IAEE INTERNATIONAL ASSOCIATION FOR ENERGY ECONOMICS

Newsletter

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Second Quarter 2003

President's Message

As we head to Prague next June, I want to note and acknowledge the hard work of all IAEE and affiliate members who organize our conferences. Year in and year out, IAEE conferences continue to advance the field of energy economics and related disciplines, enhance the quality of our organization, and extend and expand the IAEE networks largely through the efforts of the program and local planning committees. This is pure volunteer work - a true expression of service within a service organization. It takes time, energy, perseverance, and patience (and no small amount of guidance and support from our headquarters staff!). The tradition is to offer thanks after the event is over to all of those who made the effort. This year, having been there and done this myself, I want to offer thanks in advance, on behalf of the IAEE council and membership, to our fearless leaders in Prague, Jan Myslevic and Ivan Benes, to our HQ staff, and all who are helping them with this wonderful venue.

As the Prague agenda has taken shape, I have heard many comments on the meaning and symbolism of having an IAEE event in the Czech Republic, in a region of profound transitions and transformations. For those of us who participated in the 1996 Budapest conference it is a similar feeling of being witnesses to change. For all that we are trying to do with regard to student outreach, I think it is particularly important to reflect on and communicate these impressions to our younger and future members and leaders.

They are the ones who will push the frontiers, both in research and geography, for the IAEE, and we ought to help them see the bigger picture of what IAEE is all about and the roles our members play in their national and local settings.

I look forward to seeing you in Prague!

Michelle Michot Foss

Editor's Notes

North American energy trade lives! Economic uncertainties from global unrest, legislative logjams, and risk-capital scarcity may slow private projects; but Joe Dukert's article on "New Initiatives" describes the North American Energy Working Group's surprising boosts to trilateral cooperation. ("Must reading" for anybody interested in our upcoming Mexico City Conference.)Zbigneiw Mantorski reviews the development of the electric energy sector in Poland. He discussed the organization of the sector, the privitization that has taken place so far along with the barriers that remain and are hindering the sector's growth.

John Ryan writes: Everything that goes up must come down. But, is worldwide oil production *really* peaking? If so, must the trajectories be mirror images? If different, is that significant for policy making purposes? The national welfare, and the possible need to spend many billions of dollars now, may depend on the answers.

Michael Canes examines the economics of hybrid electric vehicles. His analysis looks first at civilian vehicles, where there is a private return from fuel savings and an added social return from emission reductions. He then turns to military vehicles, where fuel savings from hybrids are highly valued because of the reduced demand for logistics support. The paper concludes with an assessment of the viability of hybrid electrics in both the commercial and military markets.

Ivan Benes and Monika Mechurova present the results and analysis of the first comprehensive strategic study conducted in the Czech Republic related to the safety of the Czech energy system against the danger of terrorist attacks. The study recapitulates basic considerations for suitable response to the various forms of terrorist attack on the power infrastructure and reveals the most vulnerable elements of the system. The study was funded by the consortium of Czech energy companies.

A group from Sandia National Laboratories discusses the Electricity Generation Cost Simulation Model (GenSim), a user-friendly, high-level dynamic simulation model that

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calculates electricity production costs for a variety of electricity generation technologies. The model allows the user to conduct sensitivity analyses on key variables.

Malika Saidhodjaeva discusses the Uzbekistan economy and its transition experiences following the break-up of the Soviet Union. She notes that it is primarily a natural gas economy; gas accounting for more than 80% of total energy consumption, but that the country is at the strategic center of Persian Gulf, Caspian and Tarim oil basins.

Zbigniew Mantorski reviews the reconstruction of the Polish electricity sector. He discusses the subdivision into generation, transmission and distribution, the privitization that has occurred and is planned as well as the barriers to the sector's development.

DLW

FUTURE USAEE / IAEE EVENTS

Annual Conferences

June 5-7, 2003	26th IAEE International Conference Prague, Czech Republic Dorint Don Giovanni Prague Hotel
October 19-21, 2003	23rd IAEE North American Conference Mexico City, Mexico Camino Real Hotel
July 8 - 10, 2004	24th USAEE/IAEE North American Conference Washington, DC Capital Hilton
April 19 – 23, 2005	28th IAEE International Conference Taipei, Taiwan Venue to be Announced

PRAGUE IAEE CONFERENCE STUDENT SCHOLARSHIPS AVAILABLE

IAEE is offering a limited number of student scholarships to the 26th IAEE International Conference. Any student applying to receive scholarship funds should:

1) Submit a letter stating that you are a full-time student and are not employed full-time. The letter should briefly describe your energy interests and tell what you hope to accomplish by attending the conference. The letter should also provide the name and contact information for your main faculty supervisor or your department chair, and should include a copy of your student identification card.
2) Submit a brief letter from a faculty member, preferably your main faculty supervisor, indicating your research interests, the nature of your academic program, and your academic progress. The faculty member should state whether he or she recommends that you be awarded the scholarship funds.

IAEE scholarship funds will be used to cover the conference registration fees for the Prague IAEE International Conference. All travel (air/ground) and hotel accommodations, meal costs (in addition to conference-provided meals), etc., will be the responsibility of each individual recipient of scholarship funds.

Completed applications should be submitted to IAEE Headquarters office no later than May 6, 2003 for consideration. Please mail to: David L. Williams, Executive Director, IAEE, 28790 Chagrin Blvd., Suite 350, Cleveland, OH 44122.

Students who do not wish to apply for scholarship funds may also attend the conference at the reduced student registration fee. Please respond to item #1 above to qualify for this special reduced registration rate. Please note that IAEE reserves the right to verify student status in accepting reduced registration fees.

If you have any further questions regarding IAEE's scholarship program, please do not hesitate to contact David Williams, IAEE Executive Director, at 216-464-2785 or via e-mail at: iaee@iaee.org

INTEGRATING THE ENERGY MARKETS IN NORTH AMERICA:
Issues & Problems, Terms & Conditions

October 19-21, 2003 Camino Real Hotel México City, México

23rd IAEE North American Conference

Supported by

United States Association for Energy Economics
Asociación Mexicana para la Economía Energética
International Association for Energy Economics
Canadian Association for Energy Economics

Honorary Chair: Francisco Barnes, Undersecretary for Energy Policy, Mexico
General Chairs: Adam Sieminski, José Gonzalez Santaló, André Plourde
Program Chair: Pablo Mulás
Arrangements Chair: David Williams

Conference Objective

To explore the forces driving and opposing the creation of regional North American energy markets

Plenary Session Themes

Gas & Power Sector in North America
Oil & Natural Gas in Mexico
Energy Trade & Transport
Energy Security & Reliabity
Environment & Energy
Role of State Owned Utilities

Possible Concurrent Session Topics

Concurrent sessions will be developed from the papers selected for the program. The following is a non-exclusive list of possible topics: Resource estimates; Development challenges – deepwater, oil sands, GTL; ‑Distribution networks - LNG, refineries, tankers, terminals, pipelines; Harmonization of fuel specs, MTBE, biofuels; Relationship with OPEC; Direction of the transportation sector; Integration of gas and electricity markets; Markets issues – regulatory reform, transparency, pricing, demand side options; Power sources – fossil, nuclear, renewable, distributed technologies; Sustainability and environmental issues; Access to capital, project finance, foreign investment; Impact of economic and demographic trends on continental energy markets; Infrastructure security; Energy R&D and technology transfer.

All topic ideas are welcome and anyone interested in organizing a session should propose the topic, motivations, and possible speakers to: Pablo Mulás – (p) 52/55/5483-4027 (f) 52/55/5483-4028 (e) pmulas@correo.uam.mx

**** CALL FOR PAPERS ****

Abstract Submission Deadline: June 13, 2003
(Please include a short CV when submitting your abstract)

Abstracts for papers should be between 200-750 words, giving a concise overview of the topic to be covered. At least one author from an accepted paper must pay the registration fees and attend the conference to present the paper. The lead author submitting the abstract must provide complete contact details- mailing address, phone, fax, e-mail etc. Please specify if you will be presenting your paper in Spanish or English. Authors will be notified by July 7 of their paper status. Authors whose abstracts are accepted will have until August 18 to return their papers for publication in the conference proceedings. Abstracts should be submitted to:

David Williams, Executive Director, USAEE/IAEE
28790 Chagrin Blvd., Suite 350, Cleveland, OH 44122 USA
Phone: 216-464-2785 / Fax: 216-464-2768 / E-mail: usaee@usaee.org

USAEE Best Student Paper Award ($1,000 cash prize plus waiver of conference registration fees). If interested, please contact USAEE Headquarters for detailed applications / guidelines. Student Participants: Please inquire also about scholarships for conference attendance.

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New Initiatives in North American Energy Cooperation[1]

*By Joseph M. Dukert**

In June 2002, the Natural Resource Ministry of Canada and the energy secretariats of the United States and Mexico took a giant *symbolic* step (and a smaller but useful *substantive* step) in the evolution of a more effectively integrated continental market for natural gas, electricity, oil, and related technology. Exactly one year after the formation of a North American Energy Working Group (NAEWG), they released a joint document entitled *North America: The Energy Picture.*

Although this document is available on the websites of all three energy departments (in English, French, and Spanish)[2] and a more comprehensive version is already in the planning stage for publication next year, it has attracted relatively little attention. It has not yet received nearly as much analysis and commentary as it merits, either inside or outside government – although more should come at the next North American Conference of the IAEE in Mexico City in October.

By itself, "Energy Picture" may be just a blip in the development of the broadest regional energy market in the history of the world – which in recent years has already amounted to more than $50 billion a year. But the publication points up the special role that governments can play, even in a relatively free international market. Even though the NAEWG has no "authority" on its own[3], it also is proving the value of good-faith international dialogue – once mutual confidence can be established.

Joint projects are being developed trilaterally through the NAEWG in such areas as the modeling of large-scale transportation networks – a capability that can ultimately be a factor not only in trade but also in the protection of critical energy infrastructure. A workshop has been scheduled this spring to discuss specific problems of electricity exchange across the southern U.S. border. The U.S. and Canada already have extensive capacity for power exchange (although both could take fuller advantage of *north-south* ties if they strengthened their *east-west* connections). The main trade push for the future up north will be for more natural gas pipelines rather than powerlines; and a subgroup of the North American Working Group is beginning to focus on regulation of gas movements.

By the time this article reaches most readers the full NAEWG should be meeting for the fifth time – this time in Canada (after two sessions in Washington, one in Mexico City and another earlier one in Ottawa). It has already published a side-by-side comparative summary of regulations within the three countries affecting international electricity trade[4]; and dialogue on energy efficiency standards and labeling has helped produce analogs to the U.S. Environmental Protection Agency's successful "Energy Star" program in both Canada and Mexico.[5] Minimum energy performance standards (and test procedures) are now identical or very similar in all three countries for refrigerators, freezers, and both central and room air conditioners; and commonality is anticipated in the near future for dishwashers, clothes washers, and both fluorescent and incandescent lamps. The Science and Technology subgroup has held a series of useful teleconferences and has brought together research directors from the three countries repeatedly. These meetings (one of which I attended in Washington) have been remarkably businesslike and down-to-earth. For instance, one area being emphasized is equipment used to convert AC flows of electricity to direct current and then back to alternating current. This is critical at border interfaces where adjoining grids are not synchronized; and improvements might thus be helpful in beefing up east-west connections (e.g., between Quebec and Ontario, or the Eastern and Western Interconnections in the United States) as well as in north-south international trade.

Given the nationalistic traditions on energy in all three countries, virtually no one could have predicted 15 years ago that their respective federal governments would agree to look at the continent as a potential energy *unit*. That's what "Energy Picture" purports to do; and – although it doesn't fully succeed – it establishes a platform from which to do so. At the same time, states and provinces are well on their way to exploring and bolstering means of energy cooperation in both national and regional contexts.[6] The North American Electricity Reliability Council has taken a more vigorous continental stance, and this has led to a variety of contacts between NERC and NAEWG. The Federal Energy Regulatory Commission (FERC) – besieged by state complaints about its efforts to introduce the concept of a Standard Market Design (SMD) – is nevertheless dedicated to Regional Transmission Organizations that somehow accommodate national borders while recognizing that power can flow fruitfully across them in both directions.

