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The Role of Renewable Energy in the World Electricity System

Le rôle de l'énergie renouvelable dans le système mondial de l'électricité

High-level Expert Meeting
Réunion d'experts de haut niveau

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THE ROLE OF RENEWABLE ENERGY IN THE WORLD ELECTRICITY SYSTEM

LE RÔLE DE L'ÉNERGIE RENOUVELABLE DANS LE SYSTÈME MONDIAL DE L'ÉLECTRICITÉ

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1. INTRODUCTION

This report covers the activity carried out in the area of renewable energy sources by the E7, an international group of the world's leading companies responsible for the whole range of electric activities from generation, to transmission, to distribution and to supply * The E7 Joint Statement can be found in Annex 1.

The E7 companies cooperate on global issues which are critical for the world electricity supply industry, such as the global environment, the role of markets in electricity service and the structure of future advanced resource-recycling societies. The third issue focuses on minimization of raw-material requirements in society, which include integrated energy resource planning and electric demand-side management. The aim is proper harnessing of the virtual renewable resource of energy savings.

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* The E7 Group members are: EDF (F), ENEL (I), Hydro-Québec (CND), KANSAI (J), Ontario Hydro (CND), RWE (D), Southern California Edison (USA) and TEPCO (J).

The Network of Expertise is the E7's operational structure for the first and foremost issue: the global environment. The Network's duty is to act as an advisory body in order to provide governments, international institutions and interested utilities with the E7's most valuable resource, namely expertise covering the full spectrum of electricity activity.

The E7 is active in several of the "new renewable forms of energy": solar, wind, geothermal, mini-hydro, biomass, tidal energy sources and, by extension of the concept, municipal solid waste. Hydro-electricity, a renewable resource that has been exploited on an industry-wide basis, and will continue to be widely developed, is discussed here briefly, but only for mini hydro. Nuclear, which qualifies as a large renewable resource when harnessable by breeders and, in the longer term, by fusion, is not discussed.

The potential in using the new renewable forms of energy for electricity generation is remarkable, but the barriers are also sizeable. The research, development and demonstration activities of the E7 companies, including their current and planned projects and strategics objectives, aim at overcoming the barriers and accelerating the technical and economical viability of the most promising sources and related technologies.

In fact, the key policy guideline of the E7 utilities is to bring these options to industrial maturity, with the aim of reducing both the pressure on other energy sources and the overall impact on the environment. This guideline was the basis for the deep involvement of the E7 companies in the past, which resulted in notable successes but also in the experimentation of approaches which proved to be impractical.

Among the successes, the development of large-scale hydro projects ranks first. Specifically, the adequacy of E7 hydro-electric plants with the current stringent environmental rules - not anticipated when the source was first harnessed - must be ascribed to advanced engineering and early adoption of the most comprehensive system approach, which provided flexibility for upgrading their compatibility when the need arose. Proper design of hydro-electric plants bas become a key asset of the industrial culture of the E7.

Other notable successes were scored in geothermal energy. The expertise in this field -from the pioneering phase in the early 1900s when the first kWhs were produced, to the present one, which focuses on hard to access and marginal value resources- has been acquired and largely remains in the E7 circle. This applies even more to tidal power, harnessed in the power station of La Rance, France, which represents 90 % of the world tidal electrical capacity.

Among the experiences whose outcome was reallocation of scarce and valuable research resources to other projects, mention is to be made of the prototypes of Adrano, Italy and Themis, France, based on thermodynamic conversion of solar energy.

For the future, approaches differ by company, reflecting the different country and company strategies, but overall the E7 members develop expertise and foster technology in every important field. This enables them to properly assess the new renewable energy technologies, particularly from the points of view of satisfying electricity demand and economic performance. New renewable energy is expected to have only a limited contribution towards meeting demand. The economic performance of new renewables is predicted to be adequate in niche markets only. Noteworthily, some of these markets may arise in dispersed areas of the world, in advanced and developing countries. In the longer term, technological breakthroughs and continuously-improving designs may open larger opportunities and some E7 efforts (basic research, validation of technologies, etc.) are addressed to give shape to these expectations.

