problematic preparation, handling and management of the raw material.

For medium outputs of a few megawatts, the technological plan currently prevalent in production projects is integrated cycle gasification in fluidized beds : gasifier - gas turbine - waste heat boiler - steam turbine.

The leading companies in this field are Finnish (Ahlström, now acquired by Foster Wheeler, and Tampella/Enviropower acquired by Carbona) and Swedish (Tps). The first two companies have constructed pilot plants (~ 10 t/h) which have made it possible to conduct lengthy test campaigns on different fuels :

The «Dendrothermal» power station built in the Philippines by ALSTHOM.

wood, peat, lignite, coal... and Ahlström has built the first demonstration unit at Varnamo in Sweden for the Sydkraft Electricity Company. The size of the installation is limited (6 MWe) and it is experimental in nature.

This unit is currently the only one in the world which works on this principle. In September 1996, two years after its construction, it produced the first kWh of electricity once the gasifier had been connected to the gas turbine.

Although a few hundred hours of operation have been chalked up, a long run test period is now required before a level of "industrial" operation is reached.

Despite the support given over the past few years by international organizations such as the European Union and the World Bank, and by major public aid programmes, these projects have still not been fully realized, and several of them have already been dropped.

Prior to the Varnamo project, only one similar gasification installation was built, but this ended in failure : the EDF project in French Guiana with a production of 7 MWe based on a Biosyn/Biodev Canadian fluidized bed. The gas produced was to feed a dual engine. The installation has been completed but it has never operated, in particular because of inadequate gas filtering.

In the future, it will be necessary to look into the flexibility of gasification plants in relation to the type of raw material used, because if wood, peat, coal and even domestic waste in the form of pellets have been successfully gasified in fluidized beds, then only this equipment and not the complete energy production line has been tested.

□ Technological challenges but an industrial policy that has lost its clout

High development costs are hampering the various gasification projects. It seems that lowering the very high initial investment costs to any significant degree will be difficult.

Actually, the increase in the size of the plants, which might permit variations in their scale, is somewhat delicate because, as with combustion plants, increased output involves the problem of the availability of resources. Over and above specific situations, the supply of substantial quantities of raw materials (from 500,000 to 1,000,000 tons *per annum*) means greater distances to be covered to gather them, and this becomes prohibitive, cost-wise.

Issues to do with industrial policy must also be brought into the picture, as much for the production of gasification equipment as for accessory apparatus.

The designers of Finnish gasifiers (Ahlström and Tampella) were initially companies whose activities encompassed the whole paper-making sector, and which had developed these gasifiers on the basis of an industrial logic of integrated development. But they have been unable to find markets for these technologies. As a result, they extricated themselves from these activities in 1996, by selling them on to industrial groups which are more specialized in this type of energy-related engineering (Foster Wheeler and Carbona, respectively). There is a risk, in the future, that these technologies will receive a smaller share of the important public aid schemes allocated to research and development by the Finnish government.

Among manufacturers of gas turbines, and for the output range of between 6 and 50 MWe, which is the most relevant for biomass-based power stations, there is a lack of supply in terms of equipment. These manufacturers have no clear picture of the existence of a market for electricity production with this output, and the turbines which could be offered are very costly, because they include development costs which is difficult to amortize.

NEW WOOD-BASED BIO-FUELS ?

Many countries have attempted to develop wood-based substitute fuels. Most of the projects have to do with alcohol production processes.

Only the United States is pursuing a methanol programme based on synthetic gases obtained by wood gasification. Their work has been applied, in particular, to synthetic catalysts and engineering, in the hope of achieving production costs that are competitive with traditional fuels within the next ten years or so.

The production of wood-based ethanol or more generally of ligno-cellulosic materials is also being looked into. If, in the past, Russia managed to produce this by means of acid hydrolysis, more recent projects have turned to the use of enzymatic hydrolysis. These studies have been embarked upon using agricultural products in order to complement the conversion of sugars and starch with that of the ligneous parts of cereal crops and sugar-producing plants. Spurred on by environmental regulations which are trying to promote the use of oxygenated fuels, the United States is maintaining major research programmes on these topics, with the goal, for this sector, of competing with petroleum-based fuels in less than ten years. The planned cost is $0.67/gal in 2005, instead of the present-day $0.9/gal. There is much work still to be done to increase process productivity : improving enzyme production and product separation, reducing fermentation periods, adapting technologies to ligno-cellulosic species...

