FUELWOOD YESTERDAY AND TODAY

Tropical countries have always been large users of bio-energy. Here, selling charcoal by the bucketful in Cameroon.

THE MAJOR STAGES IN THE FUELWOOD SECTOR

JACQUELINE DOAT*
PHILIPPE GIRARD

At the dawn of human civilization, and down the centuries, wood was the most important source of energy throughout the world. Up until 1850, it was used not only for producing domestic heat (cooking food and heating), but in addition, along with charcoal, for the reduction of iron, a practice going right back to Antiquity.

In the Northern countries, industrial development resulted in a very sharp rise in energy demand, to meet domestic needs, to produce more, to travel faster and further, and so on. Because coal – in the 19th century during the Industrial revolution – and petroleum – in the 20th century after the First World War – represented a more concentrated form of energy and one easier to use, they took the place of wood.

Conversely, in the Southern countries, which had for the most part remained outside of these changes, at least in the first half of the century, the growing demand for energy was no more than slight. Wood remained the primary source of energy supply in tropical countries, as shown in the table below.

A LITTLE HISTORY

From the 1950s to the early 1970s, the Tropical Forest Technical Centre (CTFT)* showed only scant interest in fuelwood, which was far from being a priority issue in the mainly African tropical countries with

* Now called CIRAD-Forêt.

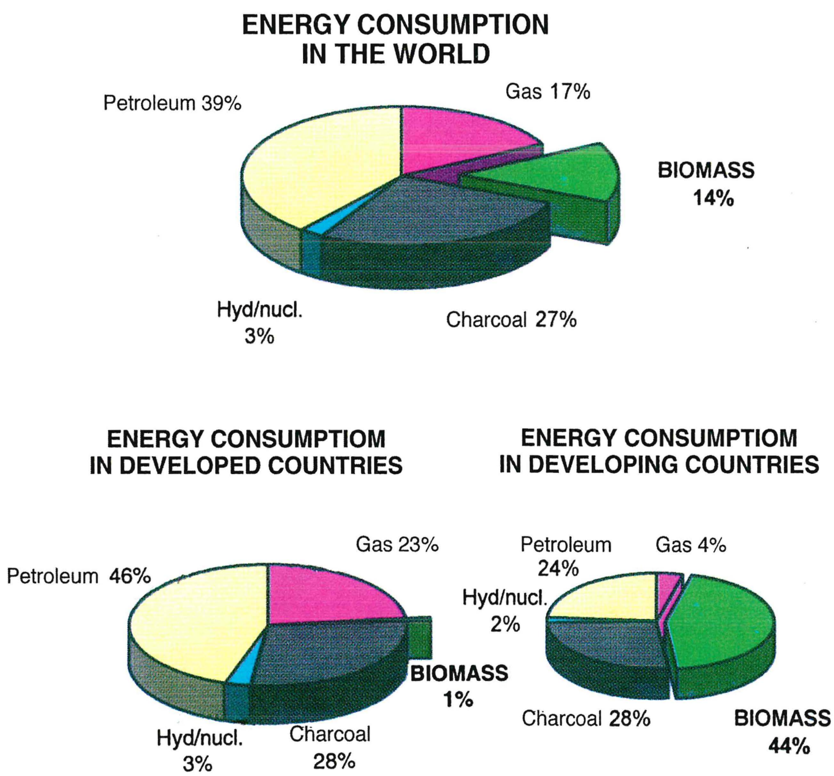


Figure 1. Consumption of energy by source of supply in 1989.

* Director of Wood Research at the CTFT, then at the CIRAD/CTFT from 1984 to 1989.

which it had cooperation programmes. Indeed, in the wake of the Second World War, supplies of petroleum had become plentiful, easy to procure, and cheap (around $3 a barrel).

In the 1970s, three important factors prompted the CTFT's interest in bioenergy, and its involvement in this field :

☐ **The first oil crisis of 1973,** after 30 years of euphoria, saw the price of crude triple. This attracted the attention of political and economic circles, but did not noticeably alter user attitudes. However, when, just a few months later, the $20-a–barrel threshold was reached and swiftly crossed, a general realization about the situation was reached in no time on the part of the powers-that-be, public and private alike. In 1974, as a result of this, the world economy was forced to tackle a new situation, which seemed to be irreversible. The rich, industrialized countries were, needless to say, penalized, but the developing countries (except for those with oil wealth : Nigeria, Gabon, Congo, Indonesia...), with weak currencies, were unable to keep abreast of this increase in costs.

