Executive Summary

ENERGY, GROWTH & THE ENVIRONMENT

Toward a Framework for a European Energy Strategy

Prepared for the Commission of European Communities

By Hans-Holger Rogner and Eric Britton
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EcoPlan International
10, rue Joseph Bara F75006 Paris, France
Tel. (33.1) 4326.1323 Fax: (33.1) 4326.0746

JOINT ENERGY PROGRAM

Developed as a continuing forum of collaboration by EcoPlan and TemaPlan in 1987, the Joint Energy Program has carried out this project drawing on a broad background covering: (i) energy modeling and forecasting; (ii) technology identification and assessment; (iii) industrial economic and impact analysis ; and (iv) policy analysis. The research is supported by extensive in-house databases and proprietary models based on more than a decade of technical work, analysis and reflection on the sector. The group's extensive past work and capacities provide a unique underpinning for the project.

EcoPlan An independent technology research and advisory group established in Paris in 1967. Activities include industry-related economic research, technology evaluation, strategic planning and advisory services to international business, industry and government. Major fields of specialization include:

* Economic research, planning and forecasting
* Transportation and communications
* Chemicals Research Group (CRG)
* Joint Energy Program (JEP)

Over two hundred public and private sector clients around the world have commissioned assignments from EcoPlan since its founding. The group's work is distinguished by two decades of proven professional capability, a highly compact and mobile operating style, strong international contacts and a reputation for quality of work, timeliness and integrity.

TemaPlan TemaPlan was established in 1972 to support international research on problems associated with technological, economic, social and environmental change, with a particular emphasis on energy concerns. The senior members of TemaPlan have long been associated with IIASA, the International Institute for Applied Systems Analysis, where beginning in 1983 they constituted the central core of the Institute's substantially revised gas and energy modeling program.

The strategic objective of the Joint Energy Program over the last several years has been to tighten and adapt earlier versions of the energy models and databases that were initially developed at IIASA beginning in 1973, moving the focus away from IIASA's very long run (fifty year) and "finite resource" orientation, with a more balanced appraisal of nuclear issues. An important part of this adaptive effort has been to simplifying the model structures and to making them more transparent to users and readers. The orientation of the Joint Energy Program is to create and put to work new tools for *medium term* energy forecasting and policy analysis -- for industry and public sector institutions faced with a need for background and support for today's strategic decisions.

EcoPlan International
10 rue Joseph Bara 75006 Paris France
Tel. (33.1) 4326.1323 Fax: (33.1) 4326.0746

This study was initiated by EcoPlan in 1987, with financing from a group of Charter Subscribers who have worked closely with the research team over the period to provide valuable strategic counsel, supporting technical and statistical information, draft reviews and guidelines for completion. In addition to the present final report for the European Commission, the program has generated a cycle of working papers, private and group review sessions, planning reports, as well as early draft versions of the present report for review and comment.

Contents

Note: This electronic copy of the 1991 report to the Commission has been reproduced without the accompanying graphics and several of the synoptic tables. <u>With this exception it faithfully reproduces all of the original text and arguments.</u>

0.1 Objectives

The objective of this project has been to trace in a neutral, informed and scientific manner the potential impact of technological change, supply availability, institutional restructuring, evolving business practices, and public policy in the energy sector in Europe in the near and medium term future[1]. In addition to establishing a valid (or at least useful) view of the global prospects for the energy sector within the region, the team has given particular attention to (1) the prospects for natural gas, (2) the special problems associated with an eventual expansion of the nuclear option, and (3) the impact of future policy choices and developments on supply security in the region.

The goal of the three year research program behind this report has been to assemble and process the best of the information and insight available on this difficult and fast changing subject, in the hope of providing for our sponsors an *independent* view of the sector, its prospects and problems. Each of the sponsoring groups have their own qualified policy research and *futures* units and modeling capabilities. Our brief, however, was to make use of our tools and approach to provide a fully independent statement of future developments and prospects in the field, to challenge and enrich their own on-going activities in this area.

The analysis has been based on four central research components:

- Study of the *historical trends and behavior* of the sector as amply documented by a wide variety of data sources and past studies, to establish a series of reference baselines for the futures analysis.

- Assessment of the main *technology* developments and process changes imminent at each of the main steps along the energy/resource chain.

- Study of the prospect for *institutional*, structural, management and policy changes and prospects in the sector.

- Evaluation of the *combined impact* of these forces and potential shifts on the aggregate energy supply and demand situation, and, behind that, on each of the principal energy sources.

A rather unusual aspect of the project (relative to most other energy studies) has been our particular attention to bringing into the analysis the potential for *technological progress*, that is, the natural inventiveness of man in the face of a world of ever changing challenges, constraints and opportunities. A second related concern which has influenced the project considerably is our long standing interest in *learning curves*, and in particular ways of trying to get a better feel for the amount of time it takes to adapt to new or unforeseen conditions.

