WORKING PAPER

The Methane Age
Likely Gains in Current Technologies
Emerging Technologies and Their Likely Consequences
Economic – Political – Geopolitical

H-H. Rogner
S. Messner
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IIASA
International Institute
for Applied Systems Analysis

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Summary of a Task Force Meeting, "The Methane Age"
May 14-16, 1986, Hotel Lover, Sopron, Hungary
Organized by

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

Foreword

This document summarizes the presentations and discussions of the Task Force Meeting on "The Methane Age" held in Sopron, Hungary, from May 14-16, 1986. It also includes insights and suggestions that emerged from post-meeting or other follow-up activities as of October 15, 1986. Furthermore, several of the papers given at the meeting have not yet been received in final form. This summary has been prepared based on IIASA-made transcripts of these presentations and the interpretation is the sole responsibility of the authors. When all papers are received in final form, this summary will be revised, if necessary, to conform to the written versions of the meeting's presentations.

Thomas H. Lee
Director

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Background and Purpose of the Sopron Meeting

Unlike most conventional gas studies, the recently completed IIASA analyses of the European gas market foresee an increasing contribution of natural gas to primary energy supplies in absolute and relative terms. Since oil and nuclear assume similar trends in all studies – the appreciable growth of nuclear and continued displacement of oil – the future market expansion of methane occurs primarily at the expense of coal, at least for the next several decades (see Figure 1).

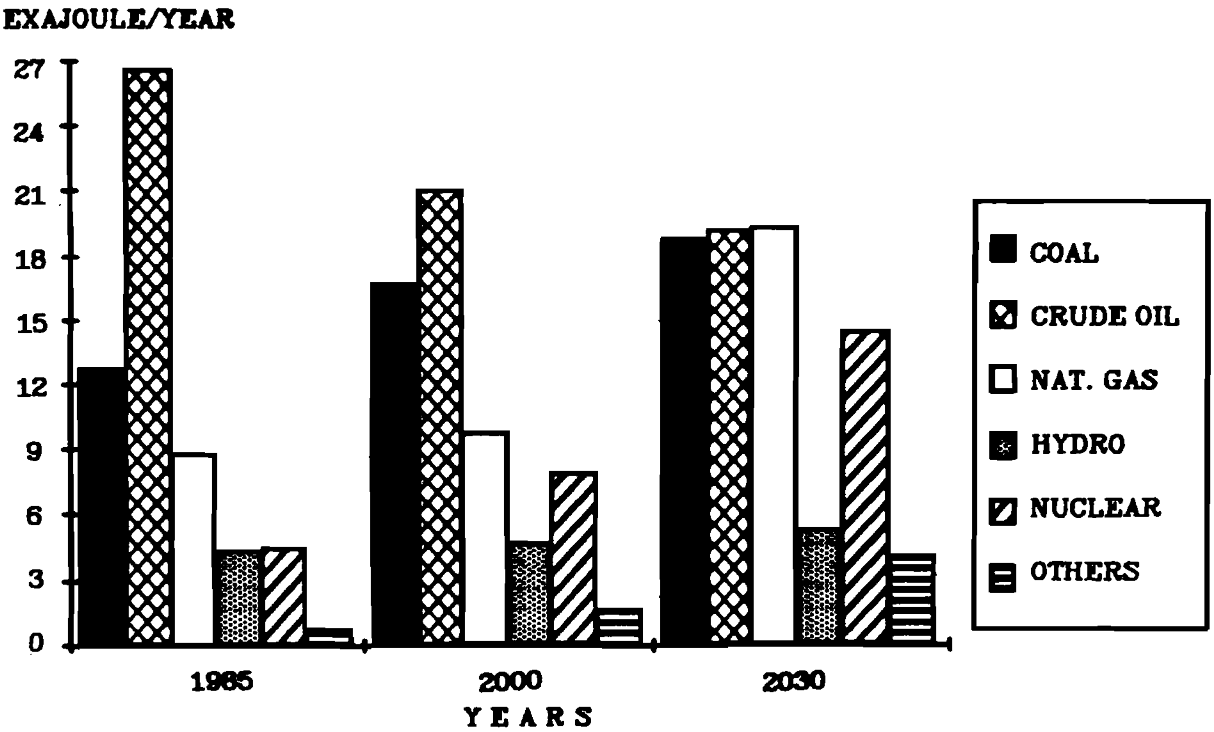

FIGURE 1. Primary Energy Consumption, Western Europe, 1985-2030.

One explanation for the deviating IIASA findings is the explicit influence of two factors, the dynamics of which are usually disregarded in medium- and long-term energy studies – technology and policy.

Regarding technology, the IIASA analyses assumed technical progress along the entire energy chain from resource extraction to end-use conversion for all energy technologies. On the aggregate, technical progress followed historically observed growth patterns. More specifically, an above average productivity growth was attributed to methane exploration and production technologies. This assumption is based on the fact that finding and producing methane as such is a relatively recent activity. Previously, most methane was produced as a consequence to finding and producing oil. Hence, the technical and perceptual environment for gas exploration and production is still rather oil-tailored. The development of a gas-tailored technical environment will be accompanied by substantive productivity increases.

Productivity is one major determinant for economic viability and thus a critical variable in long-term energy projections. The omission of technical progress in long-term systems planning may lead to diverging prospects as exemplified by the IIASA Gas Study.

The primary purpose of this Task Force Meeting therefore was to collect the best possible judgment on the pattern of future growth of methane in global energy markets, particularly when driven by constant improvement across the full array of methane-related technologies.