In 1974, the governments of the industrialized countries and a large number of research agencies started to show an interest in substitute products for petroleum. The biomass – a renewable resource – and wood in particular, quickly galvanized research centres – and the CTFT especially – into action. In fact, if a certain stock of unused forest resources was available to industrialized countries, the forestry potential of the tropics would be very sizable. It had been estimated at 50-100 Toe (tonne oil equivalent) per hectare of natural forest, 10-20 Toe per hectare of wooded savannah, and 3-10 Toe/ha/year for plantations of fast-growing species (eucalyptus) in wet regions.

THE DIFFERENT BIOMASS ENERGY TECHNOLOGIES

☐ **Combustion :** this is the first technology to spring to mind when it comes to the production of energy using wood. This energy may be used as it is for heating, cooking food, or industrially to produce steam, shaft-power, and electricity.

☐ **Carbonization (or pyrolysis) :** pyrolysis allows the concentration by weight of the potential energy of the raw material. In the absence of oxidizing products, and under the action of heat, biomass is decomposed and broken down in three phases, the relative importance of which varies depending on the operating conditions : a non-condensable gaseous part, a liquid part and a solid residue, the charcoal mainly constituted of carbon. In the developing countries, charcoal is the sought-after end product. The liquid part, tars and pyroligneous substances as well as gases can be recovered where applicable (xylochemistry). By using a method of heat treatment applied below 280 ºC it is possible to obtain an intermediate product : torrefied wood.

☐ **Gasification :** the aim behind the managed oxidization, or gasification, of a solid is the production of a combustible gas, which can be substituted for petroleum-based products. Biomass treatment is carried out at high temperatures, with a raw material that is prepared before use, dried and divided. The resulting product is a mixture of poor quality gases that can be used in engines for subsequent transformation into electricity. Gasification may also be geared towards the production of a synthesis gas that can be used in the chemical industry, in particular for the synthesis of methanol and ammonia.

☐ **Liquefaction** (or hydro-liquefaction) : the transformation of wood into liquid, or at least viscous fuel just like crude oil, which can be refined, is a demanding challenge tackled by this sector. The reaction designed to replace oxygen atoms takes place in the presence of a catalyst, under high hydrogen pressure (100-200 bars) and between 250 and 300 ºC. The reactional mechanisms involved at the level of the deterioration of the ligno-cellulosic matter are basically different from those involved in pyrolysis.

☐ **Hydrolysis :** hydrolysis is designed to separate complex raw materials to obtain from them simple compounds with a high added value. Hydrolysis of wood in an acid environment produces sugars, the majority of which (sugars in C_6 derived from cellulose) can be fermented in alcohol (ethanol).

It was also in this period, in Africa in particular, that two phenomena overlapped which heightened the effects of the oil crisis. They were :

☐ **The population growth** which, for lack of suitably adapted farming practices, resulted in the deterioration and degradation of the natural environment, greater in many regions than the annual regeneration capacities.

☐ **A new drought cycle which afflicted the dry tropical zone.** As it was emphasized by Clément and Strafogel, the horrendous images of famine which were brought to the attention of people in the industrialized countries, make them aware of the social, political and economic challenges represented by wood supplies for tropical countries (Clément, Strafogel, 1986).

THE CTFT'S INITIAL PROGRAMMES

Research programmes thus became more and more ambitious to encom-

Charcoal production and bagging in Togo.

pass the different sectors involved with processing the energy of the biomass, from the laboratory phase to the pilot phase.

The projects embarked upon at that time by the CTFT were thus at once markedly influenced by the demand of tropical countries, but also closely bound up with the development of the energy situation of the industrialized countries and to the technological developments resulting therefrom.

The CIRAD-Forêt carbonization laboratory in Montpellier : an experimental retort with its waste recovery system.

In 1975, a carbonization laboratory was installed. One of the prime objectives was to carry out pyrolytic operations and physical-chemical analyses of charcoal, in order to study the characteristics of very large numbers of tropical species and certain agro-industrial waste (coconut shells, palm stalks, peat). Today, the list of species processed is a long one, and it is currently being incorporated in a data-base.