2. THE E7 ROLE IN RENEWABLE ENERGY SOURCES

The electricity fed to the E7 electrical networks (Table 1) provides an indication, albeit limited, of the past commitment of the E7 companies in fostering the renewable energy option at the industrial level. Presently, the E7 circle is largely involved in all main research, development and deployment lines, with different emphasis depending on the individual enterprise's strategy (Table 2).

Table 1

ELECTRICITY FROM NEW RENEWABLE ENERGY SOURCES IN THE E7 UTILITIES' NETWORKS (Including Energy from Independent Producers)

ÉLECTRICITÉ PROVENANT DE SOURCES D'ÉNERGIE NON CONVENTIONNELLES DANS LES RÉSEAUX DES COMPAGNIES DU E7 (Incluant l'électricité produite par les producteurs indépendants)

	MW	Millions of kWh
SOLAR THERMAL	360	700
PHOTOVOLTAIC	7	10
WIND	920	1700
GEOTHERMAL	1190	9500
BIOMASS	570	3400
WASTE	70	450
SMALL HYDRO (< 5 MW) AND OTHERS	1000	3800
TIDAL AND WAVE	240	500
TOTAL	4357	20060

Data from 1992

Table 2

E7 COMMITMENT TO NEW RENEWABLE ENERGY SOURCES (NRES)

LES COMPAGNIES DU E7 ET LES ÉNERGIES NON CONVENTIONNELLES (NRES)

NRES	Potential	Constraining Factors	Medium Term Expected Contribution	Strong Commitment by E7 Utilities †
Solar Thermal	Medium	Efficiency, Scale of units, Economics	*	SCE
Photovoltaic	High	Efficiency, Economics	**	ENEL, RWE KANSAI, TEPCO
Wind	Medium-High	Economics, Life of units	****	SCE, ENEL
Geothermal	Medium	Long term performance Economics	****	ENEL, SCE
Small Hydro (<5 MW) & Others	Low	Regulatory, Environmental	**	ENEL, Hydro-Québec
Tidal and Wave	Low	Economic, Environmental	*	EDF, TEPCO
Biomass	Medium	Efficiency, Feedstock availability, Economics, Regulatory, Environmental	***	Hydro-Québec Ontario Hydro, RWE
Waste	Low-Medium		***	Hydro-Québec, Ontario Hydro, EDF

† The E7 utilities are present in most fields with emphasis as indicated

Legend:

* large prototypes
** niche markets
*** feasible for connection to grids
**** some contribution to overall demand

Hydro-electricity, the most common renewable energy, is well established and already forms a significant part (about 25%) of the E7 companies' energy mix (Fig. 1). In their service territories, as well as in the most industrialized countries, further opportunities are represented by:

- refurbishment of existing hydro plants, to increase their output while reducing their environmental impact;
- construction of small hydro plants to exploit very local resources.

This second option is practical only if design and construction are standardized, as was done by the E7 in the 1970s. Therefore, installing plants has become extremely simple, even with limited skills and in the most difficult areas, without incurring design and site-related cost overruns.

In many countries and geoeconomic regions (Brazil, China, Africa and even Canada), a very relevant amount of hydropower may still be harnessed. This hydropower could be transmitted to load centres by means of ultra-high voltage transmission lines (ac and dc, 380-750 KV and above), a technology well mastered by the E7 companies.

Geothermal power comes next in terms of industrial importance and the E7 expertise is being further developed both in research (deep drilling, reservoir physics, special materials) and in technology (field exploration, variable pressure turbines, etc.) Efforts for further expansion of such technology focus on means for exploiting deeper heat deposits (four thousand meters, in aggressive environments, is economically feasible), and water-dominated heat reservoirs (3.5-MW prototype tested; 30-MW station due to phase-in by 1995).

Energy from biomass, such as agricultural and municipals wastes, may be cost competitive under the most favourable conditions. However, the spread in costs is rather wide. The main problems are not technical but involve production, organization and market development. Properly managed biomass is carbon dioxide neutral, while sulphur dioxide and ash emissions are reasonably low. Biomass offers synergies with land management, as it allows the recovery of marginal lands, a problem in some advanced countries.