This judgment is to be measured by whether or not methane continues its decades-long world primary fuel market penetration (against coal, oil, and nuclear) for the next several decades (see Figure 2 for the historical methane growth).

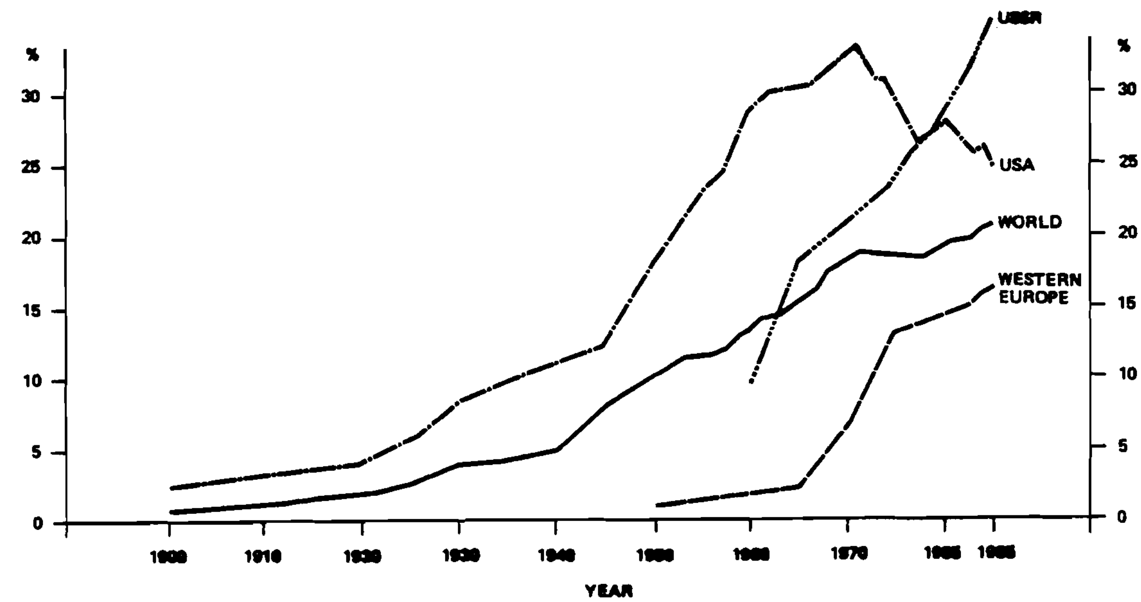

FIGURE 2. Methane Share in Primary Energy Supply, 1900-1985.

Then, to form the best judgment on how growing methane use will alter (restructure or disrupt) the existing relationship (source, grade, and consumption patterns) among the current major primary fuels coal, oil, and nuclear and especially so with regard to the electric utility industries.[1]

[1]For a general statement of the purpose of the meeting and suggested IIASA follow-up actions, see Schmidt and Vasko (1985).

In summary, the most important issues of the meeting were:

- o to survey and to the extent possible establish the state of the art of the full array of methane-related technologies from exploration to end-use conversion; and
- o to estimate how far and how fast each of the several methane-related technologies would grow.

The need to develop quantitative descriptors based on a sound data set, and subsequent rigorous analyses, is perhaps one of the most important requirements that emerged from the meeting. The longer-range target in this area is the attempt to combine many individual technological performance improvements into a single function, indexing the constantly improving attractiveness of methane to the end users as a function of time. The issue of whether or not IIASA should or would pursue this activity further was not determined at the meeting.

Planning and Conduct of the Meeting

The meeting was started by IIASA personnel reviewing the Institute's past and current energy work in general and the natural gas related work in particular. This included the work on European gas issues, the Dynamizing Technologies Study, and the Logistic Substitution of Primary Fuels Study. Furthermore, the activity of the MIT/KFA Consortium on methane-fired high performance combined cycles was also covered in considerable detail.

The contributions of the outside experts are highlighted in the following paragraphs.

R.A. Hefner III pointed out that the peculiarities of natural gas regulations in the US warrant particular attention. Despite this special situation in the US, Hefner III described promising opportunities for future natural gas use in the world. For example, natural gas shows, unlike oil, a resource base pervasiveness throughout the world. In the past, not taking into account the resource potential of natural gas, especially at greater depths, led, according to Hefner, to distorted energy policies based on the alleged scarcity of this energy carrier.

D.A. Dreyfus observed that gas also has some disadvantages when compared to oil. It is not easily stored and transported, and is a much less concentrated source of energy. The most probable scenario, based on his view, is the "provincial role". To assume this role, gas must be competitively priced with respect to electricity and petroleum, at the point of use or burnertip.

The wide variety of possible unconventional sources of gas potentially surpassing, many times, the conventional ones were assessed by R. Hanneman. These are natural gas produced by reactions of ultradeep carbon with a prior organic ancestry, and abiogenic gas with no biological history.

Scientific foundations of an abiogenic gas existence were presented by T. Gold, largely based on astrophysical considerations. He also described the recent experimental drilling in the Siljan meteorite impact crater in Sweden for a source of abiogenic gas.

Several speakers (Hanneman, Varnado) pointed out the difficulty in accommodating technology forecasts with the recent gas market situation in the US. One must take into account the "gas bubble" created by conservation measures, heavy drilling in the late 1970s and early 1980s, and interfuel switching. The possibility of abrupt changes in prices, when the bubble disappears, was not excluded.