While the situation holds enormous potential, it should not be hyped. In only a few years there has been surprising progress, an *interruption* to progress, and now a *resumption* of progress toward an integrated North American energy market – a sequence that will be discussed later in this article. This has huge economic, environmental, and geopolitical implications for the long run that deserve objective analysis; and "Energy Picture" (which generally brings together data for the Year 2000) establishes an officially agreed-upon benchmark from which to measure future assessments.

An energy analyst or policymaker should not expect to find conclusions and recommendations in the document. Those are left to the reader, who in many cases must search out unexpressed relationships between data in different sections . . . or even use the information there to draw thoughtful comparisons with other sources. Nevertheless, the value of the publication – especially as background for the Mexico City IAEE Conference – can hardly be exaggerated.

North American energy trade is (and will always remain, in part) a series of common-sense regional markets – some of which overlap international borders. A truly continental market built upon them can optimize benefits. But envisioning the *best* future courses of action (for the private sector as well as government) requires that we know "who has what", "how much", and "what kind". Unfortunately, this has been hard to pin down . . . because national statistics are often incompatible. Although projections by the three partners in "Energy Picture" of their respective energy supply and demand between 2000 and 2010 proceed from somewhat different sets of assumptions, at least these are stated. Equally important is the fact that common units of measurement are used throughout.

One unfortunate shortcoming in this "first edition" is that

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[1] See footnotes at end of text.

only two pages of text are devoted to energy *demand* and there is no breakdown of fuel preference or demand volume by consumption sector. That will apparently be remedied next year. If we hope to continue improving energy efficiency, we should also know "what *sorts* of energy we consume", "how much", and "how" – now and (in so far as we can anticipate) over the next decade or two. Even a simplistic comparison, based on EIA's "Country Analysis Briefs", shows that differences in gross energy use by sector raise interesting questions.

Percentage of Energy Consumption by Sector (NAFTA Countries, 1998E)[7]

Country	**Residential**	**Commercial**	**Industrial**	**Transportation**
Canada	17.7	15.5	48.0	18.9
Mexico	15.9	04.6	54.7	24.8
United States	19.4	15.8	38.2	26.6

Why does such a geographically spread-out country as Canada (with population nevertheless highly urbanized and concentrated pretty much in a narrow east-west line) devote such a relatively small share of the energy it expends to moving goods and people around? If Mexico's residential and commercial sectors are as scanty in energy use as they seem to be, should energy policy (and assistance) focus as much on increasing popular availability as almost anything else? With the United States expending about three-fifths of its energy on the transport and combined residential/commercial sectors, does this add impetus to energy efficiency standards for buildings and vehicles?

A five-year-old comparison such as this is obviously less than ideal, but this only highlights the need for up-to-date official statistics from all three countries, using common definitions for sectoral breakdowns. The office of Mexico's Undersecretary for Energy Policy and Development publishes detailed data on an annual basis (see *Balance nacional de energía 2001*); but it cannot be compared directly with the four consumption sectors shown here (and used generally by U.S. DOE). The Mexican figures separate Farming (*Agropecuario*) from Industrial, and they lump Residential and Commercial use.

The United States is a giant in the North American trio – in population, in wealth, and both as an energy producer and an energy consumer (see table). We (as the major customer) have doubled our net imports of all forms of energy in barely a dozen years – from less than 12 quads to more than 25 quads. In 2000, 36 percent of those imports came from our NAFTA partners. They account for about 15 percent of all the oil and natural gas consumed by the United States.[8]

Major Forms of Primary Energy Consumption (NAFTA Countries, 2000)[9]

(Quadrillion Btu)

Country	**Petroleum**	**Natural Gas**	**Coal**	**Hydro**	**Nuclear**
Canada	4.05	3.37	1.49	3.17	0.78
Mexico	3.90	1.46	0.25	0.34	0.08
United States	38.40	23.11	22.5	3.09	8.01

U.S. gas imports from Canada have grown every year since 1986, more than quintupling. Canada sends us half of its total production of natural gas (now exporting nearly 4 tcf and importing about 175 bcf annnually) and perhaps as much as two-thirds of its crude oil production (more than 1.4 mmbd out of 2.1 mmbd in 2002, according to preliminary estimates).[10] In addition, Canada provides roughly 500,000 bbl/day of refined petroleum products – a volume that seems destined to grow in the future because of U.S. difficulties in adding to its own refining capacity.

Still, the story isn't *just* U.S. imports. Mexico has long been one of our leading oil suppliers; but it depends increasingly on U.S. and Canadian natural gas, not to mention gasoline and some electricity from Texas. Last year, total U.S.-Mexican gas trade was the highest in history (although still only about 250 bcf), of which almost all goes south. In respect to electricity, Alberta and Saskatchewan are consistently *net importers* from the Lower 48,[11] and virtually all Canadian provinces count on U.S. electricity at times during each year. Although "Energy Picture" doesn't mention the fact, National Energy Board statistics[12] show that in recent years Canada has traded more electricity with the United States than across its own domestic provincial boundaries.

"Energy Picture" should have noted that much energy trade *fluctuates* in either direction across these borders. Map callouts on page 32 reveal that in 1999 the overwhelming flow of electricity was southward from British Columbia, Manitoba, Quebec, and the Maritime Provinces; but Alberta, Saskatchewan, *and Ontario* all received substantially more electricity from the Lower 48 than they sent south. Interprovincial electricity trade in Canada is relatively undeveloped, and recurrent variations in demand, plant readiness, and precipitation make two-way, north-south commerce not only economical, but at times essential to maintain reliable supply.

Maps constitute a vital part of the NAEWG document, complementing the energy production and trade data. They show the location and estimated size of oil, gas and coal reserves, as well as interconnections for both gas and electricity. They also display the impressive potential of Canada's Maritime Provinces. Reserves of conventional oil in Newfoundland and Nova Scotia rival the light oil still in Alberta (the country's energy leader). As for Canadian natural gas, the New England market beckons; and the text describes current and planned projects (some subsea) to deliver that fuel. It takes only a bit of imagination to envision an "in-and-out" hub in central Pennsylvania that could tap widespread and distinct sources – western Canada, eastern Canada, the Gulf Coast of the U.S., and perhaps even the Burgos Basin of northeast Mexico – to satisfy complementary demand in all three countries.

U.S. reserves of natural gas are large (167 trillion cubic feet, compared with Canada's 92 tcf); but Mexico's are fairly limited, based on exploration to-date (only 30 tcf). By contrast, Mexico leads in *conventional* oil reserves (24 billion barrels, followed by 22 billion bbl in the United States and only 4.4 billion bbl in Canada). Canada's wild card is its "vast reserves of oil sands, of which about 308 billion barrels are economically recoverable".[13] Discussions with U.S. government and corporate geologists have convinced me that this whopping estimate is credible. We ought to weigh its ramifications in long-range energy policy planning.

Canada's oil sands appear to contain 2.5 *trillion* barrels of oil, of which about one-eighth is considered recoverable with today's technology and economics. With development costs ranging now between $9 and $13 per barrel, oil sands production has already reached 658,000 bbl/day, with about 60 percent being exported to the United States in 2000. But environmental implications need to be evaluated, and the upfront costs are steep. With more than $20 billion (U.S.) in new projects announced for the next few years, Canada's National Energy Board has projected a production rise to 1.6 mmbd from oil sands by 2015.[14] Yet Deutsche Bank's analysts go well beyond that. Its *Oil and Gas Abacus* publication of May 27, 2002, cited $86 billion of planned industry spending and forecast as much as 4 mmbd from Alberta oil sands by 2010. It remains to be seen how much Canada's ratification of the Kyoto Protocol will dampen investor enthusiasm.

Could Canada some day be as dominant in continental oil as the United States is in coal? Is "energy independence" a prospect on a North American basis? The NAEWG document reaffirms that we are essentially independent as a continent now in gas, coal, and electricity. But the problem is still *oil*!

"Energy Picture" never touches this politically sensitive matter; but (as is frequently the case) a determined reader can pull together supply and demand figures from different sections of the report. They indicate that continental oil independence is certainly *not* realistic within this decade or probably the next, or the one after that. In fact, if the projected shortfalls between oil production and oil consumption for all three countries are combined, the total rises – from 8.7 mmbd in 2000 to 11.1 mmbd by 2010.

The situation with natural gas is less clear in "Energy Picture" – which oddly omits any demand projections at all for that fuel. The overall outlook is bright if one accepts EIA's reference case projection of 33.9 tcf in annual North American consumption by 2010.[15] But there are grounds for caution: 1) "Energy Picture" projects U.S. gas production as rising between 18.6 and 23.7 percent over 10 years – which will take lots of capital investment, despite today's risk-averse atmosphere. 2) Canada's gas production (and exports) are seen growing at almost the same speed. Yet this assumes that the scattered recent cries for "Canada First" in energy supply won't be allowed to violate the "proportionality" pledge of the Canada-U.S. Free Trade Agreement. 3) Mexico's official projection in the trilateral document (nearly doubling by 2010, to 3.2 tcf)[16] surely reflects the confidence of President Vicente Fox that foreign multi-service contracts for the development of Mexico's Burgos Basin will be approved by the national legislature and upheld by the Supreme Court.[17] Neither is a certainty.

Statistics in this report reveal (but don't draw attention to) the significant disparity among the three countries in both generation capacity and electricity production. The U.S. figures are almost 7 times as large as Canada's and more than 20 times those in Mexico. Perhaps the "Energy Picture" should also have explained that power generation consumes more than one-third of all primary energy expended on the continent. Because of U.S. predominance in the combined statistics, more than 45 percent of all North American electricity is coal-based – although, relatively speaking, Canada's smaller output depends even *more* heavily on hydroelectricity.

Mexico's government monopoly in electricity has been shifting from heavy oil to natural gas, for environmental and other reasons – both through unit conversions and the addition of capacity (largely via private investment and long-term supply contracts, rather than direct government construction). The report fails to note this . . . or a similar trend toward gas-fired generation in the United States. It does mention in another section Canada's "plans to expand hydropower generation in Quebec and Newfoundland"; but it says nothing about plans in the province of Alberta to increase its coal capacity by 30 percent (implying more coal generation). Ontario is Canada's other largest coal-burning province; and it has announced a goal of switching from coal to natural gas at some plants, although the commitment is somewhat vague and no switching has yet taken place at its largest coal plant (Nanticoke).

Early last year, Mexico's Under Secretary of Energy for Policy and Technology predicted that Mexican requirements for natural gas would grow at an annual rate of more than 8 percent for the next decade . . . and that domestic gas production would supply only 80 percent of this requirement by 2010.[18] This sets the stage for more new pipelines, tech transfer, and additional investment. It might even encourage agreement among Mexican legislators about the advantages to their own country of certain energy reforms.

The lack of any reference in "Energy Picture" to the environmental effects of energy production and use is understandable, since it was undoubtedly a challenge to win trilateral acceptance of the "hard" data that *are* included. Nevertheless, planners and analysts ought to complement this basic document on their own. Water use is endemic to oil sand development. Land rights play a role in most regulatory hearings. Emissions are a factor that must be considered in every form of fossil-fueled generation, as well as transportation.

Some useful data on energy and environment have been developed by the trilateral Commission for Environmental Cooperation, which was established in a side agreement to NAFTA. By painstakingly analyzing each generating location in North America, the Secretariat of the CEC managed to draw credible comparisons among Canada, Mexico and the United States in plant emissions for a single year (1998); and these add a thought-provoking dimension to "the Energy Picture". They showed Mexico's electricity sector at that time[19] releasing nearly as much NO_x, CO_2 and mercury as Canada – and more than two and one-half times as much SO_2 – despite the fact that Canada produced three times as much power as Mexico.[20] This year, Environment Canada has announced it will begin to publish up-to-date records of emissions of SO_x and NO_x by individual plants,[21] and this will undoubtedly facilitate such "scorekeeping" in the future.