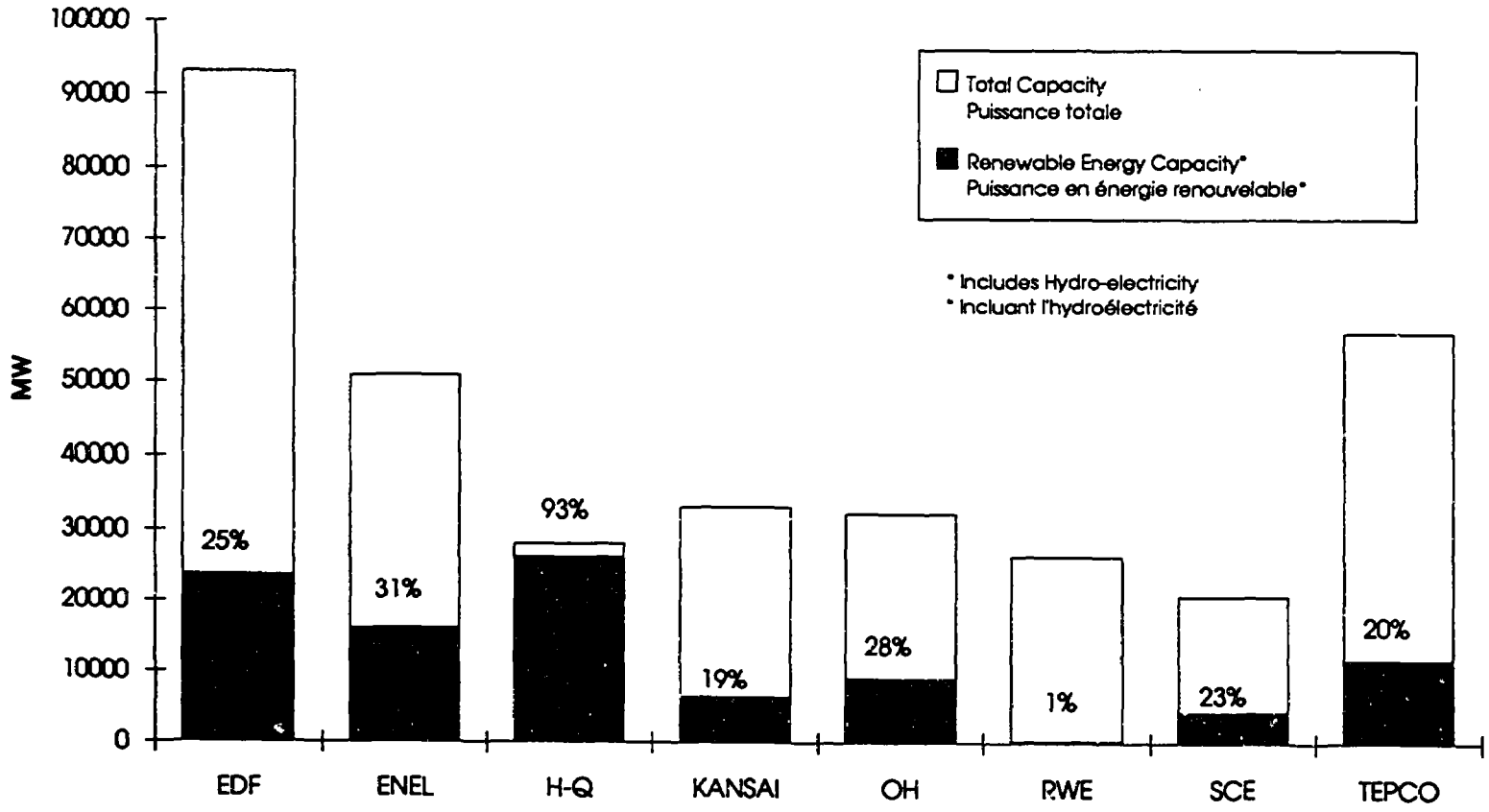
The E7 utilities will play an active role in biomass projects for bulk electricity production. Their effort are aimed at:

- demonstrating economy feasibility of electricity production with existing technologies (direct combustion);
- developing new more efficient technologies in the near future (gasification, pyrolysis, anaerobic digestion, etc.).

