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TEXTE PROVISOIRE POUR LE CLUB DE ROME

(PROJET RIO)

ENERGIE ET AUTRES RESSOURCES MINERALES

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Rapport d'ensemble

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Le rapport d'ensemble et les annexes B, D, E, F ont été rédigées par M. GIBRAT.

Les annexes A et C ont été rédigées respectivement par MM. CALLOT et NOGUCHI

Mai 1975

ENERGIE ET AUTRES RESSOURCES MINERALES

1. Dans le domaine de l'énergie et des ressources minérales un nouvel ordre international est vivement souhaité par le Tiers Monde (il ne pourra évidemment être question ici que des mesures pragmatiques fragmentaires à inscrire dans le cadre d'ensemble du rapport général). Depuis le début de l'année 74 s'en sont saisies plusieurs sessions de l'ONU ou de la CNUCED. La dernière réunion de l'ONUDI à LIMA en mars 75 y a été consacrée. Le mémoire en 105 points intitulé "le pétrole, les matières de base et le développement" présenté par l'ALGERIE en avril 1974 à l'occasion de la session extraordinaire de l'Assemblée Générale des Nations Unies nous paraît l'expression la plus documentée de toute cette action. Il nous permet d'exposer les principaux problèmes, à partir des positions du Tiers Monde, ce qui nous paraît préférable. Nous retiendrons d'abord deux affirmations significatives :

"L'emploi des matières premières riches des Pays en voie de développement engendre une rente qui est inhérente à ces matières. Les Pays développés se sont appropriés cette rente. Le pays en voie de développement doivent le récupérer" (point 80).

"Au-delà de la récupération de la rente, les pays en voie de développement doivent utiliser leurs matières de base pour lancer un processus de développement économique.

Ils disposent de peu de temps pour cela" (point 82).

Appropriation de la rente avec affirmations renouvelées et très passionnées de la souveraineté nationale pleine et entière, liaison étroite et directe avec le financement du développement tout cela ne leur paraît possible qu'avec un nouvel ordre économique international.

Mais ces concepts sont incompatibles avec celui de "patrimoine commun de l'humanité" employé des 1970 par l'ONU (résolution 2749 XXV) à propos de l'utilisation des fonds marins dont l'exploitation devrait profiter à l'ensemble de l'humanité, producteurs, consommateurs et autres. Or, n'est ce pas la seule solution finale du problème posé par l'inégale répartition géographique des ressources ? Devons-nous renoncer à une humanité pleinement solidaire où les différents peuples seront traités comme aujourd'hui les habitants d'un~~e~~ même ~~ville~~ pays ?

2. Il est évident que le Tiers Monde n'est pas prêt à renoncer à ce qui pour lui est une "arme" . Les matières premières fournis par les Pays du Tiers Monde ont une importance stratégique et peuvent, à l'instar du pétrole, servir de support à une action collective en vue de récupérer la rente. (point 50).

Il a des arguments économiques que l'on ne peut rejeter facilement en voici deux : "L'optimum collectif, au niveau du monde, appelle l'utilisation des matières premières les moins couteuses, ce sont les pays en voie de développement qui paient les frais de cet optimum" (point 78).

Ou encore "Le pétrole n'est pas une super-richesse. S'il y a une ligne de partage entre les différentes richesses, c'est bien celle qui sépare les richesses épuisables de celles qui constituent un potentiel économique inépuisable. Les gisements pétroliers et miniers sont épuisables et risquent d'être obsolescents... (point 72).

Il parait difficile de nier que le Tiers Monde doive conserver pour le moment son arme, car les pays développés contrôlent la quasi-totalité des marchés de consommation, ils ont pratiquement le monopole de la fabrication des biens d'équipement et des produits manufacturés comme celui des compétences technologiques. Ils avaient jusqu'en 1973, celui des capitaux. La disproportion des forces était et reste flagrante et ceci explique l'échec actuel des initiatives en vue de résoudre le problème capital du développement. Mais, (ceci complique considérablement les actions à court terme), des pays développés commes les ETATS UNIS, l'URSS, l'AUSTRALIE, le CANADA, ont acquis une nouvelle vigueur économique avec la hausse des matières premières intervenue depuis 1973, ils sont en fait dans les deux camps, d'où d'innombrables ambiguités.

Une phrase très dense du mémoire algérien définit la philosophie de leur action future "Dans un monde déséquilibré.... chaque combat engagé par les plus pauvres à l'échelle nationale n'aboutit à la plénitude de son efficacité qu'au moment où il parvient à s'insérer dans le cadre d'un mouvement universel dont il constitue à la fois une composante et une résultante auquel il apporte sa dynamique propre tout en s'y nourrissant en forces sans cesse renouvelées".(Point 16) Ceci est pour eux la raison du succés des mouvements de libération et de ceux qui ont entraîné pour le pétrole la récupération de la rente.

3. Nous devons donc accepter comme un fait cette position. Mais nous croyons trop dans le progrès général de l'humanité pour renoncer à long terme au concept de "Patrimoine commun de l'humanité".

Le principe même du projet RIO est de présenter des horizons différents. Nous avons pensé donc opportun de déduire nos propositions à court terme des conséquences de notre position à long terme. Comme on le verra dans l'annexe A, le concept de "patrimoine commun de l'humanité" conduit à l'introduction d'une fiscalité mondiale sur le profit ou le chiffre d'affaire appliquée aux productions minières de tous les pays du monde, les fonds recueillis étant redistribués aux pays en voie de développement. Il nécessite aussi de stabiliser les cours et de créer des instances internationales chargées d'appliquer la politique ainsi définie, autorité mondiale jouant le role d'un parlement national et agence mondiale des matières premières minérales comme organe d'exécution.

L'équilibre actuel des forces politiques ne permet pas la mise en place actuelle d'une autorité mondiale ni le recouvrement des taxes mondiales, mais un large commencement d'exécution peut être initié avec une agence mondiale des matières premières à caractère consultatif chargé en particulier de proposer des mécanismes de stabilisation. L'accord de Lomé(janvier 75) sur des garanties de recettes d'exportation entre la Communauté Européenne et un nombre très important de producteurs du Tiers Monde mérite d'être généralisé. Pour le moment en matière minérale il ne s'applique qu'au minerai de fer.

Nous citerons aussi une proposition française près de la CNUCED en 1974 combinant en cas de baisse des cours une taxe à l'importation et un reversement au pays en voie de développement du produit de ces taxes. L'instauration d'un réseau serré d'accord de produits devra être examiné ainsi qu'une indexation éventuelle de certaines matières.

Les discussions un peu vaines sur d'éventuelles pénuries pourraient être ainsi réglées au sein d'une telle agence, tous devant y être représentés de façon équitable. Les problèmes de gaspillage d'énergie (économies et recyclage) devraient aussi en relever.

4. Ayant ainsi traité des ressources minérales énergétiques et des minerais nous devons maintenant nous tourner vers les problèmes énergétiques proprement dits. Ici, une remarque préliminaire : trois points dominent aujourd'hui le sujet et cependant aucun d'eux ne semble préoccuper le Tiers Monde.

a) D'une part il paraît ignorer les batailles dans les pays développés autour des différents taux de croissance et les recherches passionnées d'un nouveau type de société différente de l'actuelle société de consommation. Cependant les unes et les autres auront une incidence très nette au même titre que les décisions des producteurs sur l'épuisement des ressources énergétiques et en premier lieu du pétrole. Toutes les échelles de temps du développement du Tiers Monde y sont accrochées. De plus, la déclaration de LIMA demande au point 28 que la part de la production industrielle totale mondiale pour les pays en cours de développement atteigne au moins 25 pour cent pour l'année 2000. Or le Tiers Monde pense à une production industrielle et à des biens de consommation du type Occidental actuel et les Pays développés en seront fort loin demain. Les technologies vont changer. Attention......

b) Ensuite le Tiers Monde semble peu sensible aux problèmes d'environnement (le mot pollution est cité une fois dans le mémoire de l'Algérie en 105 Points) Or pour ne prendre qu'un exemple le pétrole soit comme combustible avec son soufre soit comme carburant avec les oxydes d'azote et ses effets cancérigènes est le premier polluant à combattre.

c) Enfin la controverse sur l'énergie nucléaire de fission qui fait rage dans les pays occidentaux ne l'intéresse pas, or ceux-ci s'orientent peu à peu vers une acceptation résignée de cette énergie "pour une période provisoire relativement courte durant laquelle les problèmes spécifiques du nucléaire fissile, c'est-à-dire la sureté des réacteurs, laradioactivité, l'élimination des déchets restent dans des limites raisonnables, tant quantitativement que qualitativement (déclaration de M. SPAAK directeur général de la communauté Européenne à la Conférence Nucléaire Européenne des 21 au 25.04.75).

La conséquence inéluctable de cette acceptation provisoire sera de lancer les pays développés dans une recherche acharnée, presque désespérée de sources nouvelles. Or celles que l'on entrevoit aujourd'hui essentiellement géothermique, soleil, fusion nucléaire ne demandent plus de matières énergétiques minéraleset émousseront donc "l'arme" du Tiers Monde.

5) Sous estimer ces trois points serait une erreur grave ; car dans le monde occidental aujourd'hui les opposants à la société actuelle de consommation les défenseurs de l'environnement et les adversaires de l'énergie nucléaire de fission bénéficient dans l'ensemble de la population du même soutien dialectique que celui dont ont bénéficié hier dans le Tiers Monde les mouvements de libération et les efforts de récupération de la rente. (relire le point 16 du mémoire algérien ciré ci-dessus).