As noted earlier, Canada depends largely on large-scale hydroelectricity (which may have other environmental drawbacks, but emits no pollutants), while boiler plants (many using high-sulfur, heavy domestic oil) predominated in Mexico up to the late 1990s. Of course, emissions from U.S. units dwarfed both those countries because their electricity production is so much greater. Fortunately, the CEC was briefed by the NAEWG last summer; and there is now at least a vague commitment to "pursue . . . efforts in a complementary fashion."[22] There has even been some talk recently of inviting CEC representation at a future NAEWG meeting.

For all the publicity accorded to wind, solar, and biomass energy, non-hydro renewables have played a minor role in North American energy balances; and they aren't projected to do much more between now and 2010. Even if the U.S. Congress passes a Renewable Portfolio Standard with a target-date of 2020, the nearer-term effects would probably be modest. On the other hand, much might be said for an all-out effort in tech transfer to develop "appropriate technology" in Mexico – which would have spinoff value for all three NAFTA partners.

Taken together, the sections of "Energy Picture" devoted to "Infrastructure" and "Legal and Policy Frameworks" provide a quick survey of where the continental market stands, where it might head, and some of the barriers that remain. For instance, "North America's oil industry operates within an array of different national, state and provincial laws."[23] The same could be said about natural gas, electricity, and even renewable energy. If anything, the influence of public utility commissions and other *sub*-national bodies over the production, delivery, and use of energy in this country is somewhat underplayed in this document. But it does show that Canadian provinces have even *more* say about how energy is to be produced and consumed than U.S. states – which, in turn, are far more powerful in this respect than the states of Mexico.

Originally, the major moves toward North American energy integration came through *private-sector* initiatives – although they had to be facilitated by government. There has never been a "master plan", and none was needed for relatively free market forces to begin to work. That's good, because a fully homogenized approach may never be feasible politically. Pemex is not going to be privatized, the Canadian provinces will continue to buck Ottawa in energy matters, and U.S. Governors and Senators are not likely to surrender their very real influence on national energy policy. Still, the North American energy market as it stands now is living proof that mutual benefits can come from a thoughtfully cooperative approach.

BUT there have also been *problems*, especially over the past couple of years, as hinted above: 1) the California energy debacle (which splintered public faith across all three countries in market pricing), 2) the disintegration of Enron (which disgraced electronic trading in the eyes of many), 3) the serious economic troubles of the "new" merchant energy enterprises that had blossomed (which forced them to shed complementary assets and closed the window on badly needed risk capital); 4) the new threats of terrorism and war (which diverted the attention of both the public *and* private sectors from this experiment in regional cooperation), and, finally, 5) the legislative logjams in all three countries in respect to "logical next steps" to strengthen and expand the market.

These aren't the only problems either; yet the fact that the giant North American energy market has been treading water for the past couple of years instead of displaying as much fresh expansion as it did earlier does not mean that gas pipelines and power lines built and undertaken prior to 2000-2001 are going to be abandoned and overgrown. The NAEWG's willingness to show initiative instead of bureaucratic torpor is a welcome sign of renewed life . . . in that the three governments themselves are now treating the vision of trilateral energy cooperation as real rather than rhetorical.

Oil trade among the three NAFTA neighbors grabs most of the headlines – particularly during periods of unrest in the Middle East and Venezuela; and that is largely one-way, in the direction of the United States. But well over $20 billion a year of North American energy trade is commerce in natural gas and electricity, moving back and forth. In fact, it has been the *convergence* of the gas and electricity industries that always offered the most potential for future growth. This has been augmented . . . 1) by electronic trading, 2) by treatment of both electricity and gas as *commodities* under NAFTA and in the derivatives market, and 3) by a general move in all three countries toward market pricing and the "unbundling" of production, delivery, and end-use distribution. The unsettling retreats on some fronts have been cause for concern; but this should only heighten interest in two plenary sessions at our October North American Conference. One is entitled "Continental Trade and Transportation: Forward or Reverse?" A second will address the question "Gas and Power – Convergence or Divergence?"

The NAEWG mechanism is far from perfect. It is probably still too much of an inward-looking body in each country, although there are increasing contacts with governors, the private sector, and even the numerous departments and agencies at the federal levels that are concerned with energy policy. U.S. representation on the NAEWG may be strengthened especially by signs of closer liaison between DOE and higher echelons of the State Department[24]. It would also be immensely helpful, of course, if active cooperation developed between the NAEWG and the Council for Environmental Cooperation; but that may not be in the cards. Apart from disagreements over "turf", the two bodies are at different hierarchical levels.

Furthermore, a *trilateral* approach is not always the most appropriate one. For example, Mexico will have to work out *its own* way to encourage more investment where needed – whether by reforms in the fiscal condition of Pemex and its national electricity entity, implementation of contractual devices that can attract private risk capital, or both. The U.S. Congress must be more serious and imaginative in drafting comprehensive new energy legislation. Canada will have to wrestle *by itself* (I almost wrote "*with* itself") over how it can address the commitments Prime Minister Chretién has made through ratification of the Kyoto Protocol.

Governmental action (joint *or* unilateral) is only part of the unfolding story. Resumption of rapid progress in successful energy interdependency depends largely on strong economic recovery. Yet the new form of focused governmental cooperation in a traditionally sensitive area through the mechanism of the NAEWG can accomplish a great deal – say, over the next 8 to 10 years. Ultimately, this serves basic energy policy goals of all three countries – more reliable, efficient, affordable, environmentally acceptable means of producing, delivering and applying energy in all forms.

Footnotes

[1] This article is an update and extension of a paper presented by the author at the 2002 IAEE North American Conference in Vancouver. He welcomes comment at dukert@erols.com.

[2] *North America – The Energy Picture*, prepared by the North American Energy Working Group, June 2002. A limited number of printed copies of the trilateral document have been issued; but it was made available quickly on the internet at http://www.nrcan.gc/es/energypicture/index.html and later at http://www.eia.doe.gov/emeu/northamerica. The document index at the Mexican Energy Ministry's site is at http://www.energia.gob.mx/sener/docs. Some discrepancies that appeared in the printed version have been corrected on the Internet. In the rest of this paper, the document will be cited simply as "Energy Picture" – with pagination based on the printed version.

[3] NAEWG derives *some* bureaucratic clout within the three countries from the fact that each of the national units is acting under presidential or prime ministerial directive.

[4] North American Energy Working Group, "North America: Regulation of International Electricity Trade", December 2002.

[5] North American Energy Working Group, "North American Energy Efficiency Standards and Labeling", January 2003.

[6] Thanks to a relatively new agreement among three longstanding organizations (the Western Governors Association, the Western Premiers Conference, and the U.S.-Mexican Border Governors), a forum now exists for discussion of trans-border energy issues that can involve simultaneously the Governors of 16 U.S. mainland States, seven Canadian provincial Premiers, and the Governors of all six northern Mexican border states.

[7] Data from EIA's "Country Analysis Briefs" for the respective countries: Canada, February 2002; Mexico January 2002; United States May 2002. These useful documents are revised periodically and are available on the Internet at http://www.eia.doe.gov

[8] Statistics calculated by the author from various sections of the U.S. Energy Information Administration's *Monthly Energy Review*, January 2003.

[9] Data drawn from Tables E2. E3, E4 and E5 of Energy Information Administration, U.S. Department of Energy, *International Energy Annual 2000*, Washington, May 2002 . For a variety of reasons, the numbers do not add up to the totals given in Table E1 for the three countries: Canada 13.07 quads; Mexico 6.18 quads; U.S. 98.79 quads. Nevertheless, the comparisons by energy source are valid and illustrative of differences in both consumption volume and energy mix.

[10] Estimates by the author, based on latest data available from the U.S. Energy Information Administration by this article's deadline.

[11] California's electricity crisis in 2001 produced an exception, when new generation coming onstream in Alberta was used to boost exports dramatically. Alberta itself has no direct links with the United States for wholesale power transfers, but it gains access to buy or sell via interties with British Columbia and Saskatchewan.

[12] A good, thorough source of reasonably current information on bilateral electricity trade is the National Energy Board in Calgary. Its *Canadian Electricity: Exports and Imports – An Energy Market Assessment* appeared in January 2003 with firm figures through 2001 and estimates for all of 2002. Minor differences between it and the statistics published by U.S. DOE's Fossil Energy section are explained by the fact that the former is based on monthly metered flow while the other relies on scheduled transactions.

[13] *Energy Picture*, p. 7.

[14] For more detail, see National Energy Board (Calgary), *Canada's Oil Sands: A Supply and Market Outlook to 2015*, October 2000. Also, updated information on Canadian oil and gas supplies can be found at http://www.capp.ca

[15] Energy Information Administration, U.S. Department of Energy, *International Energy Outlook 2002*, March 2002, Table A-5.

[16] *Energy Picture*, p. 10.

[17] It is worth noting that *Prospectiva del Mercado de gas natural 2001-2010*, also published by the Mexican Energy Secretariat in 2001, included a projection for 2010 on p. 64 of less than 2.8 tcf.

[18] Dr. Francisco Barnés de Castro, "Mexico's Electric Industry", Siemens-Westinghouse Conference, Mexico City, February 18, 2002.

[19] Mexico's ratio of emissions to generation has almost certainly declined, thanks to conversions of old oil-burning plants to gas and the rapid augmentation of its capacity by many modern combined-cycle, gas-fueled units.

[20] Commission for Environmental Cooperation, *Environmental Challenges and Opportunities of the Evolving North American Electricity Market (Secretariat Report to Council under Article 13 of the North American Agreement on Environmental Cooperation)*, June 2002, p. 6. The entire report is available at www.cec.org

[21] Private communication, July 9, 2002.

[22] *Final Communique, Ninth Regular Session of the CEC Council*, Ottawa, 19 June 2002.

[23] *Energy Picture*, p. 17.

[24] The *National Energy Policy* report from the interagency task group headed by Vice President Cheney recommended that the Secretaries of State, Commerce and Energy be directed "to engage in a dialogue through the North American Energy Working Group to develop closer energy integration among Canada, Mexico, and the United States and identify areas of cooperation fully consistent with the countries' respective sovereignties." (p. 8-9).

Hubbert's Peak

Deja vu All Over Again

*By John Ryan**

A recent article in a popular periodical predicts that "… somewhere between two and six years from now, worldwide oil production will peak. After that chronic shortages will become a way of life."[1] This article is based on an interview with Kenneth Deffeyes and relies on his work, *Hubbert's Peak.*[2]

Sooner or later Deffeyes' apocalyptic vision must come to pass, but must it come so soon? After all, the savants have been making this dire prediction since the virtual dawn of the industry. For example, around 1910 the U.S. Geological Survey warned that the nation was running out of crude oil and that it should be conserved for its superior uses in illumination and lubrication. About 1920 a learned Michigan State professor argued that the roadside would soon be littered with abandoned automobiles for which their former owners could no longer obtain fuel. And, more recently, a geologist formerly associated with Shell Oil, Dr. M. King Hubbert, wrote in a study for the National Academy of Sciences in 1963, that the lower forty-eight states had passed their period of peak discoveries and that production must inevitably follow this decline in discoveries in about ten years. He further forecast that the maximum cumulative production from these states could not exceed about 170 billion barrels.[3] Now, using the Hubbert methodology, Deffeyes extends this prediction to the entire world to reach his forecast of impending world-wide scarcity.

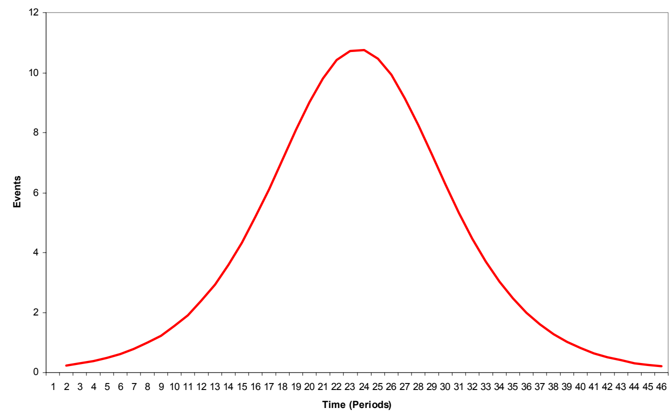
Can the experts have finally gotten it right this time? To answer this question it is helpful to consider the methodology employed, the underlying assumptions of the analysis and, of most importance, how the earlier Hubbert predictions have fared in the almost forty years of history that we now have.