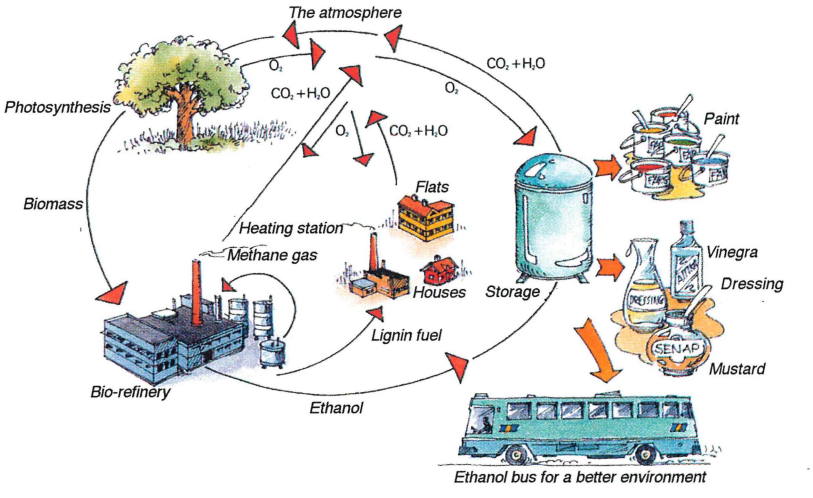
Research into the direct production of wood-based fuels now involves just pyrolysis (at atmospheric pressure). The pyrolytic oils obtained can be stabilized by an additional treatment, and may lead to a fuel that can be substituted or mixed with conventional fuels. The production costs of these products are still poles apart, however, from those of petroleum products, and experimental pyrolysis processes are far from being optimized.

□ A new sector

Doubts raised about the classic thermal engine in automobiles by the development of electrical traction systems mean that, in the years to come, we can once again foresee wood as the resource of a new energy sector : fuel cells. These fuel cells use hydrogen, carbon monoxide where applicable, and oxygen coming from the air which they convert into water and CO_2. If the cells themselves are starting to be used in pilot plants with outputs of several dozen kW, their use in a vehicle makes it preferable to have a liquid hydrogen storage system. Methanol thus represents the most appropriate form of storage, but it requires a cracking mini-unit to prepare the hydrogen. The creation of a new and major demand for methanol might well open up the market to wood-based production. Research work is currently looking into the production of synthetic gases obtained by biomass gasification and their direct use in a fuel battery. However, there are still many obstacles to be negotiated before this kind of procedure has been made reliable : gas filtering, adaptation of batteries to a mixture of gases, regulations...

□ Long-term challenges for car fuels

It is undoubtedly in the area of car fuels that the scientific and technical challenges are the most conspicuous where wood is concerned. But these challenges are limited economically by internationally established reference prices, which are currently very stable. Depending on the sector concerned, developments are called for, ranging from basic research on mechanisms to technological developments and the construction of industrial pilot plants.



The biomass, a source of renewable bio-energy : the uses of ethanol.
Source : Swedish Developement Foundation.

If many technologies have reached a level of full industrial potential, tropical countries have still derived little advantage from this, and the real challenge, today, has to do with the transfer and adaptation of these technologies. With the growth in energy consumption associated with industrial development, two sectors merit close attention :

• **Carbonization for the production of charcoal** has become the predominant domestic fuel in urban areas. The improvement of carbonization processes by the increase of production outputs and the broadening of the range of wood used are thus becoming a leading priority for the next few years, in order to meet a high social demand, and limit the pressures on forests surrounding urban centres.

• **Combustion for cogeneration based on biomass/coal mixtures** in agro-industries (oil-mills, sugar-mills, wood industry...) has the advantage of compensating for the seasonal nature of the by-products available and permits the resale in kWh on the grid.

From a technological viewpoint, the production of electricity and the cogeneration of process heat and electricity is without doubt the area where technological developments have received the most attention in the past decade. However, the development of this sector will only really take off within the framework of a determined policy and with the help of appropriate tax systems. The acceptance of these technologies by operators is nevertheless not given, and must be encouraged in the developing countries. The same applies to the opening-up of the electricity market to the private sector and the buyback of the self-produced kWh—practices which are still not very commonplace in tropical countries. ❐

FOR FURTHER INFORMATION

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