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[1] Obviously studies of this sort can never be entirely "value free", but we can at least try to be consistent and, as possible, to make clear our assumptions and point of view. In this way sponsors can modify the model structure so that future runs can be made with *their* assumptions and other inputs adjusted accordingly.

In order to be able to deal with the enormous complexity of the task, we must look at the large numbers of factors involved and their intricate and ever-changing relationships. The study team has addressed this challenge by developing a **knowledge base** in the form of a series of linked computer models supported by a multi-part database which brings together a massive body of technical, economic and other information identifying the sector and the main agents for change, actual or potential.

These elements have been devised and combined in order to create several alternative views of the situation which is likely to emerge over the coming decade and beyond (scenarios), as a structured basis for study and consideration by decision makers concerned with the future of the sector, a future which in our view has quite a surprisingly large collection of "certain" elements, against which are overlaid a considerably smaller number of uncertainties and inevitable surprises. But what is perhaps particularly interesting in the present circumstances is that, by and large, this is a future which is going to be decided by a number of policy decisions which now need to be taken.

0.2 Scope

The scope of this project is extremely wide and has required the collection, screening and treatment of a vast body of technological and economic information in a wide variety of areas. It has also required making a number of reasonable and consistent assumptions about the future development paths of a certain number of key parameters which affect the analysis.

In addition to requiring underlying projections for the future of economic activity and structures, demographic developments and lifestyle parameters, the study team has made a particular attempt to account for the dynamics of technical change, including both existing and future energy-related technologies.

0.2.1 Geographic Scope

The present report focuses specifically on the future developments and requirements of the twelve member states of the Commission of European Communities (CEC). The region was selected for study because it is a large and increasingly important political and economic entity, because it lends itself to study by the approach we proposed, because we already had an extremely strong model coverage of and data-base on the region, and because the Charter Subscribers are all at this point primarily concerned with Europe, either as a place to market their products or because they have policy responsibility in some part of the region.

The Community is an area of world-scale importance, as a market and as a source of supply. The twelve nation region and its 330 million inhabitants account for close to twenty percent of world energy production, while consuming roughly fifteen percent of world energy supply. The EC is one of the world's largest consumers of imported energy, particularly of fossil fuels in general and oil in particular. Natural gas accounts for close to two percent of all economic activity within the Community, and for approximately 18% of primary energy consumption, making it today the third most important energy resource after oil and coal, and a bit ahead of nuclear.

The scenario analysis ignores for the most part the internal borders of the Community. To a certain extent, modeling the Community as one homogenous region anticipates the imminent changes as the Single Market Act takes final shape.

In terms of resource access, the model reflects the pre 1992 borders for the largest gas producing countries. Within the borders of the EC, gas reserves and resources of the Netherlands and United Kingdom are explicitly reflected and treated in some detail, while the onshore and offshore fields of the other Community member states have generally been aggregated. The major sources of gas supply for the region brought into the analysis include: North Sea, the Netherlands, the Soviet Union, Algeria/North Africa, the Middle East and LNG from other sources.

0.2.2 Resource Scope

The scope of this study is the *entire European Community energy system*, with close attention to the scope for substitution between the various forms of primary energy and their respective technologies.

In addition to establishing an informed overview of the aggregate perspectives for the energy sector as a whole, the project team has given particular attention to: the special problems associated with eventual expansion of *nuclear power* (as one of two resources seen likely to see expanded use); the prospects for *natural gas* (the second major growth prospect); and the impact of future policy choices on *supply security* in the region.

0.2.3 Technology Scope

The study focuses on the full range of available energy technologies, from exploration and production through conditioning, transport, distribution and utilization for power production. It also scrutinizes industrial, commercial, residential, transport and other end—uses of each energy source, and incorporated information on these into the analysis as appropriate.

By its very nature, the project has required tracking and taking into full consideration the scope for technological change and supply improvements in all energy areas, to ensure full and balanced coverage. The technology content of the project in general and the models in particular is considerable, and great care has been exercised to be sure that accurate and complete information is factored in to the analysis.

The following page reproduces a diagram which, together with the detailed methodological materials that follow in Chapter 2, will help to clarify the kind and degree of technology information that has been developed and factored into the analysis.

DIAGRAM OF TECHNOLOGY NODES

[Omitted from 1991 e-version but available in print edition.]

0.3 Time Horizon

0.3.1 Horizon 1: 1990-2005

This nearer term horizon was selected as most relevant for tackling questions of growth and vested economic interests versus the likely need to curb further environmental deterioration. Within this horizon, it will be the capability of **existing technology** to provide more efficient energy services that will determine the potential for enhanced economic growth, possibly *with* improved environmental compatibility. The lead time required for full market penetration in a competitive environment will, of course, limit the potential impact of any single technology over this initial period.