For an increase of natural gas in energy consumption, technology should play a significant, even if not yet fully identified, role. S. Varnado explained the potential existing progress in material research, electronics and various processes have in increasing the efficiency of gas exploration (higher bit penetration rates, increased economy, new methods of drilling, etc.). Constantly improving technology will be a key element in expanding the use of natural gas.

T. Schur described the potential solutions needed for the wider use of natural gas in the transportation sector. Here one has to take into account the high perfection reached by competing diesel engines, burning the heaviest residual oil (efficiencies up to 53%).

M. Lönnroth described different development scenarios for the gas fields of northern Norway as well as the actors involved in other European gas markets crucial for this development. Moreover, M. Lönnroth expressed his ideas on reshaping the current electricity supply system toward more decentralized smaller generation units and a stronger interrelation between the gas and the electricity utilities.

Experts from three socialist countries (USSR, Hungary, Czechoslovakia) presented the situation of natural gas exploration and use in their countries and also the most important recent issues. The participants were informed about the research, performed under the leadership of M.A. Styrikovich, on the international natural gas market.

All papers given at the meeting, some in drafts, some in final form, are available for distribution.

Sopron Conclusions/Key Questions

The following paragraphs contain a summary of the key questions addressed by the participants and the conclusions that emerged from the meeting and several follow-up activities.

Conclusion/Key Question 1: Methane as the Major Global Fuel?

Methane will probably continue its historically observed market penetration against all other primary fuels. See Figure 3 for the increasing methane market penetration starting at the turn of the century. In future expanding methane use, market penetration will be driven by the following forces:

- Availability.
  Far more competitively priced methane is being found today than previously thought to exist. New worldwide reserves, especially outside the US, are expanding rapidly (see Table 1 and Figure 4). Furthermore, methane is now found to be broadly distributed around the earth – on-shore and off-shore alike – more so than oil. This makes it a much more attractive fuel from the standpoint of geopolitical and national security and balance of payments considerations.

  If Dr. Marchetti's logistic substitution model (Marchetti and Nakicenovic, 1979) and forecasts prove to be true (see Figure 3), the amount of methane to be found must be enormous. The analyses given at the meeting showed that methane demand would reach its peak around the year 2060-2070 at a level of about 30 trillion cubic meters (tcm). This is roughly an order of magnitude larger than present world oil consumption in energy terms, and roughly twelve times the present world consumption of 1.7 tcm of methane. The asymptotic level for integrated methane consumption is about 2500 tcm of which less than 2% have already been extracted.

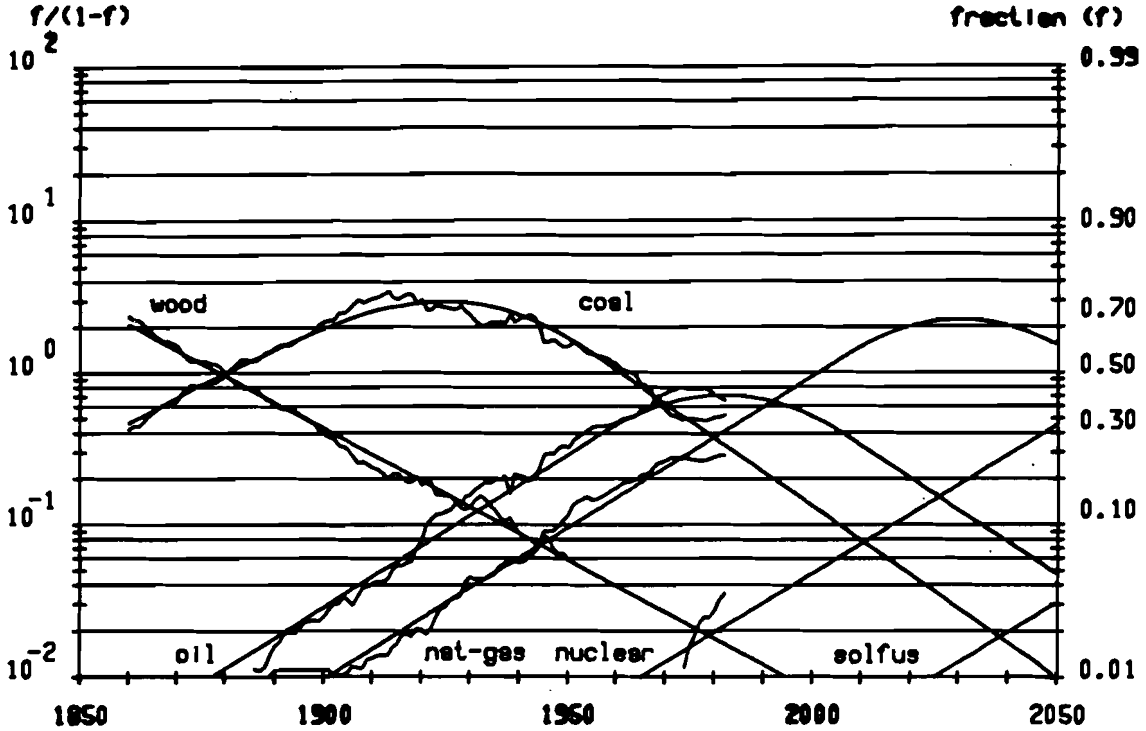

FIGURE 3. World Primary Energy Substitution. SOURCE: Nakicenovic (1985).