Before discussing methodology, however, a brief digression is in order. Neither Hubbert or Deffeyes allows for the possibility that a rise in the relative price of crude oil could result if the supply should actually become markedly scarcer and that this increase might have a significant impact on the total volume of crude oil that would be ultimately produced. Most economists, I think, would disagree with this implicit assumption. On the other hand, Deffeyes' explicit assumption that nothing much – in the absence of some catastrophic event – can have a significant affect on the supply of crude oil during the next ten years or so would probably meet with general agreement.

The basic methodology employed by both Hubbert and Deffeyes has been around for over 150 years, has been primarily used for characterizing growth patterns and was employed in its early days for describing the life cycle of Drosophila, or fruit fly. Hubbert implicitly analogizes the life cycle of a barrel of oil to that of Drosophila.

In laboratory experiments in the mid-nineteenth century a limited number of fruit flies were introduced into a bottle containing a precise amount of food. Neither the dimensions of the container nor the amount of the food supply was allowed to change during the course of the experiment. Observations were made over various time periods of the composition of the fly population – living or dead – in order to establish some sort of life cycle. The biostatisticians assumed that the initial fruit flies would breed rapidly since there would be no constraints on their growth. But, as the bottle became more crowded and food supply was slowly depleted, the rate of reproduction would taper off. Gradually, the rate at which new fruit flies hatched out would equal the mortality rate of the live flies and the number of living flies would reach a peak. The process at that point would gradually reverse with flies dying off more rapidly than they hatched. This process would accelerate until the last fly died and life would come to a halt in the bottle.

Figure 1
Events per Period



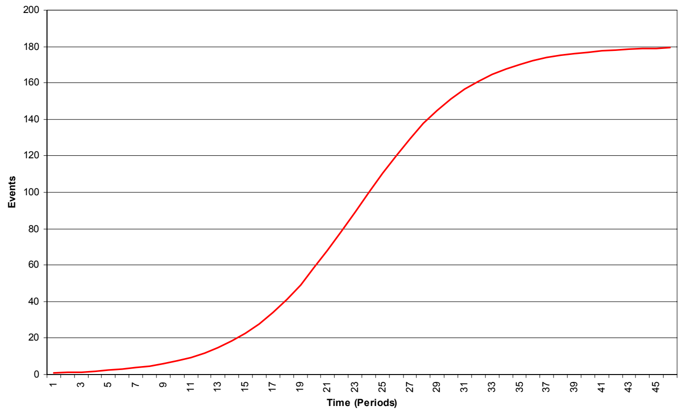
The biostatisticians constructed a simple mathematical relationship which described such a life cycle and observed that it gave a very good description of the course which life actually took in the bottles. The rate at which the flies were hatching out followed a bell shaped curve such as that illustrated in Figure 1. The equation which generated this curve was called the logistic equation (from the French word for domicile – in this case the bottle – and not from the Latin word for logical, as one might have assumed). This curve has the important property that it is perfectly symmetrical about its peak which occurs at the mid-point of the experiment. And, since the area under the curve represents the cumulative number of fruit flies which have hatched, symmetry implies an equal number hatching both before and after the mid-point. This characteristic of the logistic equation was to be of critical importance to the analyses of both Hubbert and Deffeyes.

It also proved useful to determine the cumulative number of fruit flies – living or dead – that had ever lived in the bottle at each period in time, i.e., the area under the bell curve at each point in time. This curve is an elongated S-shaped curve. (See Figure 2 for an example of such a curve.) It, like the bell curve, starts out increasing rapidly as it moves to the right. At the precise time that the bell curve begins to decline, the *growth rate* of the S-curve begins to taper off and the curve gradually flattens out until it reaches its ultimate limit; at that point life has ceased to exist in the jar. There is now a reverse sort of symmetry in that the right hand half of the curve is a reverse mirror image of the left. The number of flies which had hatched up to this halfway point was equal to the number which were to hatch out afterwards.

* John Ryan was an executive with Exxon Corporation. He has been retired for about ten years.

[1] See footnotes at end of text.

Figure 2
Cumulative Events



Demographers became enamored of this particular equation and soon attempted to apply it to human populations, but with less than indifferent results.[4] For a given geographical area, they would fit a logistic equation to that area's birth data. Then they projected mortality with an identical logistic curve displaced into the future by the average life expectancy. The difference between these two curves was an estimate of the living population of that area at that time.

In 1910, this logistic method projected a U.S. population of about 180 million in 2000 and an absolute maximum of 200 million. But, the actual population came in at over 280 million in the year 2000, more than fifty percent higher than the logistic had predicted and well over the absolute maximum. It is still growing.

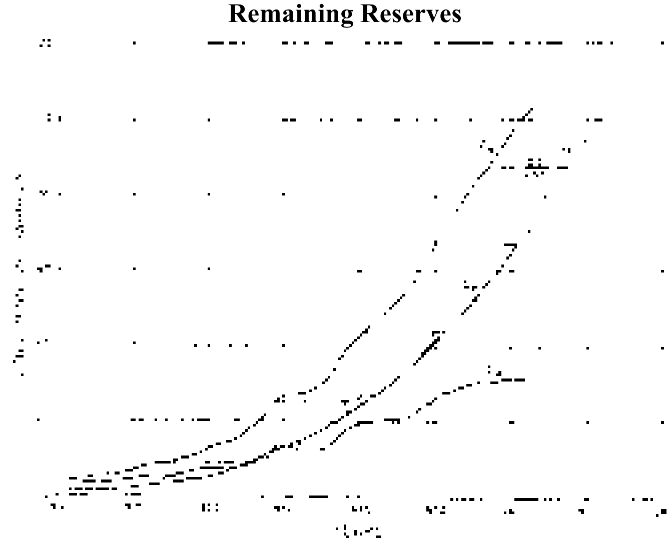
The flies behaved almost exactly as expected, so what went wrong with the human "experiments"? The simple answer is that the flies were living and dying under strictly controlled laboratory conditions and the humans were not. The human populations were not confined in a bottle, but were free to move in and out of their "domicile" in response to changing conditions. Furthermore, humans did what humans do: they imported food when it ran short (if they could), they applied more fertilizers to their crops, they invented vaccines to cure heinous diseases and, in short, they did everything in their power to improve and to lengthen life. Birth rates increased, mortality rates declined and people lived longer, on average, and some people migrated in or out.

The result was to destroy the symmetry of the growth pattern. As people lived longer, and the area experienced net in-migration, the right hand portion of the bell curve rose, the population grew at an even faster rate and earlier forecasts were increasingly short of the mark. In other words, the population became "skewed to the right" (a statistician would say that the mean exceeded the mode). The converse would also be true, of course. The skewed curves were no longer symmetrical and it is was no longer true that there was an equal number of events on both sides of the peak. And the elongated S-curve of the actual events grew ever greater than had been predicted by the logistic model.

Turning from fruit flies and people to barrels, Hubbert substitutes a barrel of new crude oil discoveries for the birth of a human or the hatching of a fly. He substitutes the production of a barrel of crude oil for the death of a fly or human. After that switch, the analysis is the same. Hubbert assumes that the curve of annual new crude oil discoveries rises to a peak (as, indeed, it must at least once) and then declines to zero. He observes further that the curve of annual crude oil production has a similar shape and that historically it lags discoveries by about 10.5 years.[5] These assumptions are entirely consistent with the available data and the fact that the oil obviously must be found before it can be produced. Then, in order to make his forecast of future discoveries and production in the U.S. lower forty-eight states, he fits the logistic equation to the historical discovery and production data (as the biostatisticians and demographers had done with birth and death data in earlier years) and projects these two curves into the future.

In Figure 3, Hubbert subtracts actual cumulative production (Q_P) from actual cumulative discoveries (Q_D) to obtain the reserves remaining to be produced (Q_R) in the same way that the demographers predicted the living population earlier by subtracting cumulative deaths from cumulative births.[6] He notes that this measure – remaining proved reserves — has a slight "dip" about 1960 and that it "clearly" reached its peak about the end of that year. (Similar conclusions from Figure 3 could have been reached from the "dips' in 1958 and 1932 and, perhaps, from the "semi-dips" occurring in 1922 and 1941. With the passage of time, it has become obvious, however, that these "dips" and "semi-dips" were mere perturbations, what the information theorists refer to as "noise" rather than "signal." It would have been amusing – though not particularly instructive – to have projected ultimate recoveries in 1932 using the logistic method and the data that were then available.)

Figure 3
Cumulative Production and Discoveries
Remaining Reserves



If the peak in remaining reserves occurred about 1960, and if the curves were symmetrical and if the cumulative production curve lagged the cumulative discovery curve by 10.5 years, then the peak of discoveries occurred around 1955 with the peak of production 10.5 years later. For technical reasons, that had little to do with his logistic equation, Hubbert chose 1957 as the peak year for U.S. discoveries (ex Alaska) and, therefore, has production peaking out some time in the late1960s. This forecast of the peak year of production in the lower 48 states was really quite good as the actual peak occurred in 1970. At the time of this presumed peak in the annual discovery rate (1957), about 82-85 billion barrels of crude oil had been discovered in total. "*By assuming that this is near the half way point,* ultimate discoveries … would be about 164-170 billion barrels [emphasis supplied]." [7] This was Hubbert's estimate of the maximum volume of crude oil that could be recovered from the lower forty-eight states. It was this critical assumption — that the lower forty-eight had produced half of its ultimate potential when annual discoveries reached their peak — that led Dr. Hubbert astray.

There were two important factors working against Hubbert's assumption of symmetry in the producing curve. The first is that those responsible for estimating new reserves are inclined to be highly conservative in their initial estimates. They base their estimates on then current knowledge of geology and the existing technology, not some extrapolations into the unknown future or guesses of what reserves lie in as yet unexplored sediments. One reason for this is that such estimates are used in planning investments in development and related downstream facilities. A deliberate decision to be conservative can generally be rectified at some relatively modest cost, if subsequent events warrant, but excessive investments would have to be largely written off. This fact tends to impart a conservative bias to early reserve estimates. Then, as subsequent producing history confirms deposits greater than initially supposed, these early estimates are revised upwards. (Downward revisions are made as well, but the preponderance is upward.) Subsequent production levels are, therefore, greater than could have been expected from the initial reserve estimates. The result is equivalent to an increase in the life expectancy on a population forecast. It is impossible to quantify this inherent bias toward early underestimation, but the effects in the case of the petroleum industry can be observed.

Of more importance, perhaps, is the fact that there have been dramatic improvements in oil recovery techniques and in our ability to extract the oil from the porous rocks in which it is trapped. The "rocking horse head" pumps which dot the landscape in the U.S. Southwest, California, Southern Illinois and elsewhere are a tribute to man's effort to pump more oil out of the ground and into the right-hand tails of the bell curves and to postpone indefinitely the time at which the tails actually fall to zero.

The effects of these "stripper wells" is insignificant, however, compared to the results of more recent enhanced oil recovery developments. Principles of chemistry and physics and improved understanding of geology and oil reservoir mechanics have been used to improve recovery rates from older reservoirs, both here and abroad, and hence to increase substantially ultimate recoveries. Today, the so-called giant fields, from which much of our production comes, seem to be like old soldiers; they never die, they only fade away. The Bradford field in Pennsylvania, for example, one of our domestic giants, was discovered in 1871 and is still producing.

Figures 1 and 2 illustrate hypothetical annual and cumulative production curves as Hubbert (and Deffeyes) assumed them to be. In theory, as our knowledge of the volume of oil originally in place increases and our technology for extracting it improves, the production curves should become skewed to the right as we are able to extract more oil than we first thought possible. The upper limit in Fig. 2 simply ceases to exist and the production curve moves ever higher. The grand cosmological constant which Hubbert sought – the ultimate amount of crude oil to be produced – becomes a moving target depending on the technology that is available at the time of the estimate. But, Hubbert simply assumed the problem of improving technology away.