Recovery of energy from municipal waste is one of the areas in which the E7 utilities are operating and intend to operate as a contribution to an environmentally-benign solution of a growing social issue. Their expertise and approach to industrial operations offer the best guarantees to communities from the point of view of satisfying the criteria of sustainable development. Both municipal solid waste and landfill gas produced by decomposition can be burned to produce electricity; municipal solid waste can either be burned directly or processed to recover recyclable materials. The resulting fuel is known as Refuse Derived Fuel. The generation of electricity from municipal solid waste fuels, using properly adapted conventional combustion technologies, is proven and well understood. Several possibilities are pursued: burning refuse-derived fuels in existing boilers, joint gasification of biomass and waste, fluidized bed combustion development. The E7 policy is flexible to respond to communities' wishes on disposal of their waste; its strength rests on the specific know-how needed in this field, which is being built up around the expertise of the E7 companies from their core business (fuel handling and burning, waters and flue-gas treatment, monitoring, etc.).

Among the new sources of renewable energy, wind energy is today near competitiveness in good resource areas, thanks to the efforts undertaken in the past to develop not only wind generators, but also properly designed balance of plant and network-compatible wind farms. As the cost of wind turbines declines, their presence will increase. However wind energy development will be limited by harnessable resource availability, environmental problems (space requirements and noise), and limitations in terms of network compatibility. Research and

Fig 1: Installed Renewable Energy Capacity of the E7 Companies
Puissance installée d'énergie renouvelable des compagnies du E7



development are targeted at improved design and size optimization of both machines and farms. Utilities are interested mainly in improved methods for optimal siting, power control and grid-interconnection. Discontinuity and unpredictability of the source put an upper limit, depending on the grid characteristics, on the wind capacity to be connected. Finally, wind generators and farms contribute to electricity production, but are rarely able to meet demand.

Solar technologies, with the potential assets of using an unlimited resource and posing no environmental impacts, are currently not cost-effective in most applications, apart from special cases. However, the E7 companies are engaged in research and development activities that, over time, should reduce costs.

As for thermal solar plants, distributed solar collector systems ("solar troughs") have been operated commercially, but at the present state of the art, they show limited possibilities of further cost reduction. Central tower solutions, which proved uneconomical in the past, are now being reconsidered, with improved technological approaches, specifically in heat transfer and storage. If successful, this solution will qualify for industrial exploitation in very sunny areas, such as Southern California. As for low-temperature solar conversion, such as water heating and bioclimatic architecture, the E7 companies actively pursue these applications since they lead to sound energy savings.

Photovoltaic technology is the most promising medium- to long-term solar option. This view, shared by several E7 companies, has been leading them to a significant commitment.

Application of solar photovoltaics will begin with high-value, smaller applications, which have expanding markets. In this way, in parallel with mass production of photovoltaic modules, costs may be curbed.

The E7 strategy to anticipate photovoltaics as an industrial option is the following:

- continue early uses of photovoltaics in already cost-effective applications (power supply to isolated, remote users);

- install photovoltaic systems to supply isolated remote communities (e.g. on small islands) both in stand-alone configuration or connected to small diesel-powered grids, to act as fuel-savers (this application can be cost-effective depending on local situations);

- install rooftop photovoltaics in grid-connected systems for residential or commercial applications (this application may be cost-effective in building integrated systems and offers demand-side management advantages); particular attention is given to the problems linked with interconnection to the distribution grid;

- continue research and tests on modules of photovoltaic power plants scalable up to multimegawatt, even if utility bulk photovoltaic power is not expected to be cost-effective in the medium-term and shares with wind energy a technical problem that burdens network operation, namely, scarce contribution to capacity requirements.

New renewable energy technology applications can also be regarded as a measure that utilities can take to modify their customers' electricity demand. This set of actions falls under the name of Demand Side Management (DSM). DSM may include the implementation of programs that aim to improve wise use of electricity, to distribute electricity demand more evenly throughout the day, and to encourage strategic load growth. DSM options, as far as they reduce overall energy requirements, ultimately alleviate the impact on both the environment and reduce fossil fuel demand.

3. ENVIRONMENTAL ASPECTS OF RENEWABLE ENERGY

Renewable energy sources can in general be considered as more environmentally-friendly than most other sources. Impact on environment and risk for human health, properly identified as the technology matures from research to pilot and to commercial scale applications, are and will be mitigated within acceptability levels.