TABLE 1. Proven Reserves of Natural Gas, Evolution by Major Geographic Regions (in $10^9 m^3$ and %).

	1970	1975	1980	1984	1985
North America	9428	8547	8015	8283	8330
Latin America	1874	2353	4353	5335	5454
Western Europe	3571	3962	3870	5435	5599
Eastern Europe	12599	24274	31613	36620	38078
Africa	3834	5243	5683	5920	5884
Middle East	6792	15516	18681	22387	25609
Asia/Oceania	1550	3362	4796	6393	7243
World Total	39608	63257	77011	90373	96197
Percentage Distribution					
Western Industrialized Countries	34	21	17	17	16
Planned Economy Countries	32	39	42	41	41
OPEC	29	35	34	33	34
Developing Countries Outside OPEC	5	5	7	9	9

SOURCE: Cedigaz, 1985.

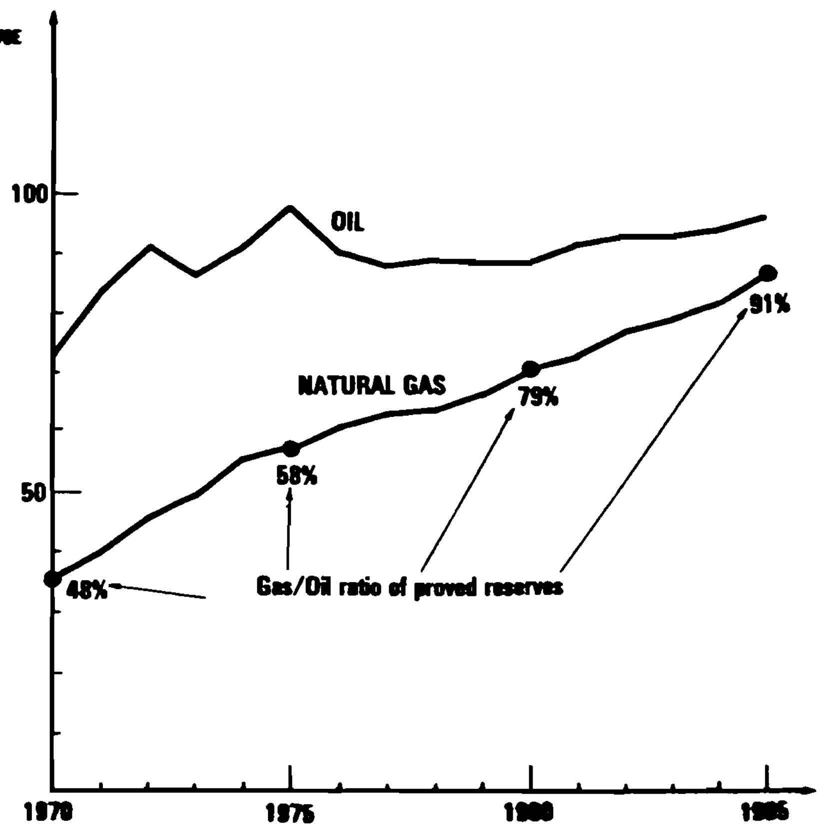

FIGURE 4. Evolution of Proven Reserves of Oil and Natural Gas in the World. SOURCE: Cedigaz, 1985.

The new super-scale dimension of the methane resource issue is obvious. If these quantities are to be realized, completely new sources of methane must be found and developed (Marchetti, 1986).

An abiogenic origin for these new required sources is postulated by Prof. Gold (Gold and Soter, 1982; Gold, 1985). A hypothesis of and by itself startling, provocative, and yet to be proven. We note here that the nonbiological hypotheses for methane formation were set forth by several USSR, German and French scientists in the nineteenth century. In essence, Prof. Gold integrates the present understanding of the formation process of the earth with the abundance of hydrocarbons in the solar system and concluded that the formation of most hydrocarbons is the result of the outgasing of abiogenic methane originating from the formation of, and trapped deep inside, the earth.

Prof. Gold's general theory of the nonbiological or abiogenic formation of most hydrocarbons continues to gain increasing creditability and increasing worldwide acceptance. Current drilling in the Siljan crater in Sweden is one attempt to confirm the existence of such resources, an effort financed by the Swedish State Power Board and the US Gas Research Institute.

Also, it might or might not be that drastic advances in exploration and drilling technology will be required to produce abiogenic methane at competitive prices.

Dr. Hanneman characterized the methane resource situation more broadly, i.e. over and above conventional and abiogenic methane sources, listing future methane source options as follows: conventional, shallow to deep, associated and nonassociated, unconventional, tight sands, Devonian shales, coal seam methane, pure pressure aquifers, gas hydrates, subducted deep sources, other abiogenic sources. Also, most impressively Figure 5 (of Hanneman, 1986) lists the unconventional resources of just the US at over 8500 trillion cubic feet (230 tcm). This compares with current official reserve figures of less than 200 trillion cubic feet (5.4 tcm), and current US annual consumption of about 17 trillion cubic feet (or 460 billion cubic meters).