A second for this choice is that the end of the period, the year 2005, coincides with the 1988 Toronto Conference "The Changing Atmosphere: Implications for Global Security" target date for cutting global carbon dioxide emissions by 20 percent, from six billion tons of carbon to 4.8 billion tons a year by 2005. (This objective has been taken as one of the main targets of what we call the *Toronto Taxes* or "Green Policy I" scenario which is explained at length below.)

0.3.2 Horizon 2: 2005-2020

A longer time horizon is needed to be able to take into full account the impact of technology change, resource depletion policies and R&D strategies. While in the shorter run, the sector is by and large confined to existing technologies, the impact of new technology will increasingly dominate in the longer run. In much the same way, investment decisions taken in the next years will display their full effects only over this extended time horizon.

This longer term horizon permits the consideration of alternative investment strategies under different assumptions and levels of uncertainty concerning future environment policy, as well as for different trajectories of technology development. In addition, the thirty year period is sufficiently long to permit the construction capital stock (industrial and housing) to turn over at least partially. This opens up additional dimensions for rational energy use through prudent technology implementations.

Finally, restricting the outer time horizon to thirty years, avoids having to attempt to project technologies or lifestyle changes which have not yet reached the research phase. As far as policy is concerned and in particular in terms of addressing the Greenhouse effect, it can be shown that the first thirty years period has a disproportionate effect on the longer term.

0.4 Overview of Long Term Energy Prospects

Estimates of "economically available" reserves of natural resources are periodically issued by government bureaus and industry alike. These estimates vary from year to year, and as one looks at the trend data based on these estimates a rather interesting pattern can be discerned.

Almost independent of the year of the estimate and the resource under consideration, these estimates show a remarkable commonality -- as long as this particular energy carrier was considered at the time as the most desirable and necessary contemporary resource. Thus, there appears to be a universal constant reserve-to-production ratio of some 20 to 30 years. This has been particularly true for oil. Already in the 1920s this ratio was widely published and quoted.

Indeed, the world does continuously shift from one resource to another, particularly in energy. It has done so for the past century and a half, and will surely continue to do so in the future. But the fundamental driving forces behind these shifts are evolutionary changes in demographic, cultural, economic and structural conditions and trends that call for energy forms better suited to new or improved products and services demanded by the market (market pull).

The shifts are equally facilitated by the emergence of new and improved technologies which make the new resource steadily more accessible and provide the marketplace with better services (technology push). In short, the historically observed transition from one resource to another has been caused by many things but never, until now at least, been the consequence of the old resource being exhausted. As a matter of fact, in the past the intensive use (call it primary dependence) of each major resource was abandoned well before the world ran out of it. The reason for this is that technology advances make the new resource much more available and acceptable than the old one, and able to serve old and new marketplace demands alike.

There are numerous examples of such substitution processes. For example, in the late 1960s the use of copper for communication links had reached a level where serious shortages in copper supplies were envisaged for the near future. New communication systems were under development, but hinged on the availability of better materials than copper. Optic fibers emerged as the superior material and, once commercially matured, began to displace copper.

The historical development of primary energy production and use lends itself as a perfect example for technology substitution analyses. First of all, of course, energy is fundamental to our material well-being, but not an end in itself. Secondly, in the past several successive transitions from one form of energy to another can be observed.

Although the "necessary" level of per capita energy consumption varies according to different schools of thought, in essence it is the energy service requirements that demand energy inputs. The energy service of, for example, a comfortably conditioned room can be achieved in several ways, ranging from the deployment of different technologies and their corresponding fuels to capital for energy substitution (popularly labeled "energy conservation").

It should be noted that fuel and technology and the available infrastructure are all intimately interrelated. Therefore, the dynamics of energy systems must be reviewed in terms of relative market shares instead of absolute values.

Against this background, the following figure shows the global primary energy consumption in terms of their respective market shares for each of the primary energy resources, starting in the middle of the last century.

Thus, on a market share basis, wood, once the dominant primary fuel, was replaced by coal. Then, that coal was replaced by oil. And today, natural gas is seriously cutting into oil's market leadership, and nuclear is rising rapidly.

These transitions occurred despite the fact that resources of wood, coal and oil are still plentiful. Today, well over a century after wood lost its preeminent position, the world's annual biomass production exceeds the needs to fuel the world many times over. Hence, wood was abandoned, not because the world was running out of it, but rather because the upcoming First Industrial Revolution demanded a fuel with higher energy density and better transport and storage characteristics. Simultaneously on the supply side, coal-mining and coal-use technology developed to a point where coal had evolved into a readily available energy source.

Similarly, decades later coal in its turn was displaced by oil, once a set of new and superior technologies (and supporting infrastructure) were made available, both upstream and downstream.

Upstream, coal's leadership position was essentially unchallenged until the discovery of oil drilling and cable rig technologies. Downstream, prime among the new oil-related technologies were chemical engineering, flow process and unit operations advances all of which combined to make possible the highly efficient refining of crude oil into a broad range of refined products and chemical feedstocks.