On the other hand, Deffeyes recognizes part of the problem with improving technology and attempts to address it. He assumes that the explorationists first picked off the easier to find fields nearer the surface. Then, gradually improving exploration technology led to substantially larger discoveries during the fifties and sixties when the geologists found many of the larger, deeper reserves such as the North Sea, the Bass Strait and Saudi Arabia. As the century draws to a close, he argues, the pace of discovery accelerates, but the finds are smaller and the curve begins to flatten out.[8]

This observation is not entirely consistent with the history of the discovery of large crude oil fields. For example, the largest field in the lower forty-eight, the East Texas field, was discovered in 1930; the largest field in North America, Prudhoe Bay, was found in 1967. The largest known oil field in the world (up to now) is Ghawar in Saudi Arabia. Its discovery well was completed in 1938, but its official discovery date is ten years later in 1948. Burgan was found in Kuwait in 1938, Ebano-Panuco in Mexico 1901, Bibi Eybat in Russia in 1850, Coalinga in California in 1887 and Carito in Venezuela in 1917. This handful of examples doesn't prove anything, but it does suggest that Deffeyes' generalization may, perhaps, be overly broad.

What is more important, however, is that Deffeyes does not allow for the fact that improvements in recovery factors simply means that more oil than was originally anticipated will be found and that it will be produced in later rather the than earlier years in the life of a given field. Furthermore, improvements in recovery factors in existing fields cannot be introduced on a massive scale overnight; the lag between the discovery of a new technology and its application can be a matter of years. Thus, even if no more improvements in extraction technology were to take place, we would still expect there to be higher production in some older fields than we predict today and that the estimates of reserves in those fields would be revised upwards in the future.

In sum, we should expect that the more recent discoveries would appear to be getting smaller and should not be unduly alarmed. If history is a reliable guide, the shortages looming around the corner will probably be displaced until some time in the more distant future. And we should also recognize that the producing patterns of individual fields — and, hence, of the universe of all fields — will also probably tend to be skewed to the right and asymmetrical.

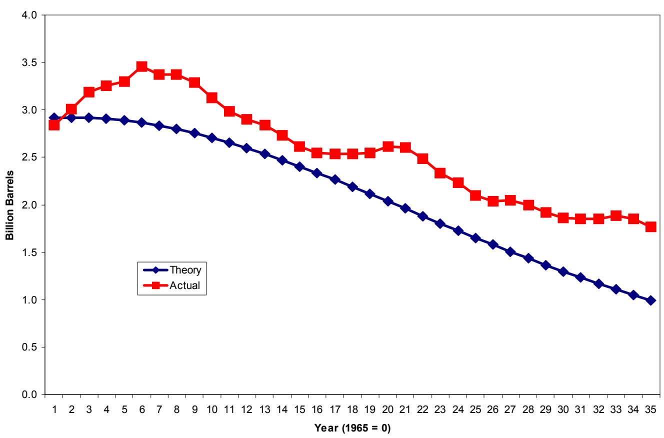
Despite misgivings about the underpinnings of the Hubbert and Deffeyes approach, it may still yield acceptable results. Accordingly, Hubbert's 1965 projections have been tested against the actual historical data. The available discovery rate figures are wildly erratic, but Hubbert's logistic equation for discoveries seems to be fairly representative of the history at the time of his forecast.[9] The production rate data are more well-behaved and seem to follow the logistic rather well except for the 1920s. Hubbert does not show his estimates of future (post-1965) discoveries and production, but merely states that the cumulative discovery curve will eventually level out at about 170 billion barrels.

I have calculated the projected values of the logistics curve after 1965 using the parameters of Hubbert's 1965 equation. The numbers do indeed rise slowly and approach

Hubbert's upper limit of 170 billion as expected. However, these forecast data fall considerably short of reality according to the Department of Energy figures.

Starting in 1968, three years after Hubbert made his forecast, a gap between Hubbert's estimated production levels and actual production began to emerge. By 2000, the total number of barrels of crude oil that had been extracted in the lower forty-eight states exceeded the maximum possible level of 170 billion barrels which Hubbert had predicted. According to his forecast, given actual rates of crude oil production since 1965, the last producing oil well in the lower forty-eight states should literally have run dry some time during the year 2000. Yet the producing industry was still healthy at that time; production in the lower forty-eight states was about five million barrels a day and over seventeen billion barrels of proved reserves remained to be extracted at year's end. Much of the nation's sediments were still unexplored, including some of the nation's most prospective remaining geological provinces which had been declared "off limits" for environmental considerations. They remain largely unexplored today.

Figure 4
U.S. Annual Crude Oil Production



(Actually, if the nation's reservoirs had been approaching a state of exhaustion, it would have been virtually impossible to have achieved the rates of production that were observed. This is just another way of saying that Hubbert's theory is inconsistent with reality.)

In Figure 4 it becomes clear why the Hubbert estimate fell so far short of the mark: the actual curve of production was strongly skewed. Production in the U.S. lower forty-eight states did not decline in the perfectly symmetrical pattern that Hubbert had predicted, i.e. the curve marked "Theory" in Figure 4. Instead, the production profile peaked somewhat later than had been predicted and was skewed markedly to the right. In every year but one after 1965, actual production exceeded the logistic forecast and by far more than insignificant volumes. Furthermore, the excess of actual over forecast was growing modestly over time. By 2000, the excess of actual over forecast amounted to sixteen billion barrels or more than eight years of production at the then current rate.

The Guterl article states, "Nowhere is it written that the oil supply must adhere to a [symmetrical] bell curve. The problem is that Deffeyes sees no reason that it won't."[10] But, if the fact that the curve has not followed such a pattern over the past forty years is not a sufficient reason to think that it may not in the future, one would be hard pressed to find a reason that is sufficient.

Another major problem with Hubbert's analysis is that it excluded Alaska. It is understandable why Hubbert omitted Alaska in his calculations; production had only recently begun, it amounted to only 30,000 barrels a day in 1965 and the potential was a huge question mark. It makes a least as much sense, however, to extend

Hubbert's analysis to the entire continental United States as it does to extend it to the entire world as Deffeyes does. But including Alaska in the analysis further undermines any support for the assumption that the peak of production occurs at the halfway point in the producing life of an area. Since 1965, production in Alaska has added over fourteen billion barrels to the cumulative total, there are now almost five billion more barrels remaining in the ground in Alaska in the form of proved reserves and there is a large volume of highly prospective, but unexplored, sediments. As a result, the skewness of the total U.S. producing curve is greater than that of the lower forty-eight states and will probably grow more so over time. Furthermore, the curve now sports two virtually identical peaks, one in 1970 and the other in 1985. No vestige of symmetry remains.

Clearly the assumptions of symmetry and halfway points led to substantial error, but these problems were only symptomatic of the fundamental flaw in the analysis: the failure to take into account the inherent bias in early reserve estimates and the effects on such estimates of technological progress. Once laboratory conditions ceased to exist, there was no reason for assuming that the growth process of a controlled environment (which is the basis of the logistic equation) would obtain and that a logistic curve (or any other particular curve, for that matter) would give a reasonable projection of future growth.

The Hubbert/Ryan discussion about domestic crude oil availability in 1965 did not take place in a vacuum. It was part of a national debate on whether or not to impose end-use controls on the consumption of oil and natural gas because of a perception of growing scarcity. Specifically, the primary proposals would have prohibited the use of oil and natural gas for boiler fuel in order to conserve them for their "superior uses."[11] The Hubbert analysis was a major weapon in the arsenal of those supporting such restrictions. But even when the Hubbert analysis was first offered, there were strong reasons for rejecting its conclusions as a basis for policy decisions. With hindsight, we know that the nation was well advised to have done so.

Today Deffeyes is reviving this same argument, on a grander scale, to justify his call for a program of Manhattan Project sized proportions — or even larger — to develop alternative sources of energy to avert the looming energy shortage that he foresees. But the reasons for rejecting his recommendations as a basis for national energy policy today are at least as sound as those for having rejected the Hubbert analysis in the 1960s. Particularly in view of the fact that the world-wide discovery and reserve data, which are the basis for Deffeyes' conclusions, are surrounded by an aura of uncertainty probably of order of magnitude greater than that of comparable measures in the United States.

There may be valid reasons for mounting a crash program to develop alternative energy sources in the United States today. A looming energy shortage is certainly not one of them.

(See footnotes on page 26)

Economics of Hybrid Electric Vehicles

*By Michael E. Canes**

Introduction

Well over 200,000 light duty hybrid electric vehicles (HEVs) have been sold worldwide within the past few years, thousands more per month are being offered, and additional models are on the way. The Toyota Prius, the Honda Insight and a hybrid version of the Honda Civic currently are being offered in the United States, Ford will introduce a hybrid version of its Escape Sport Utility Vehicle (SUV) in 2003, and Daimler-Chrysler a hybrid version of its Dodge Ram truck in 2004. In addition, General Motors and Toyota have announced plans to offer hybrid SUVs within the next few years. Other hybrid models are being sold in Europe and Japan.

Hybrid electric technology has captured policy maker attention because it is a means to conserve on fuel and to reduce emissions. The recently completed Partnership for a New Generation of Vehicles program sponsored by the Clinton Administration focused mostly on this technology to achieve its goals.

Hybrid technology also is being applied to buses and trucks, for the most part in experimental programs designed to learn more about operating and emission characteristics as well as economics. In addition, the military services are looking closely at hybrid technology as a means to curb logistics needs.

In this paper I will examine the economics of hybrid electric vehicles in civilian and military use. The analysis will examine the private return to a hybrid owner as well as the social return, which includes the value of reduced emissions. I also will assess the value to the military, where logistics concerns predominate.

The paper proceeds as follows. First, I will briefly describe HEV technology. Then, I will use net present value analysis to assess the economics of hybrid technology applied to civilian automobiles and trucks. This analysis will also look at the value of emission reductions for these vehicles. Next, I will assess the value of hybrids to the military. As will be seen, the economics of HEVs for the Armed Services are different from those of civilian vehicles. Finally, I will offer some conclusions.

Hybrid Electric Technology

In the context of motor vehicles, the term "hybrid" refers to two separate sources of power; for example, an internal combustion (IC) engine and an electric motor. There are many forms of hybrids, some of them exotic such as flywheels, fuel cells, or ultracapacitors in combination with an IC engine, but the hybrids here discussed involve an IC engine with an electric motor.

The two basic forms of hybrid electric vehicle are series and parallel. In a series hybrid, an IC engine drives a generator, which powers an electric motor. The generator also charges a set of batteries, which can supply power directly to the motor. A propulsion control system determines how much power is supplied by the generator and how much by the batteries. In a series hybrid, only the electric motor propels the vehicle. This technology is used in trains and diesel-electric submarines and also in large on-road vehicles such as buses and trucks.

In a parallel hybrid, either the IC engine or the electric motor can propel the vehicle. It also has batteries and a propulsion control system, with the latter determining how much power is supplied by the IC engine and how much by the electric motor. This type of system generally uses the motor to accelerate the vehicle and the engine to propel it at a steady speed. HEVs such as the Toyota Prius and the Honda Civic use this technology.

Energy storage in hybrids can be supplied by a variety of sources, but batteries are by far the most common. Lead-acid batteries are used in most large vehicles mainly because the technology is well known, they are relatively inexpensive, and recycling facilities are readily available. The drawbacks are that lead-acid batteries are relatively short-lived and heavy.

Small hybrid vehicles, such as the Toyota Prius, use nickel metal hydride (NiMH) batteries, which are more expensive but lighter and longer-lived. Other battery technologies in use include lithium ion and nickel cadmium. Energy storage devices such as ultracapacitors and flywheels also are under development, but these tend to be expensive or have other disadvantages that so far have prevented their practical application.

Hybrid technology also features regenerative braking, under which kinetic energy from the wheels is recaptured and transformed into electrical energy when the vehicle is slowed. The captured electrical energy then can be used to power the vehicle. The regenerative feature of hybrid braking also reduces wear and tear on the friction braking system, thus decreasing its maintenance costs over a vehicle's lifetime.