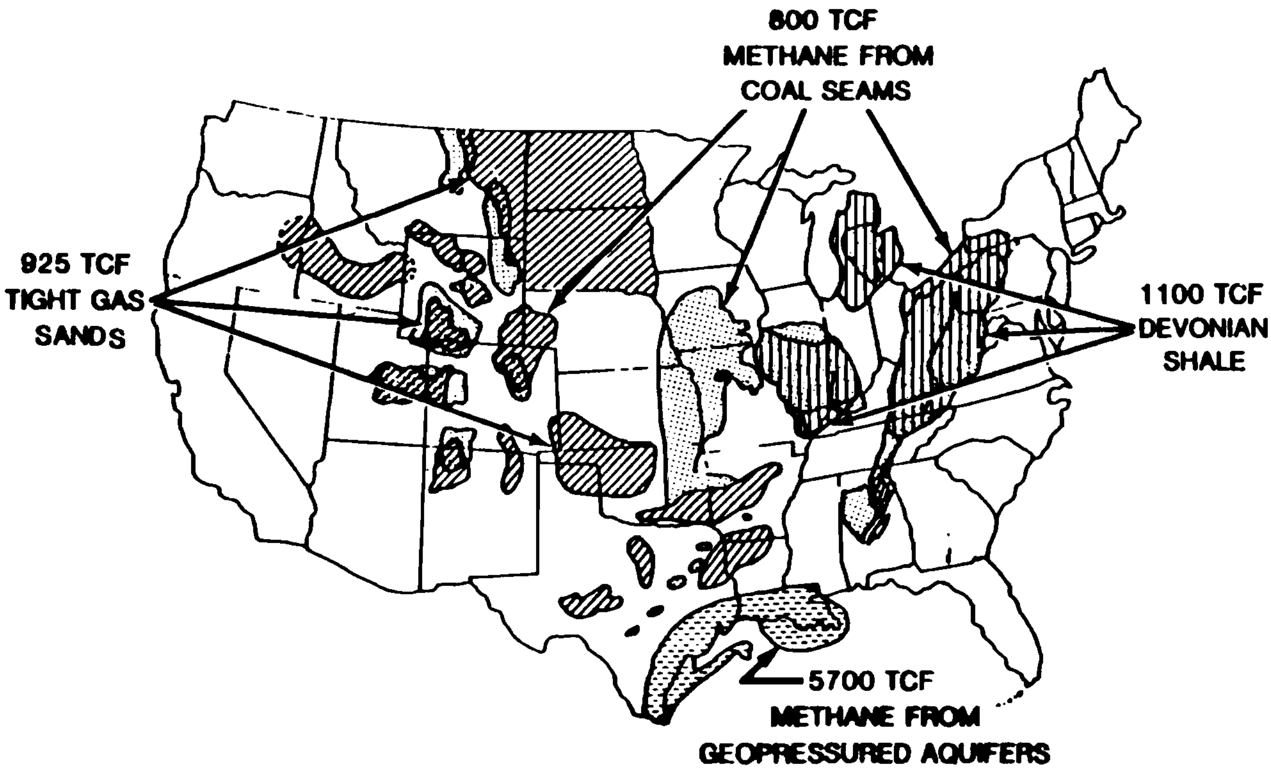

FIGURE 5. Unconventional Gas Resources of the United States. SOURCE: Hanneman, 1986.

One should note, however, there is no implication that these vast unconventional resources could be recovered with today's technology.

- Environment

  The environmental movement will continue to gain worldwide political weight. Our best judgment is that this will continue for decades to come.

  Also, methane is now quite recognized as the most benign of the other fuels by a wide margin. This is especially true if economic comparisons are made on an expanded basis that includes societal and environmental damage effects as well as the usual standard utility accounting components of fuel costs, capital costs and operating and maintenance costs. This point cannot be overemphasized.

  Specifically, the external damage caused by burning a ton of coal or oil are estimated to be over $100. The corresponding costs for methane are estimated to be about $35 (see Working Consultative Group, 1986).

- Acceptability: Anti-Nuclear Movement
  As the growing pro-nuclear movement falters, or in many cases now, is actually reversed, methane offers itself as an intriguing alternative and as a readily available and most acceptable replacement fuel.

Conclusion/Key Question 2: Technical Progress, Innovation and Improvements of Methane Technologies?

Again, it is most important to note here that no comprehensive analysis has not yet been made of how much growth is left in either the above individual or the full serial array of methane technologies. But private, off-the-record estimates based on limited, individual judgment, not calculations, range from one to two orders of magnitude for the combined serial effect of all possible technological improvements. Compared to historically observed technical progress, these estimates suggest that the overall technological improvement factor in the full set of methane-related technologies in the next 50 years could be as great as the corresponding overall performance improvement factor in commercial aviation in the past 50 years. Clearly, these estimates are rather based on lifetime experience and engineering judgment than on arithmetic.

Several suggestions were made for inclusion in the array of methane-related technologies to be examined for their potential impact on overall productivity growth. Among them are:

- Satellite search.
- Magnetic anomalies: super-sensitive aeromagnetic mapping.
- Gravimetric and density anomalies.
- Carbon isotope ratios.
- Helium and helium isotope ratios.
- Radon excesses.
- Selective metallic element anomalies.
- Vegetative anomalies.
- Electrochemical anomalies.
- Fully computerized geochemical/geophysical prospecting.
- Searching for lithogenic as well as abiogenic methane.
- Searching for methane completely unassociated with oil or sedimentary deposits.
- Vastly improved 3-D seismic.
- Ultra deep drilling techniques.
- Polycrystallic diamond bits combined with smart down hole electronics.
- Wide bandwidth MWD (measurement while drilling).
- Vastly improved down hole motors.
- Highly steerable drilling packages guided by hardened electronics.
- Vastly improved drill pipe and casing materials.
- Drilling hundreds of producing holes from a single platform (off-shore and on-shore both).
- Scientific fracturing.
- Bigger diameter pipes.
- New, highly automated pipe laying techniques.