Cela est capital car sans cela le désir d'autarcie et d'indépendance vis à vis du pétrole des Gouvernements des pays développés et de leurs experts ne serait pas suffisant pour lancer réellement la course aux sources nouvelles d'énergie. La résonance de l'idée d'autarcie dans les masses est pratiquement nulle. Les trois points ci-dessus sont par contre déterminants et un retour en arrière paraît exclu.

6) Pour notre part, adversaire résolu de la prolifération de l'énergie nucléaire de fission pour des raisons non seulement techniques, mais sociales et politiques et donc indépendamment de tout problème posé par le pétrole, partisan convaincu de recherches des énergies nouvelles nous proposons dans l'annexe B consacrée à cette question d'établir <u>une agence mondiale des énergies nouvelles</u> dont le financement serait assuré par une taxe sur chaque

kilowatt-heure d'énergie nucléaire. De cette façon, liant vitesse d'intégration du nucléaire et volume possible de recherches, nous résoudrons le problème d'autant plus vite que la prolifération viendra plus rapidement.

A detrès rares exceptions cette taxe ne frappera pas les pays du Tiers Monde, cependant, il conviendra qu'il ait des représentants à l'Agence Mondiale correspondante pour y définir ses besoins et ses possibilités.

7. La recherche des sources d'énergie nouvelle est loin d'être contraire aux intérêts du Tiers Monde à moyen et lon terme. Ainsi nous croyons profondément à l'avènement de l'énergie solaire industrielle sous réserve de faire les efforts énormes nécessaires et nous voyons dans celle-ci le relais du pétrole aussi bien pour leur propre développement que pour l'exportation. L'arrivée de la civilisation de l'hydrogène sera pour eux un facteur de croissance extraordinaire, car les pays du Tiers Monde sont largement favorisés dans l'utilisation de cette énergie par la qualité de leur ensoleillement et surtout par leurs énormes surfaces disponibles pour le captage.

L'annexe C traitera de tout cela ainsi que des énergies géothermiques etc...

L'annexe D évoquera les conditions d'arrivée de l'hydrogène.

8. Par contre, l'utilisation de la fusion thermonucléaire, grand espoir pour l'énergie du XXIe siècle, matière première le deutérium (toute eau en contient 0,2 pour mille) nécessite probablement d'énormes concentrations de puissance (plusieurs millions de kilowatts électriques par réacteur) et ne pourront pour cette raison être introduits que tardivement dans les pays en cours de développement. Ceci peut, peut-être, justifier de laisser pour le moment les recherches correspondantes entre les mains des pays développés.

L'annexe E essaiera de définir les chances d'aboutissement de cet espoir, deux voies indépendantes l'une de l'autre s'offrent dès maintenant. Nous examinerons si dans ces conditions, les surrégénérateurs restent indispensables ?

CONCLUSION

Nous croyons profondément à l'importance des problèmes précédents pour la mise en place d'un nouvel ordre international. Mais son but reste le développement des nations pauvres, aussi la question fondamentale ne doit pas être écartée. Une grande partie de ceux qui réfléchissent dans les pays riches au problème de la croissance dans les pays pauvres sont persuadés que la croissance n'est pas un bien matériel que l'on puisse acheter par de l'argent ou forcer à vendre par des moyens politiques. De nombreux leaders du Tiers Monde sont assurés aussi qu'il est parfois facile d'acheter une centrale nucléaire mais qu'il est beaucoup plus difficile de lui apporter, pour son fonctionnement et surtout pour son entretien, les innombrables services qui demandent l'appui de tout un peuple.

Le Président BOUMEDIENNE dans son discours en avril 74 devant l'Assemblée générale des Nations Unies a montré qu'il était bien conscient de cela. Aussi préconise-t-il pour les pays en voie de développement une véritable révolution industrielle "chaque pays s'il veut véritablement assurer son destin, doit prendre en charge lui-même son développement, c'est-à-dire mobiliser en premier lieu toutes les ressources humaines et matérielles qui lui sont propres". C'est ce qu'a fait autrefois le JAPON et il a su importer la croissance tout en respectant les règles du jeu des pays industriels.

Puisqu'il s'agit de modifier ces règles en créant un nouvel ordre international, il faudra pour que la croissance "s'exporte" qu'il se crée dans les pays développés, économie planifiée ou non, une volonté <u>enracinée dans les masses</u> de solidarité avec les pays en voie de développement. En paradoxant pour un moment, peu importe la structure des institutions du nouvel ordre international si elles sont bien des lieux de rencontre à partir desquels se diffuseront les idées nouvelles jusqu'au plus profond des peuples. Le moment est venu pour le tenter, mais pour réussir il faut d'abord comme le déclarait à LIMA le Secrétaire d'Etat Français aux Affaires Etrangères " se départir de l'attitude de méfiance réciproque et débarasser les thèses de tout ce qui n'est pas objectif et positif".

FIRST DRAFT
(translation from
French)

APPENDIX 10: IS RECOURSE TO NUCLEAR ENERGY INEVITABLE?
by R. Gibrat

We include in our considerations the period between the present and the year 2000 for from now on:

- On the one hand, success or failure of the only two major technical adventures in the course of development in the field of energy, namely breeder reactors and high temperature reactors will largely influence the consumption of uranium.
- On the other hand, unless a superhuman effort is made, no new sources of energy whether it be solar, nuclear, or any other form of energy will be produced on an industrial scale by that time.

One could and should be concerned with developing those sources of energy already known to be technically feasible, such as geothermal and tidal energy; these sources had been relegated to second place by cheap petrol prices; yet, in view of what is at stake, they can only exert a limited influence. The same will apply to various forms of energy derived from the sea: thermic, tidal, as well as aeolian energy.
At the same time, countries with rich coal deposits such as the U.S.A., Poland and others, will develop coal distillation and other processes within the limits imposed by environmental considerations. However, all this is insufficient even on a world-wide scale, let alone on a European one, unless nuclear power is developed immediately whatever the possible brake that might be put upon the growth rates of developed countries, consideration must, however, be given to the prodigious industrialization growth rate considered necessary for developing countries: these should attain 25 p.c. of total world industrial production by the year 2000.

Moreover, all government policies in industrialized countries do not aim at present at restraining the scope of nuclear energy development programmes. Rather, they are extending it to the maximum by accelerating research into nuclear power for industry or into the use of hydrogen as a vehicle. This is a categorical fact.

The answer to the question whether recourse to nuclear energy is inevitable is therefore "YES". More precisely, it is a qualified: "unfortunately, yes".
Why?

Leaving aside the problems posed by climate, for they are common to all sources of energy, or almost so (with the sole exception of tidal energy), we do not refer to the problem of radioactive gaseous or liquid effluents: they are not considered to be serious nowadays...

Nor do we allude to the consequences of a nuclear accident which, after all, is always possible and whose consequences might be very serious: however, ever since man's appearance on this earth, he has lived in danger and this particular danger is perhaps less likely to arise than that of various "Acts of God"....

We do, however, refer to the dangerous consequences of nuclear proliferation. The unlimited expansion of nuclear fission will not be followed by a simple multiplication of risks each of which has a very low degree of probability, but by the appearance of a new risk deriving from the innermost nature of man, carrying a high degree of probability indeed: plutonium theft.
The handling of highly radioactive waste with an enormously long life will form a constant temptation for the agressive and violent traits in man. To go entirely nuclear calls for civilized, disciplined human beings who are fully content with their fate.....

An important work by M. Willrich and T. Taylor, entitled "Nuclear Theft: Risks and Safeguards" (1974), embodying research carried out on behalf of the Ford Foundation, has analysed the risks arising from the theft of fissile material for violent ends (public or private banditry, or terrorism).
At the end of 252 pages the conclusion is clear: The terrorists' bomb does not have to give a high performance, nor is it necessary to reliably predict its behaviour as long as it can be transported by car and furnish the equivalent, say, of 100 tons of explosives. The report is quite categorical on this point: it is possible, within the span of a few months, to transform plutonium oxide into plutonium proper in a clandestine laboratory; the material might be stolen in small quantities so as to escape discovery by any stock accounting system. The equipment can be commercially purchased at the cost of several thousands of dollars or even less.

Lastly, some people (or even a single individual) with elementary scientific training in possession of 10 kg plutonium and a fair amount of conventional chemical explosive will be capable of designing and constructing a rough fission bomb within a few weeks and can do so without any specialized knowledge and with equipment that can be purchased from any supplier of laboratories for teaching purposes.

It is evident that if nuclear installations proliferate in a given country beyond a certain limit, security will call for policing or other measures which would prove more and more unacceptable.

Hence, it is necessary, without losing any further time, to set into motion a gigantic effort so as to stimulate the emergence of new sources of energy in time. Today these efforts are ridiculously inadequate as regards the quantities and the slowness with which they can become available do not leave any chances to e.g. solar or even fusion energy. The problem ought to be tackled at international level for in individual countries finance will always be refused for long term projects.

Hence our proposal to set up a world agency, properly financed, e.g. by a tax on nuclear energy in order to establish the necessary link between the expansion of the latter and the volume of research into new energy sources.
An effort identical to that made for the Manhattan project or that of sending a man to the moon should be envisaged (cf. appendices 11 & 12).

APPENDIX 11: ENERGY RESOURCES

1. The Nature of Energy Problems

Energy which maintain our social, economic and technological systems on this planet consists of the processes on discovery of energy resources, acquisition, transportation, conversion and consumption as well as safety factor and environment aspects. All of these procedures are closely concerned with the politics and diplomatic problems. For the purpose of reduction in energy cost, efforts in expansion of scale in respective stages, simplification in technologies, and concentration of energy density etc. have been pursued by mankind, while discrepansies as in the following articles have been recognized independently:

- Distribution of energy resources is rather localized on this planet.
- Energy conversion system of large scale will face the limit of the carrying capacity of environment.
- R & D on energy resources might be accelerated in future, however, energy conservation is rather difficult to get into the public acceptance.