Economics of Cars & Light Trucks

Using publicly available information on initial costs, fuel savings, and other parameters of HEV automobiles, their economics can be assessed. As a specific example, consider the Toyota Prius. The closest comparable conventionally powered model is the Toyota Echo Sedan. The Prius gets an estimated 48 mpg, the Echo 34 mpg (EPA, 2002). I make the following assumptions:

1. The car is driven 13,000 miles per year and lasts for 12 years
2. The lifetime cost of gasoline is $1.50 per gallon
3. The incremental cost of the Prius relative to the Echo is $3,000[1]
4. The batteries are replaced once, after 8 years, at a cost of $3,000
5. Prius brake wear is less, saving $50 per year.

Under these assumptions, at an 8 percent rate of interest,[2] the net present value (NPV) of savings from driving the Prius over its lifetime, relative to the comparable Echo, is –$2,983. In other words, the fuel savings and reduced brake wear are insufficient to overcome the initial incremental cost plus the one-time battery replacement.

Table 1 shows the effects of different assumptions; for example, that no battery replacement is necessary over the car's lifetime, that the vehicle goes 20,000 miles per year rather than 13,000, that the interest rate is 6 percent, or that the lifetime cost of fuel is $2 per gallon. The results vary with the

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[1] See footnotes at end of text.

assumptions but are always negative, even with no battery replacement. The basic finding is that for this type of vehicle, whose conventional counterpart already gets high gasoline mileage, HEV technology does not provide net monetary savings.[3]

Table 1
Lifetime Net Savings, Prius versus Echo

Assumptions	NPV ($)
Base case	–2,983
No battery replacement	–1,363
20,000 miles per year	–2,305
6 percent rate of interest	–3,061
$2 per gallon cost of gasoline	–2,563

The hybrid Dodge Ram truck is a different kind of vehicle. Given what Daimler-Chrysler has said so far, we can expect an initial incremental cost of $5000, a 15% gain in fuel economy (from 14 mpg to 16 mpg) and a 15 year life. I assume further that there will be one battery replacement in the 8th year costing $3000.

There is an additional feature, however. The Ram hybrid will be capable of providing power off of the vehicle. In other words, it will be a mobile power generator as well as a passenger and cargo vehicle. That feature may have value to building contractors and others who otherwise use standalone generators at remote sites.

Table 2 below shows the results of the net present value analysis.

Table 2
Net Savings, Dodge Ram Truck HEV versus Conventional Model

Assumptions	NPV ($)
Base case	–4,638
30 percent fuel efficiency gain	–3,442
No battery replacement	–3,017
10 percent rate of interest	–4,637
Generator worth $400 per year	407

The fuel and brake wear savings from a Dodge Ram truck do not come close to paying for the vehicle. Even doubling the fuel efficiency gain or assuming no battery replacement does not much improve the economics. Instead, the value of onboard power generation determines whether the vehicle pays for itself. Given the assumptions used in the base case, a flow of services worth $400 per year over 15 years implies a small positive NPV for this vehicle.

These analyses show that HEV technology applied to cars and light trucks is unlikely to save money for the owners. Of course, fuel cost in the United States is lower than elsewhere, and hybrid fuel economy might improve with time. I next look at breakeven values for these parameters.

Breakeven Analysis

Table 3 presents values various parameters would have to reach in order for hybrids to break even in an NPV sense. I include three—the lifetime cost of fuel, number of miles per year, and fuel efficiency gain—and apply the analysis to the two vehicles discussed above. Other than the parameter in question, base case assumptions are used.

Table 3
NPV Breakeven Values

	Per gallon cost ($)	Annual miles	Efficiency gain (%)
Prius	5.05	43,800	nm
Ram	5.97	51,700	108

Note: nm = not meaningful; the gain would have to be such as to make fuel almost irrelevant.

The results indicate that for the Toyota Prius, which already is highly fuel efficient, the cost of gasoline would have to be $5.05 per gallon or the car driven 43,800 miles annually to break even. This breakeven fuel cost is high even for Europe or Japan, and the mileage much higher than most people drive.

Ram breakeven values are similar to those for the Prius, except that it can reach breakeven at a smaller increment in fuel efficiency. However, as mentioned earlier, the economics of the Ram truck probably will depend more on the value its owners place on onboard power generating capacity than the fuel and maintenance it will save them.

Heavy Duty Trucks

Though a variety of applications of HEV technology seem appealing for medium and heavy duty trucks and buses, there are few on the market. Garbage trucks, delivery vans and buses incur frequent starts and stops and so appear to be potentially promising applications. United Parcel Service and Federal Express are experimenting with prototype delivery van models, but so far have not committed to large-scale purchases. New York City, on the other hand, has been running 10 hybrid buses and has agreed to purchase at least 325 more. It is well in front of other U.S. jurisdictions in so doing.

One reason may be the still-high cost of hybrid buses and large trucks. There is little published information available, but British Aerospace Engineering, which is producing the buses for New York City, has indicated the incremental charge for the hybrid is $100,000. Separately, General Motors has indicated the per vehicle incremental cost of a Class 8 (large) hybrid truck will be at least $70,000 for some years to come.[4] For present purposes, I assume a $70,000 incremental cost and one battery replacement after 8 years at $10,000.

To see how these costs compare with potential savings, I examine data for a class of large U.S. Postal Service trucks. In 2001, a Postal Service 1997 Mack Truck averaged 46,933 miles and got 5.2 miles per gallon. Assuming a 15-year life, an 8% rate of interest, annual brake maintenance savings of $654[5] and alternative fuel costs and fuel economy gains, the table below shows the potential savings from a hybrid version.

Table 4
NPV of Savings, Large Postal Truck, Hybrid v. Conventional

Assumptions	NPV ($)
Base case[a]	-$36,690
50 percent fuel efficiency gain	-$31,172
$2.00/gallon cost of fuel	-$25,654
6 percent rate of interest	-$32,348

[a] $1.50/gallon fuel cost, 40% efficiency gain

Depending on assumptions, the net savings range between -$25,000 and -$37,000. Commercial entities will require lower upfront and operating costs to purchase large hybrid trucks.

Social Benefits from Emission Reductions

Hybrids offer social value from air emission reductions, which occur because fewer gallons of fuel are combusted per mile traveled. Arguably, additional social benefits are gained from reducing dependence on oil imports, but this concept is controversial and difficult to quantify and, therefore, is not pursued here.

Several emissions contribute to the formation of smog in urban areas. These are primarily hydrocarbons (HCs), nitrogen oxides (NO_x), and carbon monoxide (CO). Other important emissions include particulates that are 10 microns in diameter or less (PM10), sulfur oxides (SO_x), and carbon dioxide (CO_2). Particulates are associated with various lung disorders, including asthma, sulfur dioxide (SO_2) with acid rain, and CO_2 with global climate change.

The U.S. Environmental Protection Agency (EPA) and Department of Energy have published emissions data for conventional automobiles and trucks. These data can be used to estimate the emissions from conventionally powered vehicles, and gains in fuel efficiency then used to roughly estimate the potential reduction from hybrids.[6] For present purposes, I assume a proportionate reduction in emissions from hybrid fuel use reduction.

To illustrate how much hybrids can reduce emissions and estimate a social value of such reductions, three different types of vehicles are analyzed: an automobile, a light duty truck, and a heavy duty truck. In each case, I calculate the reductions in the six emission categories described above. For these purposes, I assume that the hybrid auto and light truck travel 13,000 miles per year while the heavy duty truck travels 47,000 miles, and that all of the vehicles are 40 percent more fuel efficient than their conventionally powered counterparts. Table 5 shows lifetime emission reductions for each class of vehicle under these assumptions.

Table 5
Emission Reductions from Hybrid Vehicles
(tons/service life)

	Auto	LD truck	HD truck
HC	0.073	0.074	0.372
NO_x	0.059	0.060	1.153
CO	0.994	1.007	7.790
CO_2	15.854	21.800	225.600
PM	0.002	0.002	0.134
SO_x	0.002	0.003	0.040

Note: LD = light duty; HD = heavy duty

The social value of most of these reductions depends on what value a particular community puts on them and how much it costs to reduce them by other means. In large urban areas, reductions in hydrocarbons and NOx have high value and alternative means of reduction cost many thousands of dollars per ton. In more rural communities, however, the reductions have less value. Finally, since climate change is a worldwide problem, the value of reduced carbon dioxide emissions is independent of location.

The literature on valuing emissions contains a wide range of estimates for the compounds listed above. For present purposes, I use intermediate values (medians of values found in the literature) for each of the six emissions. These range from several thousands of dollars per ton for hydrocarbons, NOx and PM to $50 per ton of CO_2. Table 6 below takes present values of emission reductions for each vehicle type and adds it to the private values for the Prius, Dodge Ram and heavy duty truck shown above.

Table 6
Social Value of Three Types of Vehicles ($)

	Prius	Dodge Ram Truck	Postal Truck
NPV[a]	–2983	–4638	-36,690
Emission reduction value	959	1,068	8,005
Total	–2024	–3570	-28,685

[a]Under base case assumptions.

By these calculations, adding environmental improvement to owner NPV still does not give these hybrids positive social value. However, in some areas environmental improvement is very costly and these costs may rise further as standards are tightened. Thus, while most hybrid vehicles probably are not socially cost effective at this time, there may be exceptions and these may increase with time.[7]

Military Application

The economics of applying hybrid technology to military vehicles are different from those for civilian vehicles. The cost of fuel to the military has two components: the direct cost of purchase and the indirect cost associated with a logistics network set up for delivery wherever an engagement might occur. The direct cost is similar to what a civilian agency or private party would pay. There are economies of scale in military fuel purchase, but by and large its cost is not much different from that of others.

The indirect cost is much the larger portion. It covers the airplanes, ships, fuel trucks, portable pipelines, portable storage tanks and other equipment necessary to move fuel to a theater of operations and distribute it there. This cost also includes fuel logistics personnel at home and on the ground where operations are mounted, with accompanying ancillary services such as cooks, medical aides and chaplains.

Estimates of the cost of fuel to the military vary. A recent Defense Science Board study put the average cost of delivering fuel to the U.S. military at $11 per gallon in 2001 (Defense Science Board, 2001). That study cited an estimate done by the Army Research Laboratory of $13 per gallon, in peacetime and at home. Also, a recent report by the RAND Corporation proposes a range of $5 to $15 per gallon (Bartis and Clancy, 2000). Given these various estimates, I use a base case value of $10 per gallon.

Application to a Military Vehicle

The U.S. Army's principal light duty vehicle is the High Mobility Multipurpose Wheeled Vehicle (HMMWV, popularly known as the "Humvee"). There are about 120,000 of these vehicles, comprising over half of the Army's total number of trucks.

Analysis of the hybrid Humvee requires that certain assumptions be made about the vehicle's cost and other characteristics. According to recent articles in the military trade press (*National Defense*, 2002) the conventional Humvee costs between $57,000 and $68,000 and manufacturers estimate the hybrid version will cost 25 to 40 percent more. For present purposes, I estimate an incremental cost of $20,000.

For the base case, I assume the following:

1. The Humvee has a lifetime of 20 years, and its hybrid version generates up to 33 kW of power to offboard systems (replacing two portable 15 kW generators, at an estimated cost of $10,000 each).[8]
2. The fuel cost to the Army is $10 per gallon.
3. Batteries last for 3 years and have a replacement cost of $3,000.[9]
4. The fuel efficiency gain is 30 percent, the objective of the Army's Humvee program.
5. A conventionally powered Humvee gets 9 mpg[10] and is driven 3,500 miles annually, in peacetime or in the field.[11]
6. The interest rate with which to discount streams of benefits and costs is 6 percent, slightly above the present 20-year Treasury bond rate.

Table 7 below shows NPVs of hybrid technology applied to the Humvee under varying assumptions. In each case, one assumption is varied, as indicated in the table.

Table 7
NPV of Hybrid Humvee Relative to Conventionally Powered

Base Case	$15/ gallon	4-year battery replacement	$2,000/ battery replacement	50% efficiency gain	5,000 miles/ year	7% interest rate
$90	$5,237	$2,312	$3,491	$4,665	$4,502	$121

From Table 7, in the base case, with the upfront incremental costs offset by savings from two fewer generators, the fuel savings just cover the cost of battery replacement. In this case, the lifetime savings from a hybrid version of the Humvee exceed costs by just under $100 per vehicle.