The main environmental issues to be considered (with the main mitigation measures between parentheses) are:

- **land use:** large territories are occupied: hydro-electricity, photovoltaics, biomass crops, or "engaged": wind for source harnessing (therefore preferred siting in marginal lands, multiple land use, careful layout):

- **water quality:** hydro reservoirs may affect the chemical, physical and biological qualities of water (monitoring and countermeasures by additives); brines from geothermal systems may contain salt and toxic material (reinjection);

- **air pollution:** production of energy from biomass and geothermal systems results in a range of air pollutants, somewhat similar to fossil combustion; toxic pollutants may be produced from refuse derived fuels (counter measures are similar to the ones adopted for fuels: flue gas treatment, monitoring, etc.);

- **noise:** in wind and geothermal systems significant noise problems may arise (distance, silencing devices, etc.);

- **visual:** any system requiring large land use -photovoltaic, hydro, biomass or tall installations -wind farms- may result in visual intrusion (aesthetic architectural countermeasures);

The kind and size of the environmental problems encountered may be overcome without excessive difficulties and costs by mitigation measures or by other appropriate design approaches. The E7 companies are committed to incorporating the necessary environmental measures into its prototypes, industrial demonstrations facilities and plants.

4. BARRIERS TO DEPLOYMENT OF RENEWABLE ENERGY SOURCES

New renewable energy technologies are currently cost competitive with other forms of generation only in limited markets. The effort is in the direction of approaching competitivity by applied research and demonstration. Competitivity might also improve if fuel costs for more conventional resources rise. It might be added that, if social factors such as those reflecting concern on environment or security of energy supply, are properly internalized, renewable energy would improve their economic position, as their external costs are less than for other sources. Furthermore, since performance of near market renewable energy technologies is continually being improved, then new applications might become of interest.

The E7 views renewable energy technologies within the market system. The market will demand such technologies once it is satisfied that they are at least as economically attractive as competing technologies, that they meet satisfactory technical standards (safety, reliability, etc.) and that institutional and regulatory constraints are reasonable.

Harnessing of renewable energy implies - apart from solving economic issues - overcoming some barriers and the E7 intends to contribute to this objective. Some barriers are country dependent but others are generic, such as: limitations in entry markets; lack of awareness; regulatory inertia; financing difficulties; lack of skilled personnel.

The E7 may have a special role in addressing:

- **Advanced Planning**

  Geographic dispersion of electricity demand, especially in large and sparsely settled regions, may gain benefits from advanced planning, which maximizes overall system utilization and value to the customer by combining central generation, which takes advantage of system diversity, with local distributed generation.

- **Lack of awareness**

  Knowledge gained through R&D programs needs to be transferred to industry, commerce and the public. This should help maximize acceptance and understanding of renewable energy and thereby its potential deployment. This dissemination process should be targeted at key market sectors.

- **Lack of skilled personnel**

  The development of the necessary skills, and, with them, the development of the market, might be assisted by the provision of suitable training and guidance.

- **Limitations in entry markets**

  In the transition from the experimental stage to commercial penetration, utilities' demonstration plants validate and consolidate the technologies, accelerate the rate of their application, allow the adoption of proper design, construction, and operation practices.

5. CONCLUSIONS

It is difficult to make medium-term estimates of how much electricity can be produced from solar, wind, biomass and other new renewable energy sources, or what its cost would be. The factors to be considered are many and complex. They include: availability of the resource, characteristics of the sites, success in prototyping, guarantees for industrial mass production in the sector, future cost of conventional energy and internalization of life-cycle energy process costs. In a prudent but positive outlook, like the one in Table 2, it will be possible to satisfy a small but important portion of a utility's electricity requirements. Furthermore, network quality supply requires that, beyond provision of energy, adequate capacity be available whenever needed. The lack of a significant contribution from both wind and solar energy, given the discontinuity of these sources, is an added technical and economic problem. Their contribution should be seen in the short/medium term as an integration, not as an alternative to traditional fuels.

Renewable energy power systems, however, have characteristics (small and modular size, easily sited, local load matching, environmentally benign) which differ substantially from the mid- to large-size central generating stations traditionally employed by utilities to meet their customers' electricity needs.