- o Building the pipes in place with metal ion/plasma spray techniques (Sandvick process).
- o Substantial improvements in the efficiency of pipeline pumping turbo machinery.
- o Improving efficiency of gas turbine/combined cycles from current 48% to achievable 60% and potential 65%.

The serial effect of combining all conceivable advancements of methane-related technologies could result in as much as one-to-two orders of magnitude technical improvement over the next several decades, adding to the attractiveness of methane to various end-users. It is most important to note here that there is no generally accepted method for measuring "attractiveness" of and end-user system, or a primary energy source. We do note, however, that the old measures, i.e. cost per kilowatt hour of electricity generation, are wholely input costs based measures and have been highly misleading. In some cases they have led to catastrophic financial and societal results, to the point of imperiling the future of several new technologies and the commercial atomic power industry.

Several of the participants viewed the development of an entirely new set of measures for attractiveness, as perhaps the primary task for the system-oriented researchers and practitioners over the next decades.

Apart from the older more familiar simplistic terms relating to straight capital, fuel and operating & maintenance costs, such measures should account for

- o General societal acceptability of the entire system.
- o Total external damage caused by installing and operating the system on a cradle-to-grave lifetime basis.
- o General robustness of the system to all forms of possible interruptions.
- o Minimum lumpiness of capital and physical plant investment.
- o Minimum optical comprehensibility per systems unit (systems that can hardly be seen are liable to be evaluated as much more attractive than those with high optical comprehensibility).

No real substantive work has been done yet on developing a true attractiveness measure for energy systems. We suspect that when it finally gets done, the results will be organized in the form of rather complex functions with many terms heavily weighted with values representing comprehensive societal costs.

Conclusion/Key Question 3: New Insight from Disaggregated Component Costs? Deep Drilling in Heartland Europe Versus Peripheral Production and Imported Methane?

Transmission and distribution costs dominate even in such ultra high cost producing areas as Troll and Sleipner. The conclusion, by induction, is that it may pay to spend several times as much on ultra-deep drilling for methane in heartland Europe, i.e. on sites close to the market, than to produce on the periphery and then "pipeline in".

The point was raised by outside experts that to date, insufficient emphasis has been put on disaggregating the component costs in the cradle-to-grave process of finding and developing new methane sources, and then delivering it to the many different end-users in heartland Europe.

In response to this suggestion, IIASA produced some first-order effect calculations, after the meeting, largely for heartland Europe. The data clearly show that even though the North Sea exploration and production costs were extremely high (many billions of dollars for a single platform), the dominant cost component to the European end-user was the pipeline costs (Strubegger and Messner, 1986).

By the same token activities such as the FRG's Scientific Deep Drilling Program (DM 450 million), the USSR's well established Scientific Deep Drilling Program (Kola peninsula, etc.), and the quite new complex commercial production drilling program in the Paris Basin (with the basin perhaps positioned directly underneath the city) are both on the right track and worthy of close and careful attention.

If one to two orders of magnitude of technological performance improvement could be achieved, several of the attenders of the Task Force Meeting concluded that methane will certainly be the bridge fuel between the first and second nuclear age (first nuclear age now over). During that period, methane would continue to steadily replace oil and coal (and in some cases nuclear) for many, but certainly not all, uses.

For a recent, well documented institutional assessment of the possible performance improvement factors that should be considered here, and the extent of the RDT&E (Research Development Test and Engineering) funding see Linden (1985).

Conclusion/Key Question 4: Methane and Electricity – Fierce End-Use Competition?

This was raised as a major issue that should be investigated early, particularly so in respect to the restructuring effect it might have on the electric utility systems.

Proceeding on the assumption that abundant methane is, and will continue to be, available at attractive prices, this very interesting issue was raised by Dr. Lönnroth as to what the end-use competition would be between networked electricity generated from methane versus networked methane as an end-use fuel.

A first order assessment for heartland Europe suggests that the size of the generating stations would shrink by one to three orders of magnitude and the generating units would be much more broadly dispersed. Another possible net result would be that more power would be distributed by a finely structured electric grid (fueled by a moderately coarsely structured methane grid) rather than by a super-finely structured methane grid (Lönnroth and Schmidt, 1986).

In the United States, the results of the EGEAS (Electric Generation Expansion Analysis System) Study undertaken at MIT were unexpected (EPRI, 1982). They indicate that methane fired combined cycles would be clearly the most cost efficient method of new electric generation installations in seven out of nine utility districts making up the entire US generation grid.

The study was broad in nature, including capacity planning, government policy, and gas utilization aspects in addition to direct economic comparisons. The final results, however, were expressed in terms of direct economic comparison.

The study highlighted the fact that in a period of great and multifaceted uncertainty (public acceptance of the various systems, oscillating fuel and capital costs, oscillating load growth, cancellation of almost fully completed plants, etc.) – such as the times we are now experiencing – methane fired combined cycles offer a powerful advantage from the standpoint of having the smallest "regret" cost penalties, i.e., if the utility guesses wrong, or makes a mistake, the combined cycle system carries with it the least "regret" cost.

The study concluded with the following statement referring to natural gas fired combined cycles: "Their economic competitiveness cannot be denied. Their environmental advantages, safety aspects, ease of siting, and modularity make them an ideal system in an era of uncertainty."

Conclusion/Key Question 5: Methane: A Provincial, International or Intercontinental Fuel?