The results are sensitive to the cost of fuel and to battery replacement cost and frequency. At an assumed $15 per gallon for fuel, the NPV of the Humvee hybrid is over $5,200 (whereas at $5 per gallon, it is -$5,056). Alternatively, if battery replacement frequency increases to 4 years the NPV is over $2,300, and if battery replacement costs only $2,000 it reaches almost $3,500.

If Humvee hybrid fuel economy could be increased by 50 percent rather than 30 percent or if the Humvee were driven 5,000 miles per year rather than 3,500, the NPV would be over $4,500. The Army has set 50% as a longer term sought-for economy gain (with 30% the program goal) while trucks are used more intensively if they engage in actual operations. Thus, higher NPVs plausibly could occur. Finally, an increase in the interest rate to 7 percent does not much change the basic result.

The success of a military HEV will depend greatly on the performance of its batteries. To assess the sensitivity of the results to this performance, I conduct a form of breakeven analysis.

Table 8
Humvee Breakeven Combinations of Battery Cost and Replacement Frequency ($10 per gallon cost of fuel)

Replacement Frequency-Years	Replacement Cost Battery
1	$897
2	$1959
3	$3026
4	$4456
5	$5976

Table 8 shows combinations of battery cost and frequency of replacement for the hybrid Humvee that just achieve breakeven. For example, if the replacement frequency is 3 years, then breakeven is achieved at a battery cost of about $3000. Similarly, if the replacement frequency can be extended to four years, NPV breakeven can be achieved at a battery cost of about $4500. And if some other battery technology, perhaps Nickel Metal Hydride, could extend battery life to 5 years, breakeven would be possible at a battery cost of as much as $6000 per replacement. Thus, the military should be willing to pay a premium to extend battery life, but that premium is only about $1000-1500 per year added.

Other Considerations

Hybrid vehicles have other, difficult-to-quantify advantages in military use, e.g., extended range of operation. These provide added reason to consider them. On the other hand, there are disadvantages such as having to dispose of spent batteries, which contain heavy metals and thus can cause environmental damage if left unattended. These considerations go beyond the scope of this paper.

Conclusions

Hybrid electric vehicles offer a proven technology that can reduce motor vehicle fuel use and accompanying emissions. Many vehicle manufacturers are offering these vehicles and they are selling in several countries.

My analysis suggests that buyers of hybrids are unlikely to secure sufficient fuel or maintenance savings to offset the incremental costs of these vehicles. This is so under a wide variety of assumptions regarding enhanced fuel efficiency, annual mileage, fuel cost, and battery replacement cost. The additional costs of a second motor, an energy storage system, and a propulsion control system tend to overwhelm the potential savings.

The analysis also shows that even if the value of emission reductions is factored in, hybrid vehicles generally do not pay for themselves. A possible exception occurs when a vehicle owner highly values onboard power generation. In this case, a hybrid vehicle may have positive economic value to its owner as well as to the community in which it is located.

Of course, people buy vehicles for reasons other than economic return. Some like being among the first to try out a new technology, and others want to reduce emissions and save fuel for their own sake. Tax and other incentives provide additional motivation. Also, communities with high costs of reducing emissions may look seriously at municipal hybrid buses, garbage trucks, and the like to meet federally mandated pollution reduction goals. Thus, I do not suggest there will be no market for hybrids in the United States or elsewhere but conclude that, given present and foreseeable costs of producing hybrid vehicles, the civilian market will be largely based on non-economic factors.

Given the much higher cost of fuel to the military than to civilians, the technology can yield savings in applications such as the Humvee. However, my analysis relies on several uncertain parameter values. More complete analysis of the implicit cost of fuel to the Armed Services and results from hybrid Humvee prototype testing should help resolve these uncertainties and provide a clearer picture of the extent to which the technology is cost effective. Although not enough is known to be confident of the outcome, the analysis suggests that if certain parameter values turn out favorably—such as initial hybrid vehicle cost, battery cost, and battery replacement frequency—the economics will be favorable as well.

Footnotes

[1] This is on the low side. With some of the less expensive Echo models, the difference is closer to $5,000.

[2] This is a rough estimate of the cost of financing a vehicle.

[3] I have also analyzed the economics of the Honda Civic and Ford Escape hybrids as compared to their conventionally powered counterparts. For the Civic, the hybrid is assumed to get 50 mpg, the conventional vehicle 33 mpg. Under base case assumptions, the NPV of savings is -$2225. For the Escape, the hybrid is assumed to get 35 mpg and the conventional vehicle 21 mpg. The economics are slightly better but the NPV of savings still is -$1445 in the base case.

[4] Presentation to the United State Postal Service, Washington DC, January 2002.

[5] Based on U.S. Postal Service data for electric vehicle brake repair costs.

[6] The estimates are rough because EPA standards for most emissions are expressed in terms of grams per mile. Less fuel per mile should result in fewer emissions, but automakers could invest less in hybrid emission controls, resulting in increased grams per gallon, so that grams per mile would not fall proportionately. CO_2 emissions, however, would fall directly with the decrease in fuel utilized.

[7] Various federal and state incentives for hybrids are an indication that they provide social value that exceeds private. The incentives include a federal tax deduction of $2000 and tax credits or deductions in a few states. They also include access to high occupancy vehicle lanes in other states. Such access provides time savings to vehicle owners which, over a vehicle's lifetime, are of considerable value.

[8] A Honda 12 kW portable generator sells for $8,640 (www.Honda.com). Scaling up to 15 kW yields a cost of around $10,300, which I round to $10,000. The actual savings may be greater than $20,000 because an incremental vehicle needed to tow standalone generators possibly can be dispensed with.

[9] The lifespan and cost of batteries depend on the type and the state of battery technology. Lead-acid batteries remain the cheapest, but they are relatively short-lived; Lithium Ion and NiMH last longer but are much more expensive. The hybrid Humvee test program presently is utilizing lead-acid batteries so I assume that is the battery of choice.

[10] Like other vehicles, a Humvee's mileage varies with its driving cycle. In tests using the Federal Urban Driving Standard, the Humvee averaged 9.1 mpg ("Technology Roadmap for the 21st Century Truck Program," p. 4–40, December 2000). I round this to 9.0 mpg.

[11] The U.S. Army has about 238,000 vehicles, which recently accumulated 823 million miles in a single year, an average of about 3,460 miles per vehicle, which I round to 3,500.

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Electricity Generation Cost Simulation Model (GenSim)

*By Thomas E Drennen, Arnold B. Baker and William Kamery**

The Electricity Generation Cost Simulation Model (GenSim) is a user-friendly, high-level dynamic simulation model that calculates electricity production costs for variety of electricity generation technologies, including: pulverized coal, gas combustion turbine, gas combined cycle, nuclear, solar (PV and thermal), and wind. The model allows the user to quickly conduct sensitivity analysis on key variables, including: capital, O&M, and fuel costs; interest rates; construction time; heat rates; and capacity factors. The model also includes consideration of a wide range of externality costs and pollution control options for carbon dioxide, nitrogen oxides, sulfur dioxide, and mercury. Two different data sets are included in the model; one from the U.S. Department of Energy (DOE) and the other from Platt's Research Group. The model seeks to improve understanding of the economic viability of various generating technologies and their emissions trade-offs.

The base case results, using the DOE data, indicate that in the absence of externality costs, or renewable tax credits, pulverized coal and gas combined cycle plants are the least cost alternatives at 4.0 and 3.8 cents/kWhr, respectively. A complete sensitivity analysis on fuel, capital, and construction time shows that these results in coal and gas are much more sensitive to assumption about fuel prices than they are to capital costs or construction times. The results also show that making nuclear competitive with coal or gas requires significant reductions in capital costs, below $1320/kW for coal and $1230/kW for gas.

Model Structure and Assumptions

GenSim calculates projected levelized cost of energy (LCOE)[1] for a wide variety of electricity generation technologies: advanced coal, combined cycle natural gas, natural gas combustion, nuclear, wind, solar thermal, and solar photovoltaic (PV).[2] All values are for new plants, equipped with the best available pollution control technologies (BACT).

GenSim includes two user data sets: Department of Energy, Energy Information Administration (DOE, 2002); and 2) Platt's Research and Consulting Group (Platt's, 2002). Table 1 summarizes the key economic assumptions about each technology for the two data sets.[3] While GenSim defaults to these assumptions, the user can easily vary the assumptions and view the implications for LCOE. For example, the user can easily explore the impacts of extended project construction time on the projected LCOE or test the economic competitiveness of combined cycle plants at higher projected natural gas costs. Table 2 summarizes the performance characteristics for each technology.

LCOE is often used as an economic measure of electricity costs as it allows for comparison of technologies with different capital and operating costs, construction times, and capacity factors. GenSim calculates the LCOE before taxes, as taxes vary across regions and tax status of the producer (public vs. private producer). The LCOE calculation is given by:

Table 1
Cost Estimates for New Generating Plants (2003 $)

	Capital ($/kW)	Fixed O&M ($/kW)	Variable O&M ($/kWhr)	Fuel ($/MBtu)
Nuclear				
DOE	1821	60.84	0.00045	0.43
Platt's[a]	-	-	-	-
Coal				
DOE	1122	25.51	0.00319	1.27
Platt's	1028	18.32	0.00183	0.81
Gas CC				
DOE	586	10.63	0.00212	3.40
Platt's	443	15.27	0.00204	3.31
Gas CT				
DOE	457	8.50	0.00319	3.40
Platt's	347	5.09	0.00046	3.31
Solar PV				
DOE	3526	10.47	0.00000	0.00
Platt's	7185	0.00	0.07839	0.00
Solar Thermal				
DOE	2293	50.88	0.0000	0.00
Platt's	2514	20.36	0.0000	0.00
Wind				
DOE	976	27.15	0.0000	0.00
Platt's	896	0.00	0.01018	0.00

[a] no nuclear data supplied

Table 2
Performance Characteristics for New Generating Plants (2003 $)

	Years to Construct	Plant Size (MW)	Average Capacity Factor (%)	Heat Rate (MBtu/kWh)
Nuclear				
DOE	5	600	90.0	10400
Platt's[a]	-	600	-	-
Coal				
DOE	4	400	85.0	9000
Platt's	3	400	85.0	9100
Gas CC				
DOE	3	400	85.0	7000
Platt's	2	400	85.0	7100
Gas CT				
DOE	2	120	30.0	9394
Platt's	1	120	10.0	10900
Solar PV				
DOE	2	5	24.6	10280
Platt's	1	5	25.4	0
Solar Thermal				
DOE	3	100	24.6	10280
Platt's	2	100	25.4	0
Wind				
DOE	3	50	28.9	0
Platt's	1	50	35.0	0

[a] no nuclear data supplied

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[1] See footnotes at end of text.

$$LCOE = \frac{I * CRF}{Q} + \frac{O \& M}{Q} + \frac{E}{Q} \quad (1)$$

where: I = Capital investment, including financing charges (interest rate initially set at 10%)
CRF = Capital recovery factor
Q = Annual plant output (kWhr)
O&M = Fixed and variable O&M
F = Fuel costs
E = Externality costs (initially set to 0).

The capital recovery factor (CRF) is calculated using:

$$CRF = r * \frac{(1+r)^n}{(1+r)^n - 1} \quad (2)$$

where: r = real discount rate (initially set at 10%)
n = plant life (initially 20).

Financing costs assume that capital expenditures are uniformally distributed over the time of construction.

A key feature of GenSim is its graphical user interface. For example, the main GenSim screen shows projected LCOE at all possible capacity factors (also referred to as capacity utilization). This allows one to compare generating technologies either at comparable capacity factors (i.e., nuclear vs. gas combined cycles at 80% capacity factors) as well as technologies operating at different capacity factors (i.e., coal at 85% with solar thermal at 25%). The same data is available in tabular form. Unfortunately, the images are not reproducible in this space.[4]

The base case results, using each data set, are summarized in Table 3. These results suggest that, at historical capacity factors, and in the absence of externality costs and renewable tax credits, pulverized coal and gas combined cycle plants are the least cost alternatives at 4.0 and 3.8 cents/kWhr, respectively. The results also indicate some fundamental differences in the two data sets. Platt's assumes that any new gas combustion turbine (CT) facilities will serve solely as peaking units, with capacity factors around 10%, whereas historical data (DOE, 2002) indicates an average capacity factor close to 30% for these plants.