Form the end of the World War II, many national governments have kept energy policy under their control by varied reasons such as individual economic background, defensive and others. In order to avoid the future tragedy by ignorance for human being, the world energy policy should be established as fast as possible under the international consensus among developed and developing countries both with and without energy resources.

Fossile fuels which might be expected to remain on this planet in the order of 200 Q (Q equals to 2.52×10^{17} Kcal or 2.93×10^{14} KWH) are not sufficient enough to promise the future prosperity for mankind after the year 2000. The nuclear fission and fusion energies as well as solar, geothermal, and aeolian energies are considered as most promising as alternative sources of energy in future, diversifying their quality and quantity on supply and demand for respective countries or local area. The following paragraphs will describe the respective characteristics and their problems on these energy resources.

On the carrying capacity of our environment, the limitation to dissipate thermal energy on the terrestrial surface might exist. In order to keep our troposphere in its equilibrium in developing a large scale energy production and conversion on this planet, the net amount of energy included in the thermal pollution should be suppressed within about 10% of intensity of incoming solar radiation (max. 1 KW/m^2 as an intensity of direct solar radiation) as an overall average on the global surface, although an acceptable value at a local area may exceed this value sometimes when the dissipated heat is easily removed from the closed system by wind etc.

2. Solar Energy

The incoming solar radiation on this planet will be described as 5300 Q/year above the stratosphere, 3600 Q/year on the earth surface and 690 Q on the total land area. As compared with fossile fuel resources, these figures might be quite reliable as an alternative source of energy. Although solar energy is said to be free, abundant and can be used with far less pollution on the terrestrial surface, the disadvantages are still found on the following points, as high investment cost, and energy source is intermittent and localized in the global sense.

Further, the utilization of solar energy in large scale might induce the possibility to have an impact on microclimate in a localized area. Generation, conversion and consumption of energy of any type in large scale, such as nuclear, geothermal, ocean and any other energy sources might carefully be assessed as in the case of solar energy.

2.1 The Field of Solar Energy Application in Both Developed and Developing Countries

In the application of solar energy, one might see the fields of wide varieties as in solar thermal processes, photovoltaic and photogalvanic processes.

The solar thermal systems include solar thermal power generation, space heating, cooling and hot water supply by solar water heater, solar distillation, solar refrigeration, ice making, solar furnace for high temperature processing, solar cooker, heating of swimming pool, multipurpose uses in agricultural technology such as greenhouses, mulching, snow melting etc. Both photovaltaic and photogalvanic processes are for power and hydrogen production.

Among the solar thermal systems, solar space heating, cooling and hot water supply, and solar thermal power generation are two of the most significant technology in the R & D of solar energy science and engineering. Desalination and agricultural application might be considered very important from the view point of food production.

The cost of solar energy might be still several times higher than that of fossil fuel in this decade and it is probable that the cross section of cost reduction in solar energy and increase of fossil fuel cost might be expected in some time in the next decade. The concept of solar share will also be important from the view point of energy conservation.

In the earlier stage of R & D in solar energy technology, close international cooperation plays the significant role on standardization and measurement of insolation, testing method for solar devices such as solar collectors and solar cells, while government incentives and stimulation will be very effective in heating and cooling of school building in addition to the educational merit to younger generation. Desalination and solar refrigeration might follow in an arid zone and especially in developing countries in the tropical zone.

R & D on industrial heat source by the use of a solar concentrator and heat storage system will be the possible next step.

2.2 Perspectives and Prospectives on Solar Energy

Until the exhaustion of fossil fuels on this planet, human being will and must be wise enough to find the solution in problems on an alternative source of energy. However, it should be pointed out that developed countries may have enough time and funds to develop alternative sources of energy until the exhaustion of fossil fuels, while many developing countries have to face the difficulties in R & D of new sources of energy and in finding the solution in prior to an expected energy crisis on the earth. And this problem is not specifically concerned with only the solar energy but the development of nuclear and other energy sources will be faced with the similar situation.

The solution in the above problem might not easily be derived by the efforts with individual countries and establishment of international institution which will act both with political and economic legislation is strongly recommended.
It is needless to say that technical cooperation and education in international scale are also the important factors.

Up to the year 2000 it is very probable that more than about 30 to 50 % of total energy for space heating, cooling and hot water supply of the present day might be replaced with solar energy. Solar thermal and photovoltaic power generation will be coupled with other power generation systems such as nuclear, SNG, hydrogen, aeolian and other energy sources.

Rapidly expanding demand for water supply in future might also be met by the application of solar energy from the view point of ecological and energy conservation.

The international cooperation on information exchange, education as well as construction and operation of a large scale test facilities will be most important in developing solar energy technology, while the role of national governments in dissemination and incentives in the field of solar energy should be directed to consider on tax problems, insurance and other legislation and regulations.

Appendix

Table 1: R & D on Solar Energy Application in Various Countries *

	Solar thermal power	Photo voltaic	Space heating, cooling	Solar water heater	Solar distilla-tion	Agri-culture	Solar furnace	Solar cooker
AUSTRALIA	X	X	X	X	X	X	X	
BERGIUM		X						
BRAZIL					X		X	
BURMA				X	X	X		X
CANADA	X		X	X	X	X		X
CHILE				X	X	X	X	X
EGYPT					X			
FRANCE	X	X	X	X			X	
GERMANY FR	X	X	X					
GREECE				X	X			
GUYANA			X					
INDIA	X	X	X	X	X	X		
IRAN				X	X			
ISRAEL	X	X	X	X	X	X		X
ITALY	X				X			

JAPAN	X	X	X	X	X	X	X	
NEW ZEALAND			X	X		X		
NIGER				X	X	X		
NIGERIA		X	X					
PAKISTAN		X		X	X			
SAUDI ARABIA	X							
SENEGAL						X		
SRI LANKA		X		X				
THAILAND				X	X			
TRINIDAD				X	X	X		
TURKEY	X	X				X		
USSR	X	X	X	X	X	X	X	X
UNITED KINGDOM		X	X	X				
USA	X	X	X	X	X	X		X

* Radiation measurement is not included in this table.

Solar refrigeration is under study in Canada, France, Guyana, Pakistan, Sri Lanka, USSR and USA.

Wind power is also being studied in Canada, Germany F R, Netherland, USA and others.

Agricultural studies include greenhouses, mulching, snow melting, crop and timber drying etc.

Appendix

Cost of Solar Energy

The cost of solar energy has been referred in page 3, specifically related to that of a solar collector for space heating, cooling and hot water supply. On the other hand, when the cost of silicon solar cell will be reduced down to about 1/100 as of 1975, solar cell will be competitive to conventional fossil fuels for domestic purposes.

This target might be attained within several years,however, the present state of arts regarding the silicon solar cell indicates that the terrestrial use of solar cell such as for power supply to an unattended navigative lighthouse, robbot rain gage or snow gage, microwave relay station etc. as well as to residential lighting in remote area without electricity supply as in a desert is still competitive in a sense.

The cost of solar thermal power is still in the stage of feasibility study, and it is probable that the cost of solar energy might be less than two times of those of nuclear, hydraulic and conventional fossil fuels.

3. Geothermal Energy

Most of the geothermal energy on the earth can be extracted at an upheaved basin formed in the Cenozoic era, in the form of steam vapor, hot water or their mixture. Though the net amount of geothermal energy is far less than that of solar energy (0.1 Q), this energy reserved in the earth crust might be available in the magnitude of less than 300° C with several kilometers in depth.

The total output of geothermal power plants constructed as of 1973 was about 950 MW and that of under construction was 720 MW through the world, mainly in Italy, New Zealand, USA, Japan and others as shown in Appendix. From the view point of nature of energy sources in the long term, geothermal energy has the similar characteristics to that of solar energy and further can be extracted successively without any intermittence.

3.1 The Role of Geothermal Energy

Geothermal energy has been used almost for power production for mankind up to present, and application of geothermal and volcanic energy might expend in wide varieties depending on the temperature level of hot water and steam derived as follows, although the distribution of available energy sources is rather limited.

Various Uses of Geothermal Energy:

Temperature level	Application	
200° C	Refrigeration (NH_3 - H_2O)	
180° C	Pulp industries	
160° C	D_2 production	Power generation
140° C	Drying of agricultural product	
120° C	Desalination	
100° C	Snow smelting, drying of crops, grass, cooking	
80° C	Space heating	
60° C	Heating for stockbreeding and greenhouses	
40° C	Agricultural cultivation, domestic hot water supply	
20° C	Heating of soil, swimming pool, pisci-culture, disposal of waste water	

3.2 Problems in Geothermal Energy

Since the birth of geothermal energy technology from the boric acid industry at Larderello, Italy, almost 3/4 of a century has elapsed already and we have the evidence that this technology has grown enough to be competitive to the fossile fuels at the local and limited area in the world.

In the R & D on geothermal energy, following problems should be taken into account:

- R & D on investigation of geothermal energy sources as well as deep excavation throughout the world
- R & D on investigation on volcanic energy and energy extraction from high temperature rock bodies
- Comprehensive survey on utilization of geothermal energy
- Technology assessment on ecological and environmental effects of geothermal energy
- Government incentives and leglisation on development of geothermal plant as well as environmental integrity.

In addition to the above mentioned five problems, energy transportation is one of the important problems in the case of geothermal energy. Transportation of thermal energy for long distance is not feasible as compared with that of power transmission. Therefore, the practical application of geothermal energy might be directed to the geothermal power production among various uses indicated in the first page.