TABLE HERE

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On the end-use side, refined oil products proved superior to coal for powering trains, cars and aircraft, generating electricity, heating homes and large buildings, etc. All but one of these end-use applications can be, and were first, achieved by coal. However, since refined oil products are much better suited for these purposes, society progressively abandoned the use of coal in favor of oil. The single new application opened up by the availability of oil was of course aviation, now a large consumer of refined oil products.

By the 1960s, oil had displaced coal both on a market share and absolute basis. It is important to note here how steadily the displacement of coal by oil proceeded, and the length of time required. Once again, the replacement occurred not because the world was running out of coal. For even today, conventional wisdom still holds that coal is by far the world's most abundant fossil resource.

By now, coal has lost essentially all of its major captive markets save one, electric power generation. The coal market has had a certain number of "ups and downs" around the general downward trend, with the most recent "up" resulting from the OPEC oil disruptions of the 1970s. This latest growth-spike may well prove as a short lived aberration, and may soon end as a result of several powerful and convergent forces which are likely to influence both the cost and use of coal and its alternative energy sources:

- The increasingly recognized environmental costs and hazards of using coal.
- The likelihood of continuing availability of "cheap oil" in the long-term, albeit with frequent price oscillations around a low long-term price.
- The rapidly improving technologies of combined cycle gas turbines.
- Dynamic technological improvements in searching for and producing large quantities of low-cost natural gas.
- The dramatically lower environmental costs and impact of burning natural gas instead of coal or even oil.
- The potential introduction of "second generation nuclear" several decades from now, with much lower environmental impact and electric generation costs than coal or any other fossil fuel.
- Continued progress in the development of efficient, low cost photovoltaic cells.

Against such a background, it is difficult to be optimistic about the long term prospects for a coal-based energy system, despite the admitted institutional difficulties of the transition.

The preceding figure also provides food for thought on the near-to-medium term future of nuclear energy. One remarkable feature of the successive primary energy substitutions concerns their quasi constant speed of market penetration, represented by their respective slopes.

Compared to coal, oil or natural gas, the slope of the actually observed market penetration of nuclear ranges well <u>above</u> that suggested by the substitution model. From a system's view, this overshooting might be interpreted as a "too rapid" introduction of nuclear technology, pushed by government policy and subsidies -- disregarding the system's, or better society's, readiness to adopt and accept it.

This discrepancy between the actual and the anticipated rates of introduction may offer an explanation for the recent socio-political controversy surrounding the use, or at least the expansion, of nuclear technology. As a result, a downward swing of nuclear's market share below the trend line could easily be the result of the slow learning process of our societies -- a "datum" that policy makers will do well not to lose all sight of.

All of the above could be interpreted to signify that the first "Nuclear Age" (i.e., that based on currently available reactor technology) may already have come to an end. The learning process, together with the successful development of second or third generation nuclear technologies (i.e., the fusion option which avoids much of the radioactivity associated with fission or deuterium-tritium fusion technologies.), could combine to mitigate the current socio-political (and economic) concerns toward nuclear power. In fact, this technology might eventually (i.e., over several decades) merge nuclear's market share with the trend line again.

But even such breakthroughs may not be enough to ensure a "nuclear future". Thus, for example, any rapid breakthroughs of photovoltaic technologies and/or advances in the field of superconductivity could well impair the future role of nuclear. There are other technology areas where such advances could also make significant inroads as well.

However the future unfolds, there will first be several decades of intense technical development and competition. Given the time needed for any new technology to make major inroads in the global primary energy market, there will in the meantime be a need to fuel the world and bridge the period towards a sustainable energy system.

The crucial choice for this "swing technology" could be any of several candidates, including natural gas. Since it has been argued that technical progress and change are the true driving forces underlying energy substitution dynamics, the following focuses on the aspects of the advances in technologies and the possibility of a greatly extended reliance on natural gas or methane in global energy supplies.

Prices, Technology and Energy Supply

In addition to simple capacity expansion as a response to increasing margins between production costs and market prices, higher energy prices also impact on the performance or productivity of new capital investment.

Past expectations of continuing high energy prices have at times unleashed enormous scientific and engineering efforts focusing on technical solutions to problems, ranging from finding and tapping hydrocarbon in frontier areas to more efficient energy end-use equipment and appliances.

Upstream, these efforts translated into faster shifts of previously sub-marginal resources into economically recoverable reserves, albeit with a time lag of several years.

Similarly, on the end-use side, the replacement of energy conversion equipment by more efficient appliances and the substitution of capital for energy in the construction of better insulated building and more efficient capital stock eventually led to reduced energy requirements.

The net result of both the supply and demand developments has led to increases of reserve-to-production ratios for all hydrocarbons, the delayed effect of which began to be felt strongly after the second oil price hike in 1979/1980.

Price driven technical change seems plausible during a period of high real energy prices. The imminent question, as to what extent low energy prices affect technical change, depends on several factors and will have different impacts on supply and demand technologies.