Dr. Dreyfus heavily stressed the point that the future role of methane either as a provincial, international, or intercontinental fuel was far from clear. In the US, methane tends to be mostly a national or even regional fuel (in Dreyfus' terminology a provincial fuel). Currently, in Europe methane is an international fuel. In Japan, a truly intercontinental fuel based almost solely on LNG transport.

The fundamental issue seems to be whether or not transportation costs (particularly LNG costs) can ever be sufficiently lowered to make methane a real world, intercontinentally traded commodity.

The Japanese are clearly the leaders in testing the intercontinental methane-as-a-commodity trade hypothesis. They currently have five LNG routes in operation, importing roughly 25 million tons of LNG per year.

These Japanese supply routes are from widely dispersed geographical sources, including Cook Inlet, Alaska, the Middle East, Borneo, Indonesia, and Malaysia. Also a new super LNG source is just being developed in the Dampier Archipelago (Indian Ocean, northwest Australian Continental Shelf). This route will dwarf the existing ones, requiring the construction of a special fleet of seven LNG tankers.

Dr. Dreyfus expressed the firm view, however, that LNG in general and Japanese LNG in particular was still markedly uneconomic (cost considerations seem not to be the only criteria for Japanese LNG import). We do note that Japanese imports of LNG have increased from 3.1 billion cubic meters (2.8 millions tons of oil equivalent) in 1973 to 37.6 billions of cubic meters (34 million tons of oil equivalent) in 1985. This is over a twelvefold increase in 12 years. Still, to put matters into perspective, world LNG transport, most of which is to Japan, amounts to just 3% of total world methane use (OECD/IAEA, 1986).

Conclusion/Key Question 6: A Major Overriding Exogenous World Force – The Tradeoff Methane Versus Nuclear?

In shortest possible summary, our fundamental view here is that first generation commercial atomic power plants (and all related nuclear technology development), certainly in most of the Western World, is stalled for several decades. In turn, methane-related technologies and their directly related commercial applications are now entering a rapid growth phase. Methane may very well become the bridge fuel between the first and second nuclear ages.

This observation is generally consistent with IIASA's past work. Here, the emergence of the second nuclear age is anticipated because of growing environmental concerns regarding the potential adverse impacts of a continual CO_2 accumulation in the atmosphere. Though substantially lower than in the case of coal, the methane age is inextricably associated with CO_2 emissions, unless fossil fuel combustion processes occur in a totally enclosed system and with pure oxygen (Häfele et al., 1986). The term second nuclear age must be viewed in the broadest concept possible, including the nuclear energy supplied by the solar system. Perhaps it should be called the "second energy age." Specifically, it is consistent with the broadly-sketched interfuel substitution patterns covered in ***Energy in a Finite World*** (Häfele et al., 1981). ***Energy in a Finite World***, IIASA's largest complete undertaking to date, clearly takes the position that for the next several decades the principal competition of primary fuels and the primary fuel technologies will be methane and nuclear (see Chapter 8 of Häfele et al., 1981).

Since *Energy in a Finite World* was published in 1981, we have seen no substantial evidence to contradict this general assessment. Considerable new evidence tends to reinforce it.

Consider the facts: Since the early 1970s, nuclear power in the world has grown by a factor of seven, i.e., from 200 TW(h) in 1973 to 1385 TW(h) generated in 1985. In the OECD countries, the corresponding growth is from 188 TW(h) to 1131 TW(h), in central Europe the corresponding growth is 62 TW(h) to 444 TW(h) (Strubegger and Messner, 1986).

The growth for methane is also impressive. World methane use has increased by a factor of 1.4 in the corresponding period from 1245 billion cubic meters in 1973 to 1735 bcm in 1985.

Key Conclusion/Question 7: The Growing Anti-Nuclear Movement?

In recent years, nuclear power has come under severe attack by diverse groups and factions. This anti-nuclear movement is now so influential and efficient that it may very well result in a much slower nuclear growth rate or even a negative growth rate for commercial power reactors over the next several decades (these comments at this writing apply only to the Western world countries). In this respect, we already see the movement's dramatic early successes in Europe, the US, and even to some degree in Japan. Specifically, Austria has built a commercial atomic power plant that the electorate voted not to start. The physical removal (full site clearing) of this mint-condition plant (Zwentendorf) has also been decreed. Dismantling will start in 1987.

Sweden has voted anti-nuclear and the authorities are setting forth a schedule for the shutdown of its entire fleet of commercial reactors. Anti-nuclear public opinion certainly appears to be increasing in most Western countries with perhaps the exception of France.

The situation in the US, the world's major nuclear operator, is almost catastrophic. Cancellations of multibillion dollar nuclear power stations, frequently over 75% complete (and sometimes as high as 95% complete) are no longer uncommon. The most recent of these is the four plus billion dollar Consumers Power Midland Station (95% complete). And most important, this station will now be converted to a methane fired, combined cycle unit. The methane will most probably come from near-by high flow rate wells that have been recently completed in the same state, Michigan (the recent Prarie du Chien drill tests in the upper Michigan Basin have produced some of the highest flow rate methane wells in the world).

Investigations are now being made of the effects of shutting down all or major portions of most of the Western world's commercial reactor fleet. An analysis was made by RAND about a year ago, based on the shutdown of several site-specific reactors including the Indian Point Station (Consolidated Edison) and Zion (Commonwealth Edison) (see Stucker, 1985). The results clearly show that the net resulting effects on the consumers and surrounding industry would be almost unnoticeable.