The leglislation by local government on geothermal energy is still young and the international cooperation on this point is also urgent.

Appendix

Geothermal Power Plant in the World

	Present (MW)	Under construction (MW)
Italy	390.6	25
New Zealand	202.0	120
U.S.A.	303.0	220
Japan	33.0	130
Iceland	17.0	3
Mexico	3.5	75
U.S.S.R.	3.0	26
Chile		20
West Indies		30
Turkey		30
Phillipine		10
Taiwan		10
El Salvador		20
TOTAL	952.1	719

As of 1973

4. Hydrogen Energy

As one of the alternative sources of energy after the year 2000, hydrogen fuel is considered to be promising. Hydrogen gas which does not exist in situ on the earth surface may be produced through the chemical reaction.

In the concept of hydrogen fuel that has many advantages in comparison with other energy sources, the production of low cost hydrogen is the first and most important step among other factors such as transportation, storage, conversion etc. Hydrogen production might largely depend on thermal processes by nuclear and/or solar energy, while photogalvanic process may play the role of hydrogen production in future.

The advantages of hydrogen fuel will be described as:

- The source of hydrogen depends on water which has been the most abundant molecular species on the earth, and is low cost as well as easy to obtain.
- No disturbance in expected in the ecological cycle, without dissipating carbon monoxide or sulphur dioxide gasses and less nitrogen oxide gas than the case in fossil fuels. Combustion product of hydrogen fuel is water which might easily be assimilated with the natural environment.
- Hydrogen fuel transportation through pipe lines is much more economical and effective than the power transmission.
- Hydrogen fuel itself is a component in energy storage system in such a way that the use of surplus power may be utilized for hydrogen production by electrolysis and be coupled with an intermittent energy source such as solar energy.
- Applications in wide varieties will be expected as for heat source ranging from 200° to 2200° C.

4.1 Production of Hydrogen

Decomposition of water might be realized by the following processes:

- Thermochemical processes with the combination of multistep reactions ($+\Delta H$ and $-\Delta G$)
- Thermal decomposition of water at high temperatures
- Electrolysis
- Radiation chemistry process.

Production cost may be the prime determinant in the development of hydrogen economy as mentioned before. Hydrogen fuel can be stored as a gas, liquid, or metal hydride; while pipe lines in natural gas transportation system may be substituted for those of hydrogen system. The cost of hydrogen transportation might be in between that of natural gas and electricity in future.

4.2 Problems on Hydrogen Fuels

In the development of hydrogen fuel as an energy source, the active R & D on every step in production, transportation, storage and further safety and maintenance problems should be taken into consideration.

From the ecological view point, the total system is recommended to combine the hydrogen system with other alternative sources of energy in the development of hydrogen fuel. Even in the gasification of liquid hydrogen in large scale may have the impact to the environment as a minus thermal pollution.
The problem on hydrogen environment embrittlement must also be investigated further.

Safety factor is a high priority item among production, transportation, storage and usage. Although being as a inflammable substance, hydrogen has a high diffusion rate leaving the scene of a leak much faster.

Impact evaluation of hydrogen as well as hydrogen energy system and economics should be subjected to an international cooperative work in much more wider scope.

FIRST DRAFT
(translation from
French)

APPENDIX 12: THE HYDROGEN CIVILIZATION
by R. Gibrat

One can envisage that there will be two structures of equal interest at the beginning of the twenty-first century: electricity, and hydrogen; this latter product would be cheap, available in large quantities since it would be derived from nuclear reactions (fission or fusion) or solar energy.
It might be introduced progressively, for the presently available transport, storage, and distribution facilities could handle as from now 10 to 15 p.c. hydrogen without having to undergo any modifications. Its transport in bulk would resemble the present-day transport of natural gas and would not give rise to any problems; in the Federal Republic of Germany there is already a network of 300 km length. A network of this kind would be five to ten times less costly than that of an electricity grid.
Storage in underground reservoirs of several thousand million cu. metres could be achieved by using locations from which gas had been previously extracted and are now empty.

The diversity of uses to which hydrogen can be put is extraordinary. There is hardly any instance where it could not be used. Its uses as a reducing gas in the steel- or chemical industries are well known. At present 20 million tons are used throughout the world.

Its protagonists see no problem in its use as a fuel for motor-cars instead of petrol. Certain problems of storage still exist but to the optimists hydrides will shortly provide a good solution. Regarding its use on aircraft, they maintain the same confidence since liquid hydrogen is two-and-a-half times lighter than kerosene, yielding equal power although it requires three times as much space.

In the domestic sector its properties are equally surprising. A group of gas companies in the United States has financed the study of an "all hydrogen" house. Lighting will be produced by small quantities of hydrogen issuing bright luminiscence at low temperatures without any flame. Heating will be achieved by diffusion of hydrogen through decorative panels impregnated with an appropriate catalyst. Cooking rings for the kitchen, without flames, will be made of porous metals of ceramics. Electricity required for domestic equipment will be obtained from hydrogen in fuel batteries or from central stations operating gas turbines. Such perfection seems like a dream.

What is it then that prevents this paradise from becoming a reality? Simply, the production of cheap hydrogen from water. The entire question lies there. At present, electrolysis is the simplest means but it is too costly since yields are still very low. Experiments are going on at the moment with various processes and there is well-founded hope that results may be achieved within the next ten years.

The most important research carried out in the world nowadys is concentrating on the dissociation of water by means of a chain of reactions forming a closed circuit between the substances producing oxygen at high temperatures which then oxidise at lower temperatures producing hydrogen whereby the cycle repeats itself indefinitely. A very large number of reactions is under study at present.

Twenty-six of these have been proposed so far (sixteen by Euratom at Ispra, one at Julich, the nine others by different laboratories in the United States); they differ by the number of reactions per cycle (from two to six), by the number of elements (up to six), their maximum temperatures (ranging from 400 to 1000 deg. C), a.s.o.

Seventeen besic elements, apart from hydrogen and oxygen, are of interest.

An international conference took place at Miami from 18th to 20th March 1974 on this future "hydrogen civilization".
One hundred presentations, in eighteen sessions examined, in the presence of 700 participants, the various aspects of this subject - a subject which fascinates all those concerned with problems of energy.

One presentation demonstrated that by investigating all possible permutations - even if one limits oneself to the field covered by the twenty-six cycles known at present- one could expect a frightening number of cycles exceeding by far one thousand million.

It would therefore appear necessary to refine our knowledge of thermodynamics to a considerable extent in order to obtain supplementary conditions. Let us enumerate some of them: slow separation of the constituent elements, utilisation of liberated heat, weak possible variations or negative variations of free energy beyond the theoretical dissociation energy.

Other authors have studied the output of known cycles.
The best is obtained at a temperature of 700 deg. C achieving 45 p.c. output, hence equivalent to what one hopes to obtain from electrolysis. The indicated temperature will therefore have to be greatly exceeded if one wishes to improve on the results obtained from electrolysis.

However, this prospect should not discourage us: on the contrary, the very multiplicity of the cycles gives us the assurance that we are not limited by present outputs; there is certainly a treasure hidden in this haystack and thermodynamics should help us discover it. Mr. Gregory of the Institute of Gas Technology (U.S.A.), a highly venerable institute, thinks of a period of twenty years before this process can be operated on an industrial scale.
There are great hopes for developing countries and the utilisation of their possibilities in the matter of solar energy.

ANNEXE D

LA CIVILISATION DE L'HYDROGENE

par R. GIBRAT

On peut imaginer pour le début du XXI° siècle deux structures d'accueil parallèles : l'électricité et l'hydrogène, ce dernier produit à bon marché en grande masse grâce à la chaleur nucléaire (fission ou fusion) ou l'énergie solaire. Son introduction pourrait être progressive car les installations actuelles de transport de stockage, de distribution peuvent utiliser dès aujourd'hui sans aucune modification, 10 à 15 % d'hydrogène. Son transport massif ressemblerait au transport actuel du gaz naturel et ne poserait aucun problème ; il y a déjà un réseau en ALLEMAGNE FEDERALE de 300 KM de longueur. Il serait de cinq à dix fois moins cher que celui de l'électricité. Le stockage par réservoirs souterrains de plusieurs milliards de mètres cubes se ferait par exemple en utilisant des gisements de gaz naturel actuellement épuisés.

La diversité des usages de l'hydrogène est extraordinaire. Rien ou presque ne lui échappe. Ses usages comme réducteur en sidérurgie ou en chimie sont bien connus. Dès aujourd'hui, 20 millions de tonnes sont consommés dans le monde.

Ses partisans ne voient aucun problème dans son utilisation pour l'automobile en place du pétrole. Certaines questions pour le stockage subsistent, mais pour les optimistes les hydrures offriront vite une bonne solution. Sur les avions, même confiance car l'hydrogène liquide est 2,5 fois plus léger que le kérosène a égalité de puissance, s'il tient trois fois plus de place.

Dans le secteur domestique, ses propriétés apparaissent aussi étonnantes. Un groupe de sociétés gazières aux U.S.A. a financé l'étude d'une maison "tout hydrogène". L'éclairage sera réalisé par l'action de petites quantités d'hydrogène d'où une vive lùminescence à basse température sans flammes. Le chauffage sera obtenu par diffusion d'hydrogène à travers des panneaux décoratifs de plastique poreux imprégnés d'un catalyseur approprié. Des plaques de chauffage sans flamme, pour la cuisine, seront faites de métaux ou de céramiques poreuses. L'électricité nécessaire des appareils ménagers s'obtiendra à partir de l'hydrogène dans des piles à combustibles ou dans les grands centres à partir de turbines à gaz. On croit rêver devant une telle perfection.