Of course, the time frame plays a decisive role. Upstream, shrinking R&D budgets tend to boost productivity in the short run, and flatten growth in performance thereafter.

During the period of high energy prices, a good number of projects were initiated on a speculative basis or simply because of budget availability. Since, many of these have been discontinued or shelved. Those remaining focus on the most promising and advanced projects.

Although the rate of technical change will eventually be adversely affected, a general dip in the absolute level of productivity is very unlikely. More important, with regard to future supply and its impact on price maneuverability, is the slump in exploration and drilling activity as suggested by the rig count. This will become particularly important once production from oil and gas fields, which continue to be worked due to sunk-cost considerations, are phased out.

On the end-use side, the impact of low energy prices on technical change differs from what goes on at the exploration and production levels. Unlike upstream R&D which is motivated mainly by the difference between costs and market prices, end-use technology developments are primarily targeted to opening up new markets or volumes, piggy-backing generally on consumers' utility maximization and industries' cost minimization behaviors.

Obviously, the prospect of continuing low energy prices reduces incentives for higher levels of R&D. Under such circumstances, productivity gains will eventually drop to the level achieved by the "natural" effects of endogenous technical change -- still a level which is likely to outpace economic activity in the near-to-medium term future.

As regards the implementation of energy efficient plant and equipment, one can expect that, with the exception of the housing and transport sectors, all other economic agents will continue incorporating the latest commercially available technical efficiency standards. Electrification of industry is a powerful catalyst of productivity, whether or not the electrification in itself is energy-efficient. As long as the denominator of the energy/gross domestic product ratio (E/GDP) grows faster than the numerator, there will be a decoupling of energy and economic growth.

The remarkably stable correlation between electricity consumption and economic activity in many industrialized countries -- at a time when energy intensity has been declining -- seems to support this view. Still, there is considerable scope for further improvements of both energy and electricity intensities as advanced electric end-use efficiencies penetrate the market.

Some studies report a difference of more than 50 percent between latest electrical efficiency achievements and the current average standard for equipment installed in households and business. However, given the lead times suggested by the market penetration analyses, it may require a time horizon of several years to decades until these new technical achievements become the standard.

In summary, the elasticity of technology appears to work both ways, though in a somewhat skewed manner. In an environment of rising prices, technical change encounters a definite boost, the impact of which is felt with a time lag of several years. Declining or stable energy prices translate into what could be labeled the "natural rate of technical change".

0.5 Evolution of Research Mandate

Both the title and the theme of this study have undergone considerable change as the project evolved over the last three years. These changes have occurred not only because external circumstances have modified since the study was initiated, but also because our point of view gradually modulated as new information became available and as the analysis made headway. Fortunately, the methodology selected for the study was flexible enough to accommodate these changes.

When the study originally got underway back in 1987, the objective had been to show how a generally overlooked shift to natural gas was already in process and why in our view it was going to develop even more strongly in the future -- and, as a necessary step in this analysis, putting this specific shift within the broader energy context of which it was but one part. At the time, this was an interesting and valid theme, but as will be seen in some detail in the following, the emphasis modified fairly quickly to provide much more stress on the *global energy situation and its prospects within Europe*, with attention to natural gas when and as justified. This turns out to be a more interesting and timely consideration.

Originally entitled "The Prospects for Natural Gas", as the study moved ahead and gained its broader sector-wide orientation we referred to it for some time under the provisional title, "Europe's Uncertain Energy Future". But as work advanced further, it became apparent that there were a large number of things which appeared, to the contrary, to be quite certain. This led to yet another working title: this time, "Europe's Certain Energy Future".

However, as we got closer to the end of the studies, we eventually settled on a title that reflects the viewpoint that we finally arrived at after three full years of work and reflection. What we learned, above all, is that Europe's energy future is something that is going to be chosen. Since this is not a universally shared point of view, it will be useful to clarify it here at the outset of this report.

As a result, the report we present today is not at all what was originally contemplated and planned. It is useful to make this distinction, since we believe that the present (revised) focus is more appropriate in light of current circumstances and the policy choices that now need to be made. Also it seems to us to be much more in line with the interests and preoccupations of the subscriber group.

0.5.1 Original Mandate (1987): *Systems Study of Natural Gas Prospects*

The orientation for the project at its outset in 1987 is set out in the following paragraph which quotes directly from the original work program:

"There are currently a number of new technologies and processes on the horizon which -- together with a wide-ranging reappraisal of supply prospects -- could turn natural gas into a much more widely distributed, economical, world-scale abundant resource. The combined weight of these developments suggests that gas is not a *mature* sector as most analysts have concluded in the past. Rather, it is already in the process of a major take-off as new and largely unanticipated sources of non-associated gas are explored and brought on line. The implications for resource suppliers, industry and public policy are largely unanticipated, considerable, and need to be clarified for decision purposes."