Beyond applications where those sources are best fitted (remote areas, islands, etc.), they might be conceived as a distributed generation system, whose elements may include other promising technologies, such as fuel cells, and demand side management measures.

These elements may be designed to be integrated into the grid with the central station generating system. This view is in line with integrated resource planning, a tool that the E7 companies are adopting side by side with other planning techniques.

Another asset of renewable energy sources, particularly solar and wind, relates to their direct access by any utility, as they are both widely dispersed and user-friendly. As they become even more economically viable, they can represent an alternative solution in sparsely populated areas. The E7 Network is ready to make available its expertise to help determine specific applications, contributing, where necessary to overcoming possible barriers.

ACKNOWLEDGEMENTS

The Steering Committee of the E7 Network of Expertise for the Global Environment is particularly indebted to Ms. Debbie Gray for her timely acquisition, study and synthesis of the E7 individual companies' reports. The Committee acknowledges the contributions of: Mr. P. Mollon of EDF (F), Mr. R. Vigotti of ENEL (I), Ms. N. Noël of HYDRO-QUEBEC (CND), Mr. R. Ronchka of ONTARIO HYDRO (CND), Mr. H. G. Adam of RWE (D), Mr. R. Nunnally of SCE (US).

NOTE: The E7 companies' individual contributions are available upon request from the Secretariat of the E7 Network of Expertise for the Global Environment.

Summary

This report was submitted by the E7 Network of Expertise for the Global Environment, an international energy group made up of the world's leading electricity producers: Électricité de France (France), ENEL (Italy), Hydro-Québec (Canada), KANSAI (Japan), Ontario Hydro (Canada), RWE (Germany), Southern California Edison (U.S.A.) and TEPCO (Japan). The mandate of this group includes the promotion of environmentally-friendly electricity generation in developing and Eastern European countries.

The success of new renewable forms of energy is examined, namely hydro-electricity, solar energy, wind energy, geothermal energy, biomass, and, by extension of the concept, municipal waste. The potential in using these forms of energy is remarkable, but the barriers are also sizeable. The potential applications in the E7 and other countries is discussed, as well as the E7 companies' efforts to overcome these barriers.

Although renewable energy has not to date had great success for bulk electricity production in the E7 companies, it is very applicable in certain cases. A key policy guideline of the E7 utilities is to bring these options to industrial maturity, with the aim of reducing both the pressure on other energy sources and the overall impact on the environment.

The E7 utilities are continuing their research in this field in order to improve the existing technologies, develop new technologies and make their application more economically feasible. The E7 Network is ready to make available its expertise to help determine specific applications and encourage the use of renewable energy.

Résumé

Ce rapport a été soumis par le Réseau d'expertise E7 pour l'environnement glooal, un groupe international composé des grandes compagnies productrices d'électricité dans le monde : Électricité de France (France), ENEL (Italie), Hydro-Québec (Canada), Kansai (Japon), Ontario Hydro (Canada), RWE (Allemagne), Southern California Edison (États-Unis) et TEPCO (Japon). La vocation de ce réseau est de promouvoir une production d'électricité respectueuse de l'environnement dans les pays en développement et en Europe de l'est.

La possibilité de produire de l'électricité à partir de sources renouvelables est évidente : l'hydroélectricité, les énergies solaire, éolienne et géothermique, la biomasse et les déchets solides domestiques. Le recours à ces formes d'énergie est intéressant, mais les obstacles sont aussi considérables. Leurs applications potentielles dans la production de l'électricité sont présentées, ainsi que les efforts que les compagnies du E7 ont faits pour surmonter les obstacles liés à ces types de production.

Même si les énergies renouvelables n'ont généralement pas connu, à ce jour, un grand succès auprès des grands producteurs d'électricité, ils ont mis au point certaines applications très appropriées. Dans cette manière, l'objectif principal des compagnies du E7 est d'accélérer la mise en service commerciale des nouvelles sources d'énergie renouvelable et de réduire ainsi non seulement la pression exercée sur les autres sources d'énergie mais aussi l'impact global sur l'environnement.

Les compagnies du E7 continuent leurs recherches dans ce domaine dans le but d'améliorer les technologies existantes, de développer des nouvelles technologies et de les rendre plus efficaces et économiques. Le réseau E7 est prêt à partager son expertise au bénéfice des pays en voie de développement et pour améliorer la situation dans les pays de l'Europe de l'est.