Que manque-t-il donc pour que ce paradis devienne réalité ? Simplement une production d'hydrogène à bon marché à partir de l'eau. Toute la question est là. L'électrolyse est aujourd'hui le moyen le plus simple, mais il est trop couteux, les rendements étant encore très faibles. On expérimente en ce moment plusieurs procédés pour obtenir mieux, et il y a de solides espoirs pour aboutir d'ici dix années.

Les recherches les plus importantes faites aujourd'hui dans le monde se portent sur la dissociation de l'eau à travers une chaine de réactions formant cycle fermé entre des corps produisant de l'oxygène à haute température, puis s'oxydant à une température plus basse en produisant de l'hydrogène, le cycle se répétant indéfiniment. Un très grand nombre de ces réactions est actuellement étudié.

Vingt six ont été proposés jusqu'ici (seize par l'Euratom à Ispra, un par Jülich, les neuf autres par divers laboratoires des U.S.A.). ils se différencient par le nombre de réactions par cycle (de deux à six), le nombre de composants (jusqu'à six), leurs températures maximâ (de 400° à 1000°C) etc.

Dix sept éléments simples en dehors de H et O paraissent intéressants.

Une conférence internationale a eu lieu à MIAMI du 18 au 20 mars 74 sur cette future "civilisation de l'hydrogène" ; cent communications présentées dans dix-huit sessions ont examiné devant sept cents congressistes, les divers aspect de ce problème qui passionne aujourd'hui le monde énergétique tout entier.

Une communication a montré qu'en recherchant toutes les combinaisons possibles, même en se limitant au domaine couvert par les vingt-six cycles actuellement connus, on pouvait compter sur un nombre de cycles effarant dépassant largement le milliard.

Il apparaît donc nécessaire d'affiner beaucoup nos connaissances thermodynamiques, afin d'obtenir des conditions supplémentaires. Nous citerons par exemple : faible travail de séparation des constituants, utilisation des chaleurs dégagées, faibles variations possibles ou variations négatives de l'énergie libre au-dessus de celle théorique de dissociation.

D'autres auteurs ont étudié les rendements des cycles connus. Le meilleur avec 700° de température maximum atteint 45%, donc l'équivalence avec les espoirs de l'électrolyse. Il faudra donc dépasser largement cette température pour surclasser cette dernière.

Ceci ne doit pas nous décourager ; au contraire, la multiplicité des cycles nous assure que nous ne sommes pas limités par les rendements actuels : une perle se cache certainement dans les bottes de foin et la thermodynamique doit aider à la trouver. M. GREGORY, de l'institute of Gas Technology (U.S.A) institution très vénérable, pense à un délai de vingt ans avant la mise au point industrielle. Il y a de grands espoirs pour les pays en voie de développement et l'utilisation de leurs possibilités en matière d'énergie solaire.

FIRST DRAFT
(translation from French)

APPENDIX 13: NUCLEAR FUSION- IS THE BREEDER REACTOR INDISPENSABLE?
by R. Gibrat

1. Here the phenomena are very different from those occurring in fission. The reactor under study, called DT for short, is built on the principle of the fusion of two hydrogen isotopes: deuterium and tritium; this corresponds to a loss of mass and hence, in accordance with Eistein's law, to a generation of energy. The DT fusion yields eight times as much energy per mass unit as fission but the reaction can take place only if these elements are imparted very high accelerations to make them collide. The required temperature is one hundred million degrees. How can such a temperature be generated and maintained without the mixture thus heated coming into contact with the reactor walls? Research begun more than twenty years ago uses the principle of magnetic constraint whereby magnetic fields force the DT mixture to remain in the centre of the torus; however, these fields have proved highly unstable and only today, after many efforts, does one begin to see a ray of hope.

The first objective is to obtain a DT reaction which generates as much energy as that used for the process of heating up. The required conditions have been known for a long time: certainly a temperature of 100 million degrees mentioned above is required but in addition a sufficiently large product is needed composed of particle density multiplied by the dwell time in the torus under constraint by the magnetic force. This product of density, measured in cu. centimetres by dwell time measured in seconds must reach 10^{14}.

Today, with a configuration studied in the U.S.S.R. and in France which goes by the name of Tokomak, it is possible to obtain 20 million deg. and a product of 5×10^{12}; the temperature is therefore five times weaker and the product twenty times weaker. This explains why prior to going further in studying problems of production on an industrial scale, one thought it advisable to attain the desired magnitudes figures.

Euratom will almost certainly decide to construct a large Tokomak called JET (Joint European Torus) by 1980, furnishing by 1982, if all goes well, proof of feasibility but no more than that. In particular the structure of the equipment will not yet be capable of resisting the highly destructive neutrons produced by the reactions and no attempts will be made at recovering the generated heat.

A second phase towards 1985 will be designed te resist the force of the neutrons but will not yet recover the generated heat which constitutes a difficult problem, nor will endeavours be made to regenerate the tritium. A third and last machine will then try and solve this last problem and to prepare also the first industrial prototype. With some optimism all this might enable scientists to submit the beginnings of industrial production by the year 2000.

2. Some two or three years ago it was learned in Canada from a revelation made by Teller, the father of the hydrogen bomb, that a second possibility was being studied secretly by the military, namely, that of the micro-explosion.
Gradually the United States of America, the U.S.S.R. and France have been publishing their own results. An American industrialist, Siegel, decided at once to spend a considerable part of his fortune on research on this matter and at a given moment appeared even to be ahead of the Atomic Energy Commission. Unfortunately, he died recently and thus this unique adventure in nuclear history has now come to an end. However, one has learned a great deal. The conditions under which fusion takes place are the same as those of the thermonuclear bomb, the energy generated corresponding to the disappearance of one milligram of the deuterium-tritium mixture is that of 80 kg TNT; therefore, by submitting much smaller quantities to the process one could hope to constrain the micro-explosion in an adequate vessel and by repeating it regularly to generate energy practically continuously in the same manner as in an internal combustion engine.

In order to enable the reader to evaluate the chances of such a method, we deem it necessary to furnish some technical explanations. Only in understanding these will one realize the difficulties that have to be overcome and the time required.

Evidently, first the substance will have to be triggered off by the DT reaction at a given point whereupon the reaction will have to propagate itself like a detonation. The starting energy is supplied by one or several laser beams. Two essential points concern the efficacy of the transfer of laser energy to the substance and the adequate use of this transferred energy for compression and heating the DT particles.

a. Energy trasfer is normally achieved by collision between ions and electrons oscillating under the laser field which transforms the coherent energy of the electrons into thermic energy.
Since the laser waves cannot penetrate into the interior of the matter this action takes place at the periphery, creating a plasma halo. However, with the resulting increase in temperature the bond between ions and electrons becomes less effective; fortunately, it is replaced by an "anomalous" bond between the ions and the plasma waves excited by the laser in an unstable manner. Nothing definitive is kown as yet about the magnitude and the exact mechanism of this action and here we have arrived at the very questions one might raise on the validity of this method as such.

b. The heat of the plasma thus generated propagates itself toward the interior of matter whereas this latter tends to vaporise at a velocity that may amount to several hundreds of miles per second on account of pressure gradients. The problem is analogous to that of a rocket where a certain distribution of energy takes place between the ejected gases and the remaining matter. One of the mathematical models has shown here 8 p.c. yield for use in compression and heating whereas 92 p.c. is disspiated with the ejected matter.

Let us assume now that at a given point the temperature would be sufficient, as a result of the compression of matter, to trigger off the DT reaction where the deuterium-tritium impact creates neutrons and alpha rays. The reaction will propagate itself like a detonation (explosives theory) if the heat supply compensates the enormous losses of propagation.

The neutrons produced (80 p.c. of the reaction energy) do not add to the matter (the spectrum being too large) one can therefore only count on the alpha rays (20 p.c. of the reaction energy); their free passage at 20 KEV/100 million deg. centigr. through matter of normal density is 1 cm; there would therefore not be any transfer of energy in the DT particle whose density is several tenths of a mm. However, if the density is 1000 times greater because of the preceding processes, the free passage would be ten microns and the particle diameter would be reduced to 100 microns only. One can therefore hope for a good propagation of the triggering action: the probability of collision of the alpha particle is in fact proportional to the square of the density and can thus be multiplied by 20,000.

Computations give rise to the hope that a combustion output of 50 p.c. and a multiplication factor of the triggering-off energy by 1500 can be achieved. However, the computation also shows that for all this one has only one nanosecond available.

The recoverable energy for the generation of energy is essentially that of the neutrons; this will be the role of the liquid lithium envelope which, however, has not yet been implemented.

In the United States it is considered that for triggering off it is necessary to project upon the target an energy of 20 to 30 g. TNT in a nanosecond in order to set off a very small reaction, it is true, but one that is sufficient for verifying the numerical computations. Today one can only produce in this space of time one hundred times less energy but progress on lasers is such that one can hope to achieve this within two or three years and then to begin on the long sequence of prototypes to find, eventually, at the beginning of the next century, the beginnings of industrial production.

3. Fusion is preferable a priori to fission at the ecological level since it does not produce any radioactive waste and in particular no transuranic elements with a very long life. Lastly, the quantities of tritium stored in the reactor are very small (a maximum of 1 kg for 1,000 MWE). However, the very potent neutrons arising from the reaction will activate, unless one is very careful, the structural materials at least as much as in fission reactors. Seen by and large, however, one cannot deny that there is a very clear advantage in fusion, particularly in comparison with plutonium breeder reactors; hence the often raised question: "are breeder reactors indispensable between thermic reactors and fusion"?
Could one not, by stopping their further development, save thousands of millions of dollars which they will still call for before their industrial production stage?