In a phrase, the original orientation of the project was *to document and provide advance intelligence on the prospects for higher-than-usually anticipated growth of gas.* The thesis was that the resulting broad redefinition of the resource base was going to bring in its wake a very significant expansion of the gas market, and in particular of the market for electrical power generation and bulk industrial uses. (The bearish consensus of most energy analysts then was a result of their uncritical acceptance of three related axioms: (1) "natural gas is a scarce resource"; "the supply of gas is politically unstable"; (3) "gas should be restricted to so-called premium uses".)

Against this background, the EcoPlan team set out to provide a **realistic definition of the boundaries of the sector's actual future growth potential in the decades immediately ahead**, as a critical first step toward identifying policies and plans more fully in tune with the kind and scale of opportunities and challenges likely to open up in the sector.

In doing this, it was at no point the intent of the project team to push or emphasize the notion of any one future path for the sector, but rather to provide a flexible framework whereby we and our sponsors could readily identify and consider the impacts of **alternative futures and courses of action in a changing world**.

Fortunately, the model framework and databases we have developed have permitted us to scan readily the impact of a wide range of assumptions concerning such factors as relative prices, alternative levels of resource availability, technology, policy, et al. -- in a phrase a number of the principal elements of the future that looms before us, uncertain perhaps, but one which nonetheless needs to be planned for.

That was essentially the situation at the outset of the active research and database development in 1988. As work progressed, however, a number of significant changes took place, reflecting both what was learned through the research process -- and also as a result of the not-inconsiderable changes which have taken place in the energy sector itself and its broader policy frame.

0.5.2 Revised Mandate (1989): *Charting Europe's Energy Futures*

A draft report of the Economic Commission, "Energy in Europe: Major Themes in Energy", of September 1989, put into clear relief the situation we found ourselves facing as we approached our final rounds of work under this project toward the end of that year. If our work was to be relevant and useful, we needed, like them, to be able to take into account that :

"Currently energy policy is unclear. Indeed there is little consensus as to the basis for future policy. Consequently the need arises for a full debate of the factors which could determine the structure of the sector - a debate facilitated by the availability of a clear and objective analysis which looks at how energy will interact with economic development, and the internal market with the environment (sic.); how technology will assist in being more efficient in energy production and use; and what risks there could be to energy security."

As we saw it at the time, the main determinants which have shaped the energy sector in the past in Europe -- i.e., historic patterns of demand, availability of supply, supporting infrastructure, institutional structures, technology, economics, finance et al -- are all so fundamentally inertial in their basic nature, so many in number, massive, heterogeneous, multi-sided and diversified that we can expect them to combine to provide a relatively stable backdrop for the sector's development over the period under study. This is not to suggest that the future will be without its fair share of surprises and adjustments, but rather that, policy and major mishaps aside, the underlying pattern will be one of fundamental consistency and relatively slow change -- exactly as one would anticipate in a situation characterized by large numbers, multiple sources of supply, well developed supporting infrastructures, vigorous inter-fuel competition and sufficient institutional flexibility and technological capacity to confront exogenous changes.

Basically what happened was that "the environment", for a number of reasons, emerged not as a second-order constraint for the future of the energy sector, but rather as major shaping force. This realization gradually took shape as the research proceeded and the analysis began to show that the following, all of which were given considerable importance in the original work program, were *not likely to emerge as the critical constraints over the plan period*: [2]

The analysis suggests that "the environment" will emerge, not as a second-order constraint as in the past, but rather as the major shaping force for the energy sector over the coming decades. This realization gradually took shape as the research proceeded under this project and the analysis began to suggest that the following, all of which were given considerable importance in the original work program, were *not likely to emerge as the critical constraints over the plan period*:

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[2] This analysis is not intended to run by the problems of leads and lags in the shorter run, but rather focuses on what we see as the longer term trends.

i. **Limited resource availability** -- Resource limitations in any energy area are unlikely to emerge as the critical constraint.

ii. **Demand** -It is unlikely that demand is going to emerge as the critical limitation (in either direction).

iii. **Technology** -- Lack of adequate technical adaptive capability is not likely to emerge as the central issue -- the only real problem being the factor of the "time lag" (lead times).

iv. **Alternative products** -- It is not considered likely that any unexpected new energy sources will emerge over the study period (at the right price, quality, etc.) to tilt the overall balance radically, though we are sure to see some reshuffling in some energy areas as well -- e.g., nuclear.

v. **Supply security** -- The whole tissue of considerations and worries which had in the past combined to make supply security a dominant consideration has altered, as the number and variety of supply sources has increased, the adaptive capacities of the EC nations have been convincingly demonstrated, and the general change in the geo-climate toward more cooperation and less confrontation (in spite of Saddam Hussein).

The net result of these trends with early findings was an appreciation that the situation we are going to be faced over the next decade and beyond is almost sure to be one where *policy* is going to emerge as the main driving factor -- and that now translates to *environment*.

Briefly, the reasons behind this include:

1. The emerging scientific, media and political consensus that our future must be "green", if we are going to survive at all.