In the late 1970s, the CTFT's Energy laboratory was equipped with a chromatographic analysis laboratory which helped, well ahead of the concerns associated with the greenhouse effect, to develop analytical methodologies for liquid by-products (pyroligneous substances, tars) and gaseous by-products.

A SOCIOLOGICAL APPROACH

When, in the industrialized countries, people discovered the advantages of renewable sources of energy, and of bio-energy in particular, these sources were still only in the evaluation stage in the tropical countries. Foresters back then, who were used to carry out large forest inventories, thus tackled the problem in the same way, by assessing the situation. The initial projects encompassed a sociological dimension. They concerned studies and surveys to do with the consumption and supply of firewood, essentially in large urban centres.

The problems of firewood consumption were swiftly pinpointed :

- In rural areas, the supply was the result of wood gathering undertaken by the family. It was thus hard to come up with an accurate assessment, both quantitatively (consumption *per capita*) and qualitatively (proportion of dead wood in relation to standing wood and farming waste).

- In urban areas, where "the growth of needs is spectacular, especially in Africa" (A. Bertrand, 1977). The rate of population growth in African towns and cities, which ranged from 5 to 14 % *per annum,* led to a rise of the same scale in the need for domestic energy, firewood for heating and, above all, charcoal.

In the developing countries, consumption rates are progressively better known as a result of many surveys carried out. To supply urban areas, the ever growing use of charcoal, made through technologies that are often poorly controlled, with low conversion yields, is increasing pressures on the forest.

A FORESTRY AND TECHNOLOGICAL APPROACH

In order to cope with this situation and preserve forest ecosystems, the solutions accordingly planned can be grouped under two types of approach :

□ **A forestry approach** to increase resources and improve supply, with the establishment of firewood crops and the introduction of agro-silvo-pastoralism. Because the environmental area most dramatically affected is situated in the dry tropical region, those plantations are often subject to very severe climatic factors, which have considerably limited both productivity and longevity – and this in spite of selection procedures. The results are often disappointing. Indeed :

"We can go by the following scale as a rough guide :

- 600 mm isohyet : productivity from 1.5 to 3 m^3/ha/year (this second value should be regarded as exceptional).
- 800 mm isohyet : productivity from 3-5 m^3/ha/year (same observation).
- 1 000 mm isohyet : productivity from 6-10 m/ha/year (same observation)".

(Bailly *et al.*, 1982).

The costs of wood, as a result of low productivity and high cost, exceed the market price by a factor of at least two, and remain prohibitive.

□ **A technological approach** to reduce consumption and thus demand, which consists in improving energy efficiency of cooking stoves in use. Field tests and applied research projects have been implemented since the late 1970s to reduce the consumption of firewood in the Sahelian countries.

Small-scale production of lime in Indonesia using sawmill waste.

WOOD, MAIN SOURCE OF FUEL AND ENERGY IN THE TROPICAL COUNTRIES

Wood is the predominant " traditional" source of domestic fuel in developing countries. It also represents a modern source of energy capable, with all the efficiency required, of meeting the demand for heat or power of the most specialized activities, whatever the area of economic activity affected (with the exception of transport).

Its use has resulted in many advantages, on the economic and social level :

- When properly managed, it fits the bill for an indigenous, renewable, and on-going source of fuel and energy, and offers the best guarantees as far as energy independence is concerned. In the most favourable regions, it can help to adjust supply to growing demand, as this increases from one day to the next.
- When used to replace conventional fuels, it helps to save precious currency, which can then be recycled in the form of industrial equipment and infrastructures, and lower the level of pollution resulting from energy uses. Bearing in mind its capacity to recycle CO, it emits less greenhouse gas than petroleum products and coal, and it emits no sulphur monoxide at all.
- Its production, harvesting, and packaging for use as fuel generate a large number of jobs and local added value.

If bio-energy thus helps to meet a very wide range of energy and fuel needs, certain areas are still more or less out of its reach :

- transport, as long as the production of liquid fuels (methanol, charcoal in suspension) has not achieved the level of economic profitability to compete with petroleum products,
- large stand-alone power stations for supplying national grids.

This is a situation which can be helped, in the medium term, by the development of *new avenues* with much more favourable technology efficiency (gasification/gas turbines) and a better control of forest plantations, giving better and better harvests.