The above clearly demonstrates that it is too soon to give a reply to this question despite its importance. Neither of the two paths toward fusion has as yet achieved the basic reaction needed and the fact that it may be achieved will not in itself guarantee industrial production. Therefore, to our great regret, we think that one cannot raise the problem of abandoning breeder reactors before the potential of the two methods, and not only one, have been clearly demonstrated. We shall therefore have to wait for several years before such potential has been demonstrated. The development of the breeder reactor would appear ineluctable and thus with it all the problems raised by the generation and possible theft of plutonium.

R. GIBRAT

CLUB de ROME - Annexe F

Rejets thermiques et eaux profondes des océans

Dans le corps du rapport, nous avons insisté sur le rôle de la source froide. Dans une centrale nucléaire du type actuel, la chaleur rejetée est plus de deux fois celle transformée en énergie électrique. Or la source froide aujourd'hui est uniquement l'atmosphère et depuis quelques années on se préoccupe beaucoup des conséquences climatologiques de ces rejets.

Car les phénomènes météorologiques sont probablement souvent instables : on cite toujours deux exemples où l'équilibre naturel est, dans un cas stable, dans l'autre non.

. on rejette de la chaleur sous un ciel nuageux, on augmente l'évaporation, donc le volume des nuages, donc l'albedo (coefficient de réflexion de la radiation solaire) on refroidit l'atmosphère, d'où stabilité,

. on rejette de la chaleur sur un sol enneigé, la surface neigeuse décroit, l'albedo aussi et on réchauffe l'atmosphère, d'où fusion supplémentaire, il y a instabilité.

I. - On a coutume de rappeler que la production de chaleur par l'homme est aujourd'hui très faible par rapport aux échanges globe terrestre/atmosphère, mais on oublie que cette quantité supplémentaire de chaleur aura d'abord à modifier la circulation générale de l'atmosphère avant qu'elle puisse s'évacuer vers l'espace interplanétaire et ainsi permettre un nouvel équilibre. Quel sera ce nouveau type de circulation ? Le changement des températures sera-t-il proportionnel aux quantités de chaleur en jeu ou une instabilité apportera-t-elle des modifications disproportionnées ?

Tout récemment, on ne rencontrait que des raisonnements très généraux utilisant surtout le bon sens et fixant en général à un pour cent le pourcentage de production artificielle de chaleur pouvant entraîner une modification perceptible du climat à l'échelle mondiale ; ceci avec les taux de croissance économique actuels nous donnait cinquante ou peut-être cent ans de tranquilité.

Des études récentes de l'I.I.A.S.A. (Institut International d'Analyse des Systèmes Avancés) ont apporté du nouveau assez inquiétant. L'Institut admet le scénario bien connu de Weinberg : quinze millions d'habitants et vingt kilowatts chacun. Il utilise le grand modèle mathématique de la circulation générale de Boulder City (USA) en injectant dans les calculs la chaleur rejetée correspondant au scénario et obtient des variations de température locales atteignant 12°C pour une variation moyenne de quelques dizièmes, ce qui suffirait sans peine à créer des bouleversements absolument inacceptables.

Encore plus étonnant est le résultat donné par le modèle en injectant dans une deuxième expérience aux différents points de la maille mathématique, des quantités de chaleur ou positives ou négatives déterminées au hasard : on retrouve le modèle précédent de modification de température. Ceci paraît indiquer que les climats possibles ne sont pas une suite continue d'états d'équilibre mais quelques climats séparés que l'on obtient sous l'action de variations de chaleur de nature et d'intensité différentes. Les équations de la circulation générale de l'atmosphère ne sont pas linéaires, le résultat n'est donc pas extravagant.

Deux expériences analogues faites avec un modèle météorologique anglais ont donné le même genre de résultats, bien qu'il ne couvre que l'hémisphère nord.

Certes ces résultats sont provisoires et devront être confirmés par des études beaucoup plus complètes que l'IIASA a entreprises. Mais on ne doit plus se satisfaire des conclusions rassurantes admis jusqu'ici.

II. - Le rayonnement solaire dans nos régions avec ciel couvert en été ou clair en hiver sur 100 km2 a un effet moyen équivalent au rejet de chaleur d'une tranche nucléaire de 1 GWe (un million de kilowatts). La centaine de tranches prévues pour la France équivaut donc à 10 000 km2, soit 2 % du territoire, d'où, sous les réserves précédentes, une certaine tranquilité pour le climat général français. Mais la centrale d'avenir sera de 5 GWe, donc correspondra à un rayonnement solaire moyen sur 500 km2 et il est nécessaire de réfléchir aux influences sur le micro-climat.

Il peut y avoir des conséquences favorables par exemple dans le cas de centrales situées sur la Manche ou la Mer du Nord, par la suppression des brouillards dits "d'advection" (arrivée d'une masse d'air chaud et humide sur une surface plus froide).

On peut avoir des indications sur la probabilité d'accidents météorologiques tels que tornades, trombes, etc. par la comparaison avec des incendies provoqués de forêts (Australie ou U.S.A.) qui correspondent à des effets thermiques de même ordre. Ils apparaîtront probablement pour des concentrations de puissance que l'on envisage parfois (50 GWe) climat détérioré dans une zone de la centrale entourant la centrale et pouvant couvrir jusqu'à 1 000 km2 en fonction de la topographie correspondante. Mais pour le cas de demain (5 GWe) cela paraît presque impossible. En tout cas, il y a d'immenses progrès à faire en météorologie avant de pouvoir répondre à toutes ces questions avec précision.

Il semblerait donc que la vraie limite à la croissance économique soit, non dans un épuisement des matières premières ou dans l'ensevelissement de l'humanité sous la pollution, mais dans les réactions de l'atmosphère aux rejets thermiques. Pour la première fois, l'homme rencontre un obstacle dont il ne sait pas s'il pourra le contourner ou l'abattre.

/...

III. - Une lueur d'espoir cependant dans l'utilisation des eaux profondes océaniques. La masse des océans est deux cent cinquante fois celle de l'atmosphère, la chaleur spécifique de l'eau quatre fois celle de l'air. La capacité calorifique de toute l'atmosphère équivaut à seulement 2,5 mètres d'eau, et c'est la seule que nous utilisons en fait.

D'après la majorité des océanographes, deux tiers au moin du total des eaux océaniques, plus d'un milliard de kilomètres cubes ont des propriétés communes en température et salinité, donc en densité dues à des phénomènes de surface prenant place en des lieux de dimensions très réduites (quelques pour cent de la surface des océans et pendant un petit nombre de mois par an.

Les océans sont naturellement stables suivant la verticale eaux froides au fond, eaux plus chaudes en surface, et cette stabilité n'est troublée qu'en quelques rares endroits par des variations en surface du budget des échanges calorifiques avec l'atmosphère ou de la salinité par glaciation des eaux de surface, la conséquence étant des variations de densité dans la colonne verticale amorçant des mouvements verticaux à des vitesses de quelques dixièmes de millimètre par seconde, mais correspondant à des débits de plusieurs millions de m3 par seconde.

Trois surfaces océaniques seulement sont des sources d'ea profonde, la principale étant la mer de Weddell dans l'Antartique, ensuite celles de Labrador et de Norvège.

Les conditions exactes favorables à la formation des eaux profondes sont encore très mal connues, l'accès en hiver à la mer de Weddell par exemple étant presque impossible. On les étudie actuellement avec beaucoup de sérieux dans la Méditerranée où un tel phénomène existe à échelle réduite à 100 km au sud de Marseille. Des variations de densité de un pour 10 000 sont significatives.

Les remontées ont lieu dans l'Atlantique Nord aux lieux des pêcheries après un long parcours en profondeur de plusieurs dizaines de milliers d'années peut-être (vitesse de remontée extrêmement lente, quelques dizièmes de millimètre par heure).

On comparera la masse de ces eaux profondes à 1°,5 de température moyenne (un milliard de kilomètres cubes) avec la consommation par an d'une tranche nucléaire (un kilomètre cube et demi) ainsi que le débit mer de Weddell (plusieurs millions de mètres cubes par seconde) à celui d'une tranche nucléaire (50 m3/sec). Il y a là des possibilités extraordinaires de source froide d'autant plus qu'il faudra des millénaires pour qu'une modification en surface depuis la descente se fasse sentir en surface à la remontée. Mais comment les utiliser ?

Cela ne paraît pas facile, car en supposant résolus les problèmes d'installation des centrales aux aires de descente et d'utilisation de quelques mois par an, le rejet thermique a l'effet inverse

/...

FIRST DRAFT
(translation from
French)

APPENDIX 14: THERMIC WASTE AND DEEP OCEAN WATERS
by R. Gibrat

In the main body of the report we stressed the role of cold sources:

In a nuclear power station of the current type the waste heat is twice that produced as electric energy. Now, at present the only cold source is the atmosphere and for some years past, concern has been envinced about the climatological effects of this waste.

For metereological phenomena are probably often unstable: two examples are always quoted where in one case, the natural equilibrium is stable, and unstable in another.

- Heat is evacuated under a clouded sky, evaporation is increased, hence also the volume of the clouds, hence also the albedos (reflection coefficient of solar radiation), thus the atmosphere is cooled and stability achieved.
- Or, on the other hand, heat is evacuated on to soil blanketed in snow: the snow cover decreases in volume, so does the albedo, the atmosphere is heated, hence there is additional fusion and there is instability.

1. It is habitually said that the heat produced by man is little compared to the heat exchanged between the land surface of the earth and the atmosphere; however, one forgets that this additional amount of heat will have to modify first of all, the general circulation of the atmosphere before it can evacuate itself into interplanetary space and thus allow a new equilibrium to become established. What will this new type of circulation be? Will the change in temperature be proportional to the quantities of heat in question or will instability cause disproportionate modifications?