2. The increasingly vigorous support for such policies in many if not all EC countries, including continuing outside pressure from Switzerland, Austria and the Scandinavian countries together with the distant drum of US concerns and policies.

3. The fact that this is rapidly becoming the EC's stated policy (and that it appears to be getting follow through).

What appears most likely is that Europe's energy future over this period will be shaped primarily by no single one of these historic determinants, but rather by the *choices* that are to be made by policy makers in the next few years. There is now a *window of opportunity* for policy makers in Europe to ensure for the continent an energy future which is not only secure but also one that will make the region a better place in which to live and bring up our children. So we can actually *choose* Europe's energy future. Or, quite possibly, *decide not to choose*.

0.6 Uses of the Report and the Models

This project has tried to be useful to subscribers in several ways:

- As an informed, independent statement of the sector and its prospects -- in order to challenge and enrich the subscriber's own ongoing work in this area.

- As a basis for planning and policy discussions, providing a well documented view of several of the energy "futures" which are among the most likely to occur in the decades immediately ahead.

- By virtue of its comprehensive coverage and systematic approach, reducing uncertainty to the extent possible by exposing to the analysis a wide range of structural factors of possible significance (including factors often not brought into such studies).

- Putting firm quantities on these prospective developments as a basis for these considerations, together with a well documented methodological "trail" to permit cross-checking, alternative hypotheses, other data, etc.

- Providing a well identified methodology for identifying, measuring, and evaluating the impact on the sector of technical and institutional change, which could eventually be further developed or adapted to the individual subscriber's particular planning needs.

- Making this information available to subscribers in a way that can help them to look at and weigh alternative strategies for dealing with, in particular, the twin (and traditionally conflicting) issues of energy efficiency and the need to preserve our ecological heritage.

- Presenting this information in a form which allows for vivid comparisons, provokes useful questions and debate, and can serve as a framework for organizing yet further research and policy analysis programs.

- As an outside check on current longer range plans and proposals.

- Stimulating creative thinking in in-house policy and "futures" groups through the supply of "generative ideas", checklists of issues and novel analytical techniques;

If it does its job, this report should raise at least as many questions as it answers. That is, we believe, entirely appropriate at this stage of the research and policy defining process. Fortunately, the modeling framework provides a means for addressing a certain number of these in a cost and time effective manner. In addition to the printed report, the subscriber may in due course wish to consider further extensions or uses of the methodology in general and/or the models and databases more particularly.

0.7 Organization of Project and Communication of Findings

The research effort behind this project has been financed by an international subscriber group consisting of several international energy suppliers, a national gas monopoly, an international agency with policy responsibility in the energy field, and the Commission for the European Community. The *means for communicating* the views and findings of this program to the sponsors have been five:

1. A process of interim communications and report generation that has proceeded in iterations over the three years of the project. This process has included the submittal and discussion of both the initial research plan and then subsequently in 1989 the revised work plan, a number of interim working papers and an earlier draft of the full report to each sponsor for critical appraisal, comment, and guidelines for finalization.

2. A cycle of roundtables and review meetings with most of the sponsors at several stages over the project. These sessions provided opportunities for critical reviews of draft materials and working papers, direct communication by the sponsor of their particular interests and requirements, and debriefing by the project team of views, findings and conclusions other than those which appear in the written papers.

3. The present final report, which has been prepared for the sponsor group as a whole. This document is intended as the main reference document and a full statement of the program, its intentions and its detailed findings. With more than one hundred tables and charts covering a considerable variety of sub-sectors and topics, and further supported by a number of technical references and working papers, it cannot be considered a fast read and is not intended as such.

4. A number of technical working papers have been made available in support of this report to the sponsors, including in particular more detailed statements of the methodology and additional technical background on the systems analysis and modeling component. A listing of these supporting documents will be found in the appendix to the report.

5. An Executive Summary has been prepared for the busy reader who wishes to inform himself about the main lines of the project and its findings and recommendations, but who does not have the time or need to confront the full report and associated database and supporting working materials and reference documents. The Summary is intended both as a comprehensive introduction to the full report and its contents, and as a document which can be circulated widely within the sponsoring group to provide a readable synopsis of the project's main findings and conclusions. It is keyed to the full report for easy reference purposes. Individual summaries have been prepared for each sponsor.

0.8 Presentation of Report

This report brings together two types of rather different information and insight: (a) the actual numerical results of the scenarios and model runs, and (b) the commentary and interpretations of the research team. The report is laid out in an attempt to make the distinction between the two clear to the reader. The model results are communicated principally in tabular and chart form, while the analysis and interpretation is always presented separately as text. The body of the report has been prepared in seven chapters with one supporting annex as follows:

Chapter 1, Background and Introduction, introduces the report and the research project on which it is based, going briefly into matters of study scope, objectives, methodology and the modeling background to the analysis. It next goes on to provide a statement of the "null hypothesis" of the project at its outset in 1987 (roughly, technology-led growth for natural gas over the next several decades), and then summarizes the principal changes in the research mandate which evolved considerably over 1987/89 in response to changing external circumstances and the research results themselves. It then considers briefly the broader flow of the sector's dynamics and growth perspectives, as food for thought on the near to medium term future of the main competing energy resources (as opposed to the more focused and specific statistical results of the scenarios analysis that follows). The chapter concludes with a section on report organization and model uses.