The goal of these projects, organized in collaboration with different European NGOs and universities, whose funding is guaranteed by major international organizations (UNOID, OECD, UNDP, etc.) is to spread the use of "improved stoves", in dry tropical regions, to replace the "three-stone fire-place" with its appalling energy output, which does not exceed about 5%. In tandem with these tests, it was thus interesting to draw up a "data catalogue" about the calorific value of species with quite different provenances and characteristics. This study (Doat, 1977) showed that the NCV (Net Calorific Value) varies from one species to the next with a margin of ± 20 % according to the chemical composition of the wood. But it also shows that there is no correlation between the density of the wood and its NCV. The advantages of these measurements have been especially appreciated during the development of more sophisticated processes (wood boilers, gasifiers...).

Faced with a relative failure, in terms of impact on energy consumption, through improved stoves and firewood-crops, funding organizations are steering major programmes towards substitution solutions. Sights are thus set on limiting the harvesting of wood in forest stands, by resorting to other forms of fuel, such as gas. Because this demand is more removed from the expertise and know-how of the CTFT, the various projects undertaken by that time, with the exception of torrefied wood, are turning to power generation technologies, or methanol production. At that time, the CTFT had already evaluated the challenges of biomass for the energy supply in the tropical countries, no longer just to meet domestic needs exclusively, but also to meet the requirements of the industrial sector. The biomass could become a fuel source in its own right, especially in wet regions.

This period was a very fertile one in terms of various projects undertaken in Europe, and in France in particular. While major gas substitution programmes were implemented, in the early 1980s the CTFT attempted to reconcile both the control of energy and the production of a bio-fuel with a high calorific value, by exploring, with the ARMINES Research group, a new path : torrefaction (Doat, 1985). It corresponds to partial pyrolysis of wood (a process that is stopped before the exothermal reaction phase, i.e. at about 280 ºC), giving a weight-related yield of 70-72 % and an energy efficiency of about 80-82 %. Laboratory works and pilot projects showed that it is possible to obtain, from tropical wood, a product that can be used as such, or after agglomeration without the use of bonding agents, in domestic stoves. However, the field results were still disappointing.

A SCIENTIFIC APPROACH

During the 1980s, it was above all the number of the scientific projects carried out in Europe and the United States which galvanized the CTFT's research programmes, causing them to focus on a better use and development of the energy potential of tropical forests. The CTFT's research teams were involved in extensive programmes : gasification for electricity production, the synthesis of methanol, and hydroliquefaction.

□ **Gasification of wood for electricity production :** these initial studies on gasification by instant pyrolysis were carried out in the laboratory, in collaboration with the University of Nancy in 1981-1982 (Deglise, Doat, 1982). The processing of tropical species and mixtures compared with certain French species helped to define the mechanisms of the reactions more effectively and specify the nature of the resulting gases. Furthermore, the CTFT followed up the tests carried out by many French equipment manufacturers developing gasifiers of variable power range, moveable equipment of up to 100 kW, and stationary industrial equipment of up to 3,500 kW. Some units may be combined with generators accepting the direct use of poor quality gases for the production of electricity.

□ **The production of methanol** based on ligneous products aroused definite interest around the world, France, Canada, the United States and Brazil in particular, between 1975 and 1985. The process on which different organizations, including the CTFT, were then working, corresponded to a gasification process under oxygen pressure, in order to obtain (after getting rid of the carbon dioxide) a clearly defined gaseous mixture of carbon monoxide and hydrogen : CO and H_2, the basis of the synthesis of methanol CH_3OH. A group, ASCAB, was set up in France with such diverse organizations as the AFME, the CTFT, the CEMAGREF, Creusot-Loire, oil companies, etc. A pilot project involving 60t/day was set up by the ASCAB and showed the technical feasibility of this branch. An economic approach to the production of methanol by using wood nevertheless showed, in 1986, what was subsequently confirmed in 1994 : namely, that the cost price was distinctly higher for productions of 50-500 t/day of methanol than for methanol produced from natural gas.

☐ **The possibility of obtaining liquid or viscous products** with a high calorific value was explored by the CTFT between 1981 and 1984, as a result of contact with North American sources. The CTFT set up a specific device working at high temperatures under high hydrogen pressure and in an alkaline environment (Doat, 1984). But the obligatory presence of solvents and a high external energy input increased the cost of the process ; this, together with the difficulty of transposing it industrially, led the CTFT to abandon these projects for the time being.