Until very recently, only very general arguments were heard, based chiefly on common sense; they fixed, generally speaking, the percentage of artificial heat production which might cause a noticeable modification of the climate at world-wide level at one per cent; this, at present economic growth rates would give us fifty or perhaps one hundred years of respite.

Recent studies carried out by I.A.S.A. (International Institute of Advanced Systems Analysis) have revealed new, rather disquieting facts. The Institute accepts the well-known Weinberg theory: fifteen thousand million inhabitants and twenty kilowatts each. It uses the large mathemetical model of the traffic in Boulder City (U.S.A.), injecting into the calculation the waste heat corresponding to the theory and obtains local temperature fluctuations of up to 12 deg.C. for a mean variation of some tenths of a degree; this would suffice to create absolutely unacceptable upheavals.

Even more surprising is the result yielded by the model when, in a second experiment, random values of positive or negative quantities of heat are inserted at the different points of the

mathematical network: the result is the preceding temperature modification model. This would appear to indicate that all possible climates are not a continuous sequence of states of equilibrium but some separate climates obtained from the effect of heat fluctuations of varying nature and intensities.
Since the equations of general atmospheric movements are not linear, the result does not appear to be exaggerated.

Two analogous experiments carried out with an English atmospheric model have yielded the same type of result although the model covers the northern hemisphere only.

True, these results are provisional and must be confirmed by much more complete studies which I.A.S.A. has undertaken.
However, one must no longer acquiesce to the reassuring conclusions accepted hitherto.

2. Solar radiation in our regions with the sky covered in summer or clear sky in winter over an area of 100 sq. km has a mean effect equivalent to waste heat emitted by a nuclear unit of 1 G W e (one million kilowatt).
The one hundred units planned for France therefore equal 10,000 sq. km or 2 p.c. of the country's territory; hence, with the reservations expressed above, a certain tranquillity can be assumed for the general climate in France.
However, future power stations will have an output of 5 G W e which will correspond to a mean solar radiation over 500 sq. km and one has therefore to consider its influence upon the microclimate.

There may be favourable consequences e.g. when a power station is located on the shores of the Channel or the North Sea through elimination of advection fog (arrival of a mass of hot and humid air over a colder surface.

One may obtain indications on the probability of meterological catastrophes such as tornadoes, cloudbursts, windhoses a.s.o. by comparison of forest fires (Australia or the United States) with corresponding thermic effects of the same order of magnitude.
They will in all likelihood make their appearance in power concentrations sometimes envisaged (50 G W e) when the climate deteriorates in a zone round the power station that may extend to 1,000 sq. km all depending on the prevailing topography.
However, where the immediate future is concerned (5 G W e) this would appear hardly possible. In any event, a great deal of progress will have to be made in meteorology before precise answers to all these questions can be furnished.

It would therefore appear that the true limitation to economic growth would not lie in raw materials becoming exhausted, nor in manking being buried by pollution, but in the reaction of the atmosphere to thermic waste.
For the first time man has encountered an obstacle which he does not know how to circumvent or conquer.

3. However, there is a spark of hope in making use of deep ocean water. The mass of the oceans is two hundred and fifty times larger than that of the atmosphere, the specific heat of water four times that of air. The calorific capacity of the entire atmosphere equals only 2.5 metres in depth of water which is, in fact the only one we are using.

According to the majority of oceanographers al least two thirds of all the ocean water, over one thousand million cu. km., show common properties of temperature and salinity, i.e. of density which properties derive from surface phenomena taking place within very limited locations and dimensions (a few per cent of the ocean surface and during a very few months of the year only).

The oceans are naturally stable, following a vertical line: cold water at the bottom, warmer water on the surface: this stability is disturbed in a very few rare places only by fluctuations in the household of calorific exchanges with the atmosphere or in the salinity because of glaciation of surface waters, the consequence being fluctuations in the density of the vertical column causing vertical movements at speeds of some tenths of a millimetre per second but corresponding to a flow of several million cu. m. per second.

Only three ocean expanses are sources of deep water, the chief one being the Weddell Sea in Antarctic, followed by the Labrador and Norwegian oceans.

The exact conditions favouring the formation of deep waters are still very little known as access to e.g. the Weddell Sea in winter is virtually impossible. These conditions are at present being studied very thoroughly in the Mediterranean where this type of phenomenon exists on a small scale at a distance of 100 km south of Marseilles. Density fluctuations of one per 10,000 are significant.

Upward motion of the water takes place in the North Atlantic fishing grounds after having travelled at great depth for probably several tens of thousands of years (speed of upward movement being extremely slow - some tenths of a millimetre per hour).

One can compare the mass of these deep waters at a mean temperature of 1.5 deg. centigr. (one thousand million cu. km) with the annual consumption of a nuclear unit (one-and-a-half cu. km) and the flow of the Weddell Sea (several million cu. m per second) to that of a nuclear power unit (50 cu. m/sec). Here there are extraordinary possibilities of using a cold source, all the more since it will require milleniums before a surface modification caused by the downward movement of water will make itself felt again at the surface in the reflux. But how can we use these possibilities?

This does not appear to be easy, for assuming that the problem of installing power stations at the location where these downward movements take place has been solved, as well as the problems inherent in their use during just a few months per year, the thermic waste has an inverse effect on density, heating the water, thus reducing density. One might consider adding sea salt to the waste water to compensate the effect of temperature on density but the idea appears to be puerile.

The immense interest attaching to this difficult and costly oceanographic research cannot be contested for the stakes justify the efforts made.
Man has hitherto found his limits in the calorific capacity of the atmosphere; he can increase them by at least a hundred-fold by using deep ocean water.

Oceanography and meteorology are thus becoming vital disciplines in the study of economic growth.

MANAGING THE WORLD'S RESOURCES

Foreword

Preface (inc. acknowledgements)

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March 29, 1975

For the report to be made by Professor TINBERGEN at the request of the Club of Rome on the "New World Economic Order"

Chapter ~~9~~ 8 Annexe C

very fragmentary

Energy Resources

The nature of energy problems

Energy which maintain our social, economic and technological systems on this planet consists of the processes on discovery of energy resources, acquisition, transportation, conversion and consumption as well as safety factor and environment aspects. All of these procedures are closely concerned with the politics and diplomatic problems. For the purpose of reduction in energy cost, efforts in expansion of scale in respective stages, simplification in technologies, and concentration of energy density etc. have been pursued by mankind, while discrepancies as in the following articles have been recognized independently:

1. Distribution of energy resources is rather localized on this planet.

2. Energy conversion system of large scale will face the limit of the carrying capacity of environment.

3. R & D on energy resources might be accelerated in future, however, energy conservation is rather difficult to get into the public acceptance.

From the end of the World War II, many national governments have kept energy policy under their control by varied reasons such as individual economic background, defensive and others. In order to avoid the future tragedy by ignorance for human being, the world energy policy should be established as fast as possible under the international consensus among developed and developing countries both with and without energy resources.

Fossile fuels which might be expected to remain on this planet in the order of 200 Q (Q equals to 2.52 x 10^{17} Kcal or 2.93 x 10^{14} KWH) are not sufficient enough to promise the future prosperity for mankind after the year 2000. The nuclear fission and fusion energies as well as solar, geothermal, and aeolian energies are considered as most promising as alternative sources of energy in future, diversifying their quality and quantity on supply and demand for respective countries or local area. The following paragraphs will describe the respective characteristics and their problems on these energy resources.

On the carrying capacity of our environment, the limitation to dissipate thermal energy on the terrestrial surface might exist. In order to keep our troposphere in its equilibrium in developing a large scale energy production and conversion on this planet, the net amount of energy included in the thermal pollution should be suppressed within about 10 % of intensity of incoming solar radiation (max. 1 KW/m^2 as an intensity of direct solar radiation) as an overall average on the global surface, although an acceptable value at a local area may exceed this value sometimes when the dissipated heat is easily removed from the closed system by wind etc.

Solar Energy

The incoming solar radiation on this planet will be described as 5300 Q/year above the stratosphere, 3600 Q/year on the earth surface and 690 Q on the total land area. As compared with fossile fuel resources, these figures might be quite reliable as an alternative source of energy. Although solar energy is said to be free, abundant and can be used with far less pollution on the terrestrial surface, the disadvantages are still found on the following points, as high investment cost, and energy source is intermittent and localized in the global sense.

Further, the utilization of solar energy in large scale might induce the possibility to have an impact on microclimate in a localized area. Generation, conversion and consumption of energy of any type in large scale, such as nuclear, geothermal, ocean and any other energy sources might carefully be assessed as in the case of solar energy.

The Field of Solar Energy Application in both Developed and Developing Countries

In the application of solar energy, one might see the fields of wide varieties as in solar thermal processes, photovoltaic and photogalvanic processes.

The solar thermal systems include solar thermal power generation, space heating, cooling and hot water supply by solar water heater, solar distillation, solar refrigeration, ice making, solar furnace for high temperature processing, solar cooker, heating of swimming pool, multipurpose uses in agricultural technology such as greenhouses, mulching, snow melting etc. Both photovoltaic and photogalvanic processes are for power and hydrogen production.

Among the solar thermal systems, solar space heating, cooling and hot water supply, and solar thermal power generation are two of the most significant techrology in the R & D of solar energy science and engineering. Desalination and agricultural application might be considered very important from the view point of food production.

The cost of solar energy might be still several times higher than that of fossil fuel in this decade and it is probable that the cross section of cost reduction in solar energy and increase of fossil fuel cost might be expected in sometime in the next decade. The concept of solar share will also be important from the view point of energy conservation.