Chapter 2, Study Methodology, introduces the main approaches and technical tools used in support of this project. In order to deal with the great complexity of the task, we needed to look at the large numbers of factors involved and their intricate and ever-changing relationships. This chapter explains how we went abut this, by developing a **knowledge base** in the form of a series of linked computer models supported by a multi-part database which brings together a massive body of technical, economic and other information identifying the sector and the main agents for change, actual or potential. Readers whose primary interest is in policy conclusions may wish to scan it only; but for those who wish to understand whether or not the approach taken here is a valid one, these materials should be helpful as a *first* presentation. Additional supporting materials on the models and other aspects of the analytic methodology are available in the form technical working papers and background documents, which are identified in the annex to the report.

Chapter 3, Scenario Selection and Specification introduces and describes the basic structure of the several *scenarios* which have been developed for the purposes of the futures analysis. It explains the criteria for selecting the scenarios, and then goes on to define each in terms of the major assumptions and specific values which characterize it. These scenarios are presented not as predictions or forecasts of what we believe is likely to happen, but rather as broad but structured frameworks within which we can explore the major issues and trends likely to occur.

Chapter 4, Alternative Energy Futures for Europe, constitutes the main body of this report and presents the detailed results of the two main scenarios selected for analysis and commentary. The chapter is organized into nine sections, each of which looks at and reports on a specific sub-set of issues. Each presentation follows a common order: beginning with a graphic overview of the base year situation; followed by an introductory commentary on some of the main issues and trade-offs involved; then several sets of tables which provide contrasting statistical estimates of performance for each scenario for the target years 1990, 1995, 2000, 2005, 2010 and 2020. This is followed by a graphic representation (bar and line chart) contrasting the levels achieved for the indicators for each of the two test scenarios, comparing each with performance in the baseline year. Each section closes with a brief word of conclusion and commentary on the most notable points emerging from that specific aspect of the analysis.

Chapter 5, Energy, the Environment and Public Policy, has as its goal to give the reader a better feel for the environmental implications of the two main scenarios used for this analysis. It presents a certain number of ideas as well as specific quantitative feedback from the models concerning the impact of the "Toronto Taxes" scenario on the energy supply and demand situation within the EC over the study period. In this chapter the implementation of market oriented mechanisms through emission taxation for pollution control is assumed. The emission taxes used for this pilot study are offered as a first test as to the consequences of such a policy instrument and must be viewed in this context. The results suggest that the specific standards probed here *(Toronto Taxes*) will possibly be adequate to bring emissions down to the minimum targeted levels. The analysis suggests also that, within the area of the European Community, a reduction of greenhouse related emissions of this magnitude is techno-economically feasible. The analysis also suggests that cost-induced energy savings through capital-energy substitution (conservation) on the one hand, and better energy management on the other, combine to lead to lower levels of final and primary energy use under the *Toronto Taxes* scenario.

Chapter 6, Nuclear Constraints (Sketch Scenario). In the light of the socio-political controversy surrounding the use of nuclear power in many member countries of the European Community, it is quite likely that the unfettered expansion of nuclear power may no longer be an option. Under the circumstances, we thought it appropriate to develop an additional scenario to test, at least in a provisional way, the response of the European energy system to emission taxation in an environment of restricted nuclear capacity expansion. To do this, we constructed the scenario, "Nuclear Constraint", which assumes: (a) that all nuclear capacities currently under construction will be completed and (b) that no new orders for capacity additions will be filled. This chapter reports on these results.

Chapter 7, The Special Role of and Prospects for Natural Gas, concludes the report with an overview of the particular situation of natural gas, on the grounds that it is both a resource with an important future role in Europe and one which has often tended to be underestimated in the past, including by those institutions most directly concerned. The chapter concludes with the observations that: i) of all fossil fuels, natural gas is the only one with growth potential under all three scenarios; ii) the major surge of gas use under all scenarios is in the first decade of the study period, due to the fact that its market share can be more quickly increased than, say, nuclear or any other of the alternative sources -- at present technology levels; and iii) the direct competitive coupling of gas and nuclear, with the edge almost certain to go to that resource which is eventually favored by public policy. The chapter closes with the observation that lobby support by industry and government within Europe for nuclear substantially outweighs the level of commitment of those involved in the gas business, and that it may eventually be this politico-industrial backing that determines the outcome of the gas/nuclear trade-off. The changing nature of the gas sector's market is thus quite striking; certainly this is going to be one area where the future is not going to mirror the past.

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The report concludes with an annex identifying the main sources consulted for the purposes of the database development and analysis.