☐ **The production of ethanol,** an oxygenated energy compound (C_2H_5OH) from wood can be obtained by hydrolysis of wood using enzymes or mineral acids, and then fermentation. However, these projects never came full circle, mainly because the production of ethanol using wood was not competitive.

From the latter half of the 1980s onward, the contribution of fuelwood rose only slightly in Europe, and marked time in North America after the boom resulting from the PURPA regulations (Public Utility Regulatory Policies Act). The growth in demand remained constant in the countries of Africa, South America and Asia, with respective annual growth rates between 1970 and 1993 of about 2.5, 1.5 and 1.6 %/year (cf. fig. 2). As a result of this, with the sustained drop in oil prices, the interest in fuelwood more or less vanished completely at the European and North American level, from 1987-88 onward.

On the contrary, the need in tropical countries to meet the requirements of the people as far as possible maintained the pressure on the governments concerned, so as to ensure a better use of natural resources, and, in particular, of the energy from biomass (cf. table below), and this in spite of :

- an environment in the process of deterioration, which results in an increasing scarcity of wood,
- a dramatic economic situation of poverty affecting the bulk of the population,
- the boom in the demand for energy and fuel, and electricity in particular, for those countries which had witnessed their economies taking off (southeast Asia...).

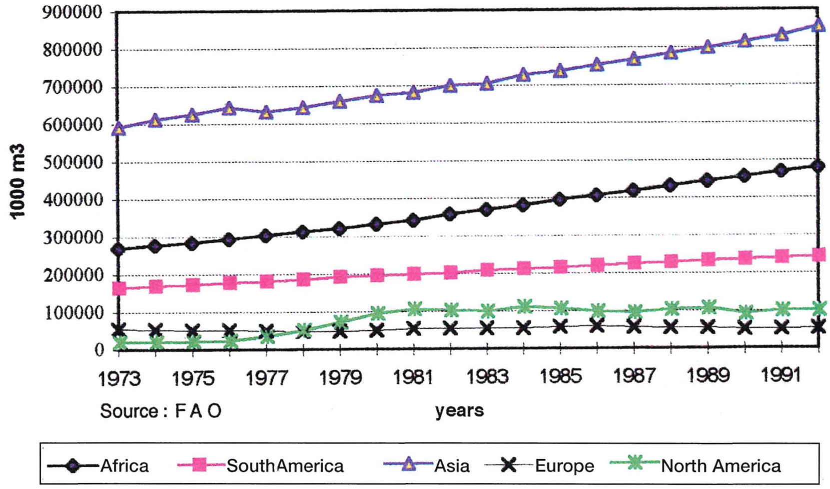


Figure 2. Production of fuelwood and charcoal between 1973 and 1992.

THE SHARE OF FIREWOOD IN THE FUEL SUPPLY OF SELECTED TROPICAL COUNTRIES

	Source 1978	Source 1982	Source 1990
Senegal	60 %	82 %	54 %
Mauritania	69 %	94 %	na
Mali	93 %	90 %	80 %
Burkina Faso	94 %	94 %	91 %
Niger	88 %	95 %	80 %
Chad	89 %	na	80 %
Côte-d'Ivoire	65 %	60 %	72 %
Thailand	na	na	24 %
Philippines	na	na	43 %

na = not available.
Source : Club du Sahel/CILSS, 1983, FAO, P. GIRARD, 92.