In the earlier stage of R & D in solar energy technology, close international cooperation plays the significant roll on standardization and measurement of insolation, testing method for solar devices such as solar collectors and solar cells, while government incentives and stimulation will be very effective in heating and cooling of school building in addition to the educational merit to younger generation. Desalination and solar refrigeration might follow in an arid zone and especially in developing countries in the tropical zone.

R & D on industrial heat source by the use of a solar concentrator and heat storage system will be the possible next step.

Perspectives and Prospectives on Solar Energy

Until the exhaustion of fossil fuels on this planet, human being will and must be wise enough to find the solution in problems on an alternative source of energy. However, it should be pointed out that developed countries may have enough time and funds to develop alternative sources of energy until the exhaustion of fossil fuels, while many developing countries have to face the difficulties in R & D of new sources of energy and in finding the solution in prior to an expected energy crisis on the earth. And this problem is not specifically concerned with only the solar energy but the development of nuclear and other energy sources will be faced with the similar situation.

The solution in the above problem might not easily be derived by the efforts with individual countries and establishment of international institution which will act both with political and economic legislation is strongly recommended. It is needless to say that technical cooperation and education in international scale are also the important factors.

Up to the year 2000 it is very probable that more than about 30 to 50 % of total energy for space heating, cooling and hot water supply of the present day might be replaced with solar energy. Solar thermal and photovoltaic power generation will be coupled with other power generation systems such as nuclear, SNG, hydrogen, aeolian and other energy sources.

Rapidly expanding demand for water supply in future might also be met by the application of solar energy from the view point of ecological and energy conservation.

The international cooperation on information exchange, education as well as construction and operation of a large scale test facilities will be most important in developing solar energy technology, while the roll of national governments in dissemination and incentives in the field of solar energy should be directed to consider on tax problems, insurance and other legislation and regulations.

Appendix

Table 1. R & D on Solar Energy Application in Various Countries *

	Solar thermal power	Photo voltaic	Space heating, cooling	Solar water heater	Solar distillation	Agri-culture	Solar furnace	Solar cooker
AUSTRALIA	X	X	X	X	X	X	X	
BERGIUM		X						
BRAZIL					X		X	
BURMA				X	X	X		X
CANADA	X		X	X	X	X		X
CHILE				X	X	X	X	X
EGYPT					X			
FRANCE	X	X	X	X			X	
GERMANY FR	X	X	X					
GREECE				X	X			
GUYANA			X					
INDIA	X	X	X	X	X	X		
IRAN				X	X			
ISRAEL	X	X	X	X	X	X		X
ITALY	X				X			

JAPAN	X	X	X	X	X	X	X	
NEW ZEALAND			X	X		X		
NIGER				X	X	X		
NIGERIA		X	X					
PAKISTAN		X		X	X			
SAUDI ARABIA	X							
SENEGAL						X		
SRI LANKA		X		X				
THAILAND				X	X			
TRINIDAD				X	X	X		
TURKEY	X	X				X		
USSR	X	X	X	X	X	X	X	X
UNITED KINGDOM		X	X	X				
USA	X	X	X	X	X	X		X

* Radiation measurement is not included in this table.

\# Solar refrigeration is under study in Canada, France, Guyana, Pakistan, Sri Lanka, USSR and USA.

\# Wind power is also being studied in Canada, Germany F R, Netherland, USA and others.

\# Agricultural studies include greenhouses, mulching, snow melting, crop and timber drying etc.

Appendix

Cost of solar energy

The cost of solar energy gas been referred in page 3, specifically related to that of a solar collector for space heating, cooling and hot water supply. On the other ahand, when the cost of silicon solar cell will be reduced down to about 1/100 as of 1975, solar cell will be competitive to conventional fossil fuels for domestic purposes.

This target might be attained within several years, however, the present state of arts regarding the silicon solar cell indicates that the terrestrial use of solar cell such as for power supply to an unattended navigative light-house, robbot rain gage or snow gage, microwave relay station etc. as well as to residential lighting in remote area without electricity supply as in a desert is still competitive in a sense.

The cost of solar thermal power is still in the stage of feasibility study, and it is probable that the cost of solar energy might be less than two times of those of nuclear, hydraulic and conventional fossil fuels.

GEOTHERMAL ENERGY

Most of the geothermal energy on the earth can be extracted at an upheaved basin formed in the Cenozoic era, in the form of steam vapor, hot water or their mixture. Though the net amount of geothermal energy is far less than that of solar energy (0.1 Q), this energy reserved in the earth crust might be available in the magnitude of less than 300°C with several kilometers in depth.

The total output of geothermal power plants constructed as of 1973 was about 950 MW and that of under construction was 720 MW through the world, mainly in Italy, New Zealand, USA , Japan and others as shown in Appendix. From the view point of nature of energy sources in the long term, geothermal energy has the similar characteristics to that of solar energy and further can be extracted successively without any intermittence.

The Roll of Geothermal Energy

Geothermal energy has been used almost for power production for mankind up to present, and application of geothermal and volcanic energy might expend in wide varieties depending on the temperature level of hot water and steam derived as follows, although the distribution of avilable energy sources is rather limited.

Various Uses of Geothermal Energy:

Temperature level	Application	
200°C	Refrigeration (NH_3-H_2O)	
180°C	Pulp industries	
160°C	D_2 production	Power generation
140°C	Drying of agricultural product	
120°C	Desalination	
100°C	Snow melting, Drying of crops, grass, cooking	
80°C	Space heating	
60°C	Heating for stockbreeding and greenhouses	
40°C	Agricultural cultivation, Domestic hot water supply	
20°C	Heating of soil, swimming pool, pisci-culture, Disposal of waste water	

Problems in geothermal energy

Since the birth of geothermal energy technology from the boric acid industry at Larderello, Italy, almost 3/4 of a century has elapsed already and we have the evidence that this technology has grown enough to be competitive to the fossile fuels at the local and limited area in the world.

In the R & D on geothermal energy, following problems should be taken into account:

1. R & D on investigation of geothermal energy sources as well as deep excavation throughout the world

2. R. & D on investigation on volcanic energy and energy extraction from high temperature rock bodies

3. Comprehensive survey on utilization of geothermal energy

4. Technology assessment on ecological and environmental effects of geothermal energy

5. Government incentives and legislation on development of geothermal plant as well as environmental integrity.

In addition to the above mentioned five problems, energy transportation is one of the important problems in the case of geothermal energy. Transportation of thermal energy for long distance is not feasible as compared with that of power transmission. Therefore, the practical application of geothermal energy might be directed to the geothermal power production among various uses indicated in the first page.

The legislation by local government on geothermal energy is still young and the international cooperation on this point is also urgent.

Appendix

GEOTHERMAL POWER PLANT IN THE WORLD

	Present (MW)	Under construction (MW)
Italy	390.6	25
New Zealand	202.0	120
U.S.A.	303.0	220
Japan	33.0	130
Iceland	17.0	3
Mexico	3.5	75
U.S.S.R.	3.0	26
Chile		20
West Indies		30
Turkey		30
Phillipine		10
Taiwan		10
El Salvador		20
TOTAL	952.1	719

As of 1973

Hydrogen Energy

As one of the alternative sources of energy after the year 2000, hydrogen fuel is considered to be promising. Hydrogen gas which does not exist in situ on the earth surface may be produced through the chemical reaction.

In the concept of hydrogen fuel that has many advantages in comparison with other energy sources, the production of low cost hydrogen is the first and most important step among other factors such as transportation, storage, conversion etc. Hydrogen production might largely depends on thermal processes by nuclear and/or solar energy, while photogalvanic process may play the role of hydrogen production in future.

The advantages of hydrogen fuel will be described as:

1. The source of hydrogen depends on water which has been the most abundant molecular species on the earth, and is low cost as well as easy to obtain.

2. No disturbance is expected in the ecological cycle, without dissipating carbon monoxide or sulphur dioxide gases and less nitrogen oxide gas than the case in fossil fuels. Combustion product of hydrogen fuel is water which might easily be assimilated with the natural environment.

3. Hydrogen fuel transportation through pipe lines is much more economical and effective than the power transmission

4. Hydrogen fuel itself is a component in energy storage system in such a way that the use of surplus power may be utilized for hydrogen production by electrolysis and be coupled with an intermittent energy source such as solar enrgy.

5. Applications in wide varieties will be expected as for heat source ranging from 200° to 2200°C.

Production of hydrogen

Decomposition of water might be realized by the following processes;

1. Thermochemical processes with the combination of multi-step reactions ($+\Delta H$ and $-\Delta G$)

2. Thermal decomposition of water at high temperatures

3. Electrolysis

4. Radiation chemistry process.

5. biological process

Production cost may be the prime determinant in the development of hydrogen economy as mentioned before. Hydrogen fuel can be stored as a gas, liquid, or metal hydride; while pipe lines in natural gas transportation system may be substituted for those of hydrogen system. The cost of hydrogen transportation might be in between that of natural gas and electricity in future.

Problems on hydrogen fuels

In the development of hydrogen fuel as an energy source, the active R & D on every step in production, transportation, storage and further safety and maintenance problems should be taken into consideration.

From the ecological view point, the total system is recommended to combine the hydrogen system with other alternative sources of energy in the development of hydrogen fuel. Even in the gasification of liquid hydrogen in large scale may have the impact to the environment as a minus thermal pollution. The problem on hydrogen environment embrittlement must also be investigated further.

Safety factor is a high priority item among production, transportation, storage and usage. Although being as a inflammable substance, hydrogen has a high diffusion rate leaving the scene of a leak much faster.

Impact evaluation of hydrogen as well as hydrogen energy system and economics should be subjected to an international cooperative work in much more wider scope.