Individual European governments are now making similar analyses. For example, in the FRG six independent studies came to similar conclusions as the RAND study. IIASA has made one such first-order-effects analysis for a nuclear phaseout in central Europe (Messner, Golovine, Strubegger, 1986). Several quite significant conclusions emerge from this IIASA Study:

(1) In heartland Europe, if such commercial atomic power moratorium (adopting the Swedish presidence) were declared today, the macro-effects on the consumer in particular and industry in general would be entirely manageable.

(2) The full effect of a phaseout would occur after the turn of the century. Much of the make up (networked) replacement energy would come from new electricity generated by methane fired combined cycle plants or from additional directly pipelined methane. Most simply stated: methane would be the major replacement fuel. Also, there is plenty of it around at an acceptable price.

(3) The impact on the environment would not be of any concern.

Conclusion

The final session of the Task Force Meeting was devoted to conclusions and recommendations for further work at IIASA. From the discussions the following can be summarized:

- Increased methane use would make an excellent case study as a part of the field of the dynamics and impacts of new technology.
- It was agreed that it would be useful to study the role of countries endowed with large gas reserves (Algeria, Australia, the Near and Middle East in general) and the impact of increased gas trade on world trade, national security considerations and geopolitics.
- This study requires a systems approach because both the technology and methane as an energy source act in an international political and economic environment.
- IIASA could provide the appropriate structure and coherence required for the studies on methane and establish confidence in a methane resource data base with information from those who consider gas separate from oil.
- There is a gap in the knowledge of the technology-economy relationship in methane exploration and use. The gas producers indicated that they would appreciate it if the whole "causal technological chain" from drilling to burners could be assessed economically. This constitutes an important input for decision making in the exploration area. The trade-off between local deep drilling costs and long distance transportation costs must be clearly established.
- As for the study itself, the major cost elements trend should be identified over a 20–40 year span and their effect disaggregated. This should show what the potential is for methane price reduction.
- The widespread use of methane will have an impact on the other utility networks, especially on electricity. The trend will obviously be toward large-scale dispersed systems. There is a need for new policy measures to secure cooperation between a gas network and "companion" electric power network.

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Task Force Meeting
on

THE METHANE AGE

Likely Gains in Current Technologies
Emerging Technologies and Their Likely Consequences
Economic - Political - Geopolitical

May 14-16, 1986 Hotel Lover, Sopron, Hungary

Organized by:

The International Institute for
Applied Systems Analysis
(IIASA), Laxenburg, Austria

with the cooperation of

The Hungarian Committee for Applied Systems Analysis
Bureau for Systems Analysis of the
State Office for Technical Development,
Budapest, Hungary

Program

Tuesday, May 13:

	Arrival of Participants
20:00	Dinner (Dinner Speaker: Robert A. Hefner III)

Wednesday, May 14:

09:00-09:10	Opening; Objective of Meeting -- Advice and Counsel on IIASA "Methane Age" Research Plan (E. Schmidt)
09:10-09:35	Overview of IIASA's Technology-Economy-Society Program and its relation to Methane Technology (N. Nakicenovic)
09:35-10:00	Results of Current Gas Studies (H. Rogner) - IIASA Gas Studies - European Communities - Gas Research Institute - International Gas Union - World Energy Conference - etc.
10:00-10:15	Coffee Break
10:15-11:15	The Technology and Implications of Combined Cycle Systems (T.H. Lee)

Wednesday, May 14 (continued):

11:15-12:00	The Engineers' Contribution to the Methane Age (J.R. Metz / T. Schur)
12:00-12:45	What are the sensitivities (exogenous, policy and technological dynamics) on methane in energy markets? (Discussion)
12:45-14:30	Lunch
14:30-15:30	Energy Technology Substitution & Long Waves and Pulses (C. Marchetti)
15:30-16:30	New Theory, New Exploration Techniques and Recent Developments in Astrophysics (T. Gold)
16:30-17:00	Coffee
17:00-18:00	Exploration on Drilling (S. Varnado)
19:00-21:00	Visit to Local Wine Cellar

Thursday, May 15:

09:00-10:30	Presentation by A. Khorkov
10:30-10:45	Coffee
10:45-11:30	Presentation by J. Subai
11:30-12:30	Gas Research Institute - Technical Survey (R. Hanneman)
12:30-14:00	Lunch
14:00-15:00	Gas Research Institute - Policy Survey (D. Dreyfus)
15:00-16:00	Troll Dance (M. Loennroth)
16:00-16:30	Coffee
16:30-17:30	Discussion of non-IIASA participants to make recommendations on what IIASA should do in the field and what their own involvement might be)
19:00	Dinner

Friday, May 16:

09:00-12:30	Continuation of Discussion and Closing Session
12:30-14:00	Lunch/Departure

List of Participants

Dr. D. Dreyfus
US Gas Research Institute
Chicago

Prof. T. Gold
Cornell University, Ithaca, NY &
Trinity College, Cambridge, U.K.

Dr. R. Hanneman
Vice President
Reynolds Metals Co.
Richmond, Vir.

R.A. Hefner III
President
The GHK Companies
Oklahoma City

Dr. A. Khorkov
USSR Academy of Sciences
Moscow

Dr. M. Lönnroth
The Prime Ministers Office
Stockholm

T. Schur and J.R. Metz
Sulzur Bros.
Winterthur, Switzerland

Dr. S.G. Varnado
Vice President
NL Industries
Sugarland, Texas