ANNEX 1

E7 JOINT STATEMENT

APRIL 9, 1992

The seven major electricity companies (the E7) have resolved to participate actively in the international debate on the environment and development, including the issue of global warming. They bring their expertise to this debate in order to improve diagnoses, pool their analyses, propose solutions, and implement those solutions in their respective spheres of competence.

Citizens of their own countries

The major electrical companies signing this statement are active, responsible citizens of the countries in which they operate. To fulfil their respective mandates and public obligations, make available the electric energy that is needed to improve living standards, and expand the economic activities of their fellow citizens, these utilities have developed safe and efficient technical processes and made great efforts towards environmental protection. They make major decisions with due consideration of conflicting objectives and constraints. They consider the management of environmental protection among the highest of corporate priorities and a key determinant to continued development. In their own countries, with their own generating methods, these utilities supply energy at rates of efficiency they have increased considerably over the years, and which they steadily improve. In many instances, they go beyond the environment standards of their jurisdictions.

They pay particular attention to the development of renewable energy sources, the promotion of research and the choice of equipment that minimizes environmental impacts.

They will continue to advise their customers on how to use electrical energy efficiently and with moderation, while making clear electricity's many benefits for the environment, particularly at the point of use.

Citizens of the world

In view of the international debates and scientific advances of recent years, the E7 utilities are convinced that, despite remaining differences in scientific opinions, preventive measures are necessary at world level to avoid deterioration of the climate and of the environment. Such measures require a common strategy.

All the world's countries legitimately desire to improve their living standards by developing electricity infrastructure. This desire will be fullfilled compatibly with the global environment if developed countries cooperate with each other and with developing countries on programs of demand management, environmental protection and efficient supply.

The E7 companies believe that achieving optimal utilization of environmental resources requires greater technological transfer to developing countries. Future action plans should be applied to the areas where they can be most effective. A wider range of action plans is available than simple fiscal regulation; technological transfer is just an example of one such action plan.

As citizens of the world, in harmony with their respective national governments and related domestic and international organization, the E7 companies strongly wish that the experience, competence and know-how of their companies should serve more efficient generation and use of the world's electric energy.

Conclusions and proposals

In view of these questions and issues, the heads of the major utilities signing this statement met on April 8 and 9,1992 at James Bay, Québec, and adopted the following joint commitments.

- They agree that, in order to be effective, all measures intended to mitigate the influence of electricity generation on the global environment must be suited to the economic, ecological and technical possibilities of each region. In this context, an integrated energy management approach must be developed, on both demand and supply sides, aiming at efficient use of all renewable, hydro, nuclear and fossil generation. Only this kind of approach can secure a sufficient and environmentally acceptable energy supply on a world scale, to respond to the energy needs of a growing world population.

- Many criteria must be considered when developing an appropriate energy plan for any jurisdiction. Overall environmental impacts are key, but other criteria include a country's natural, financial and technological resource base. By the criterion of global environmental warming alone, the technologies of demand management, nuclear, hydroelectric and other renewable energies are important components for energy plans, where appropriate. Just as important, modern improvements in plant efficiency measures for fossil-fuel generation have made, and will continue to make, significant impacts in reducing global warming.

- The E7 companies are setting up a joint network of expertise which will improve cooperation between the E7 utilities and act as an ecological, technical and industrial advisory group for supranational institutions and governments, especially in the developing countries. The E7 utilities would encourage international funding agencies to focus their investments on projects with minimized environmental impacts. They are convinced that, accompanied by parallel action by governments and supranational institutions to expand financial resources directed towards third world countries, this initiative should have a positive impact on the sustainable development of the world.

- They will make this joint network available to developing countries to help them make their energy diagnoses, and propose projects to the international financing organizations.

- They will continue to develop their ideas in periodic meetings in order to seek ways of harmonizing sustainable economic development and environmental protection, including cooperation with their colleagues in developing countries.

Signed at James Bay, this 9th day of April 1992.

Pierre Delaporte
Président du conseil d'administration
Électricité de France

Werner Hlubek
Member of the Board
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Richard Drouin
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