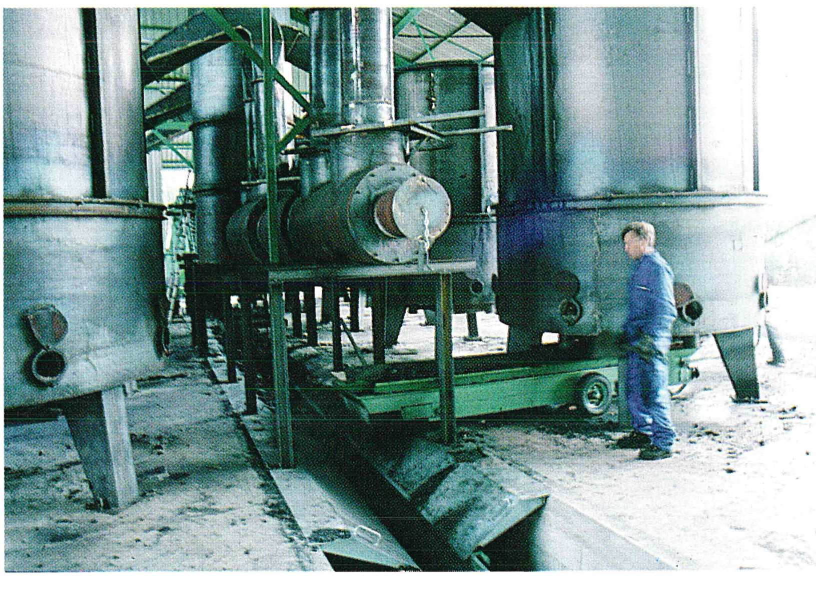
A MORE APPLIED APPROACH

THE DEVELOPMENT OF EQUIPMENT

The more applied projects conducted since 1985 have endeavoured to assess and certify performances prior to the transfer of equipment and materials. To this end, with the support of the ADEME, the CTFT has been equipped with an experimental base making it possible to work on full-scale materials for :

- optimizing the production of charcoal at its experimental carbonization base at Spoir, and subsequently at Emancé (Doat, 1985 ; Girard, 1986 ; Vergnet, Corté, 1989),
- developing the gasification branch with a view to producing electricity or heat in partnership with manufacturers (Pinta, 1994),
- optimizing combustion, with the CETIAT, by offering support to manufacturers in order to improve the functioning of new materials : turbo boilers.

In 1985, aware of the environmental stakes and challenges involved, the CTFT, along with the LNE, the EDF and the CITEPA, carried out studies at experimental level and on industrial sites, in order to evaluate the environmental impact of exhaust from partial combustion charcoal kilns (Mezerette, Girard, 1992). Anxious to make the best possible use of the energy contained in these fumes, the projects quickly culminated in the development of fume incinerators, in collaboration with manufacturers. The effectiveness of the treatment enabled companies to comply in every way with the rules and regulations ; the heat produced could thus be used for drying wood prior to carbonization, permitting a very appreciable output gain and a sharp rise in productivity.



Carbonization exhaust gas treatment system by incineration (CML process).

TECHNOLOGY TRANSFERS

After testing equipment in Europe, between 1990 and 1995, the CIRAD-Forêt embarked upon technology transfer programmes which forced it to give more far-reaching and thorough consideration to the economic aspects of the situation, and equip itself with the tools required for technico-economic project assessment (Girard, 1996).

- In Southeast Asia, with the European COGEN programme, which encouraged the setting-up of joint ventures between European and ASEAN manufacturers for co-generation in the agro-industries (sugar, rice, palm oil and coconuts) and in the wood industries, using efficient European technology that was already proved outside ASEAN. The idea was to introduce full-scale demonstration projects capable of creating user manufacturer dynamics in the region.
- In West Africa, with the introduction, in 1992, of the Regional African Thermochemical Centre (PRAT) in Abidjan. The goal of this centre was to bring together the skills and know-how of the countries of North and South alike in research and development within a structure that enabled it to bring into play complementary regional and thematic combinations. It was thus possible to pinpoint obstacles in the way of transfers and implementations of technologies adapted to the energetic improvement of the biomass in the developing countries, for the benefit of households and industries. The PRAT made it possible to meet the needs of the research and development, as well as those of demonstration and training, important for the promotion and sound use of effective and efficient technologies. In addition, it encouraged manufacturers to make significant commitments to

Wood-based cogeneration unit in an industrial complex in Malaysia.

Professional training in the regional thermochemical centre for Africa jointly managed by IDEFOR-DFO in Côte d'Ivoire and CIRAD-Forêt.

the development and use of bio-energy-oriented solutions.

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An awakening to the environmental challenges linked to energy has helped to relaunch international research all the easier as three-quarters of the world's population are currently living in developing countries, and only use one third of the world's conventional energy source. Population pressures and the incipient industrialization of these countries will, of necessity, lead to marked and swift growth in their demand for energy. This demand can only be met on a sustainable basis by taking renewable forms of energy into consideration, by incorporating more efficient technologies, and by introducing energy-saving measures. A more comprehensive approach embracing specific local and regional factors will have to be taken at the same time. It is this turning-point that the CIRAD-Forêt is just negotiating with certain tropical countries. Malaysia and Thailand have now established incentive-based rules and regulations promoting the use of the biomass as energy (Girard, 1993), and Côte d'Ivoire has embarked on deliberations in this same direction, in order to make better use of agro-industrial waste. ❐

▶ Jacqueline DOAT
Former Director
of wood research
at the C.T.F.T.

▶ Philippe GIRARD
Programme Valorisation
des Produits forestiers
CIRAD-Forêt/Montpellier

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LIST OF THE ACRONYMS USED IN THIS ARTICLE

ADEME :
Agence de l'Environnement et de la Maîtrise de l'Énergie

AFME
Agence Française pour la Maîtrise de l'Énergie

ASCAB :
Association pour le Développement des Carburants par la Gazéification du Bois

ASEAN :
Association of South East Asian Nations

CEMAGREF :
Centre d'Étude du Machinisme Agricole, du Génie Rural, des Eaux et Forêts

CETIAT :
Centre d'Étude Technique des Industries Aérauliques et Thermiques

CILSS :
Comité Inter-études de Lutte contre les Sécheresses au Sahel

CITEPA :
Centre Interprofessionnel Technique d'Etude de la Pollution Atmosphérique

COGEN :
A programme of economic cooperation between the EEC and the ASEAN to promote and transfer European technologies in the energy-related use of agro-indusrial waste

IDEFOR-DFO :
Institut des Forêts – Département Foresterie

LNE :
Laboratoire National d'Essais

OECD. :
Organization of Economic Cooperation and Development

PRAT :
Pôle Régional Africain de Thermochimie

UNOID
United Nations Organization for Industrial Development

UNDP
United Nations Development Programmes

UTC :
Université Technologique de Compiègne

ABSTRACT

FUELWOOD YESTERDAY AND TODAY

Tropical countries have always been major users of bioenergy. Through the research carried out by the C.T.F.T. and then by CIRAD-Forêt, the authors here retrace the principal stages which have staked out this field since 1970, taking into account the sociological realities of developing countries : population explosion, migration to cities and towns, impoverishment, severe drought... The scientific and technical approach to energy reactions has also been tackled by different groups concerned with the biomass, established in the industrialized countries.

Lastly, technology transfers in Southeast Asia and West Africa got under way in 1990, in order to deal with the growing demand for energy in tropical regions — a demand which it will only be possible to meet on a sustainable basis with the help of renewable raw materials.

Key words : Tropical zone. Energy. Biomass. Fuelwood. Charcoal.

RÉSUMÉ

LE BOIS-ÉNERGIE HIER ET AUJOURD'HUI

Les pays tropicaux ont toujours été de gros utilisateurs de bioénergie. Les auteurs retracent ici, depuis 1970, au travers des recherches menées par le C.T.F.T., puis le CIRAD-Forêt, les grandes étapes qui ont jalonné cette filière, en prenant en compte les réalités sociologiques des pays en développement : explosion démographique, migration vers les zones urbanisées, paupérisation, sécheresse accentuée... L'approche scientifique et technique des réactions énergétiques a également été abordée avec différents groupements intéressés par la biomasse, mis en place dans les pays industrialisés.

Enfin, des transferts de technologie en Asie du Sud-Est et en Afrique de l'Ouest ont été initiés dès 1990, afin de faire face à la demande croissante en énergie des régions tropicales, demande qui ne pourra être satisfaite durablement qu'avec l'aide des matières premières renouvelables.

Mots-clés : Zone tropicale. Energie. Biomasse. Bois de feu. Charbon de bois.

RESUMEN

LA MADERA-ENERGIA DE AYER Y DE HOY

Los países tropicales vienen siendo, desde siempre, grandes consumidores de bioenergía. Los autores describen en este artículo, desde 1970, a través de las investigaciones emprendidas por el C.T.F.T., y más adelante el CIRAD-Forêt, las principales etapas que han jalonado este proceso, teniendo en cuenta las realidades sociológicas de los países en vias de desarrollo : explosión demográfica, migración hacia las zonas urbanizadas, pauperización, sequía acentuada, etc. El enfoque científico y técnico de las reacciones energéticas se han abordado también conjuntamente con los diversos grupos interesados por la biomasa, implantados en los países industrializados. Finalmente, las transferencias de tecnologia en Asia del Sureste y en Africa del Oeste se han iniciado a partir de 1990, con objeto de hacer frente a la demanda cada vez mayor de energía de las regiones tropicales, demanda que únicamente se podrá satisfacer de forma duradera por medio de las materias primas renovables.

Palabras clave : Zona tropical. Energía. Biomasa. Leña. Carbón vegetal.