The largest difference in the base case results is for the case of solar photovoltaic. Estimated costs using DOE and Platt's data are 22 and 62 cents/kWhr, respectively. This major difference is due to the assumed capital costs: 3526$/kW for the DOE data, compared to 7185 $/kW for the Platt's data.

Table 3
Comparison of Base Case Results Using DOE and Platt's Data (2003 $)

	DOE ($/kWhr)	Platt's ($/kWhr)
Nuclear	0.050	-
Coal	0.040	0.037
Gas CC	0.038	0.038
Gas CT	0.061	0.103
Solar PV	0.223	0.618
Solar Thermal	0.173	0.205
Wind	0.066	0.059

Sensitivity Analysis

GenSim's structure makes sensitivity analysis simple and powerful. GenSim allows the user to compare LCOE costs at either comparable capacity factors (i.e., all at 50%), or at default or user defined capacity factors (i.e., solar PV at 20% with nuclear at 90%). The LCOE estimates change as the user changes key assumptions in the model. For example, changing the assumed capital costs for solar PV from 3,526 $/kW to 1,500 $/kW reduces the LCOE from 22.3 cents/kWhr to 9.8 cents/kWhr.

Another key assumption driving LCOE estimates is construction time and financing rates. LCOE estimates change as the user varies construction times, capital costs, or financing rates. For example, the default setting for nuclear plant construction time is 5 years. If construction time increases to 8 years, the LCOE increases from 5.01 to 5.63 cents/kWhr. This difference is due to the effects on financing as the total financed costs increase from 2446 $/kW to 2863 $/kW. Construction time is clearly a key factor in the future financial success of nuclear power. If delays in construction lead to an extended construction period of 12 years, LCOE costs increase to 6.68 cents/kWhr, assuming a linear borrowing pattern and the default capital costs.

The sensitivity analytical tools are also ideal for answering "what-if?" type questions. For example, using the default DOE assumptions, gas combined cycle plants have a slight economic advantage over advanced coal plants at historical capacity factors (3.84 vs. 4.03 cents/kWhr). A typical type of "what-if" type question might be: at what real natural gas price over the life of the plant does the coal option become cheaper? The answer, using the sensitivity screen, is that the breakeven natural gas price is 3.67 $/MBtu, 0.27 $/MBtu higher than the default assumption. This has important implications given the volatility in natural gas prices. Using the same process, the breakeven natural gas price at which nuclear becomes competitive with gas is 5.07 $/MBtu.

Tables 4 – 7 summarize the key results of sensitivity analysis for new gas combined cycle, coal, nuclear, and wind generating technologies. Each table shows breakeven fuel and capital costs for each technology. For example, Table 4 shows the results for new gas combined cycle facilities. The first numerical column indicates the breakeven natural gas prices at which other technologies can compete with gas combined cycle facilities. Specifically, using the DOE base assumptions, nuclear becomes cost competitive with a gas combined cycle facility at a delivered natural gas cost of $5.07/MBtu, 1.67 $/MBtu higher than the DOE assumption. The breakeven natural gas cost for a coal facility is $3.67 $/MBtu, or just 0.27$/MBtu higher than the assumed price.

The second numerical column demonstrates the fuel price sensitivity for 10% changes in capital costs. Increasing the assumed capital costs for gas combined cycle facilities by 10% lowers the breakeven fuel cost for nuclear and coal to 4.91 and 3.51 $/MBtu, respectively.

The final column indicates the capital cost for the gas combined cycle facility at which the competing technologies become cost competitive. As indicated in Table 4, holding all else constant, the nuclear option would only be competitive with gas combined cycle plants if the capital costs for the gas plant increased from the assumed cost of 586 $/kW to 1205 $/kW. Capital costs for gas combined cycle facilities would have to increase to 2015 $/kW before the wind option was competitive.

Table 4
Gas Combined Cycle Sensitivity Analysis

	Gas CC Fuel Price ($/MBtu) (DOE Capital Cost)	(+10% Capital Cost)	Capital Cost ($/kW)
Nuclear	5.07	4.91	1205
Coal	3.67	3.51	687
Gas CC	-	-	-
Gas CT	6.61	6.45	1775
Solar PV	29.80	29.64	10350
Solar Thermal	22.55	22.40	7670
Wind	7.27	7.11	2015

Tables 5 – 7 summarize results for nuclear, coal, and wind technologies. Interesting results include:

- Nuclear capital costs would have to fall to around 1239 $/kW (from 1821 $/kW) to be competitive with coal (Table 5).
- Decreased nuclear fuel prices alone cannot make nuclear competitive with coal or gas CC plants (Table 5).
- Small decreases in coal prices or increases in natural gas prices can make coal the cheapest option (Table 6). Coal becomes competitive with gas at 1.06 $/MBtu or if gas prices increase by about 0.27 $/MBtu. The base case assumes a delivered coal cost of 1.27 $/MBtu.
- Wind is competitive with nuclear, coal, and gas CC plants at installed costs of 703, 528, and 494 $/MBtu respectively (Table 7). Assumed capital costs for wind are currently at 976 $/MBtu.

Table 5
Nuclear Sensitivity Analysis

	Fuel Price ($/MBtu) (DOE Capital Cost)	(+10% Capital Cost)	Capital Cost ($/kW)
Nuclear	-	-	-
Coal	NC	NC	1335
Gas CC	NC	NC	1239
Gas CT	1.47	1.12	2362
Solar PV	17.08	16.73	10475
Solar Thermal	12.20	11.85	7940
Wind	1.91	1.56	2595

[a]NC, Not Competitive

Table 6
Pulverized Coal Sensitivity Analysis

	Fuel Price ($/MBtu) (DOE Capital Cost)	(+10% Capital Cost)	Capital Cost ($/kW)
Nuclear	2.35	2.11	1615
Coal	-	-	-
Gas CC	1.06	.81	1026
Gas CT	3.55	3.31	2155
Solar PV	21.59	21.34	10310
Solar Thermal	15.95	15.71	7765
Wind	4.07	3.82	2385

Table 7
Wind Sensitivity Analysis

	Capital Cost ($/kW)
Nuclear	703
Coal	528
Gas CC	494
Gas CT	895
Solar PV	3787
Solar Thermal	2883
Wind	-

Construction Time Sensitivity

Figure 1 illustrates the overall sensitivity of nuclear economics to construction time. These results assume constant capital expenditures over the life of the project. Even reduced construction time does not allow nuclear to compete with coal or gas CC facilities. If nuclear plant construction is delayed beyond 11 years, then wind technologies become cost competitive with nuclear. Varying the assumed nuclear capital costs by 10% shifts the breakeven point for nuclear by 2 years compared to wind technologies, but does not make nuclear competitive with gas or coal technologies. According to these results, the only way to make nuclear competitive, even with a reduced construction cycle, is by drastically reducing capital costs, or if non-nuclear fuel or externality costs increased significantly.

Externality Analysis

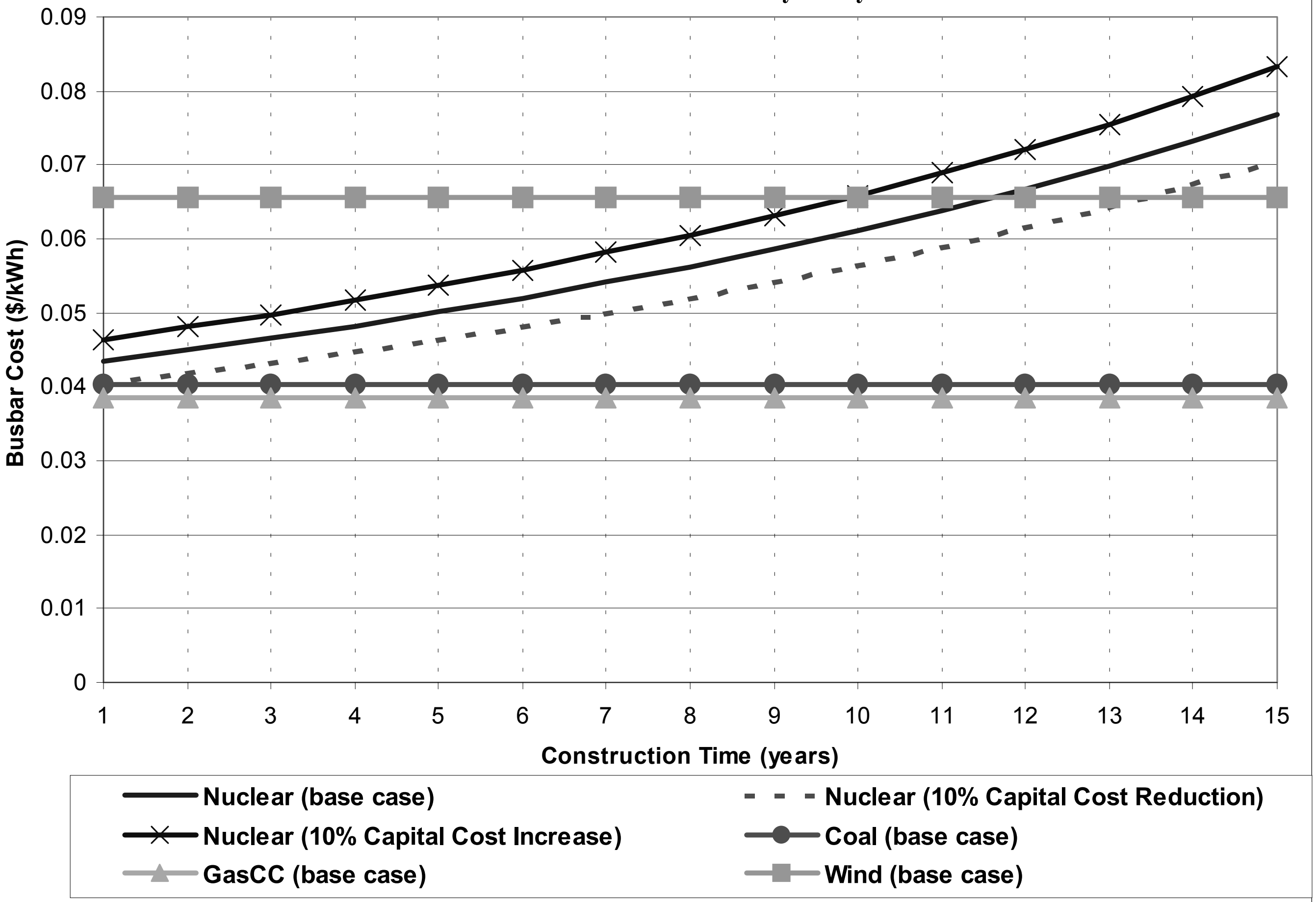
GenSim includes an extensive externality component that allows the user to consider the costs of externalities on LCOE estimates. Initially, GenSim assumes that the prices for all four externalities, CO_2, SO_2, NOx, and mercury (Hg) are set at zero. The capital costs for each generating option includes capital costs associated with the best available control technologies for both SO_2 and NOx. CO_2 and mercury emission technology costs are not included in the default capital costs. Using this externality component, the user can explore the effect of externality costs and/or different pollution control technologies on the estimates of LCOE.

For example, assume there are externality costs imposed on CO_2, SO_2, and NOx of $100/ton, $150/ton, and $1500/ton, respectively. This increases the estimated LCOE of coal from 4.03 to 6.39 cents/kWhr. The estimates for gas CC increase from 3.84 to 4.91 cents/kWhr. This increased cost for coal and gas CC is equivalent to increased fuel costs of 2.62 $/MBtu and 1.53 $/MBtu, respectively. Coal is affected more than gas as natural gas does not contain sulfur and releases less CO_2 per unit of energy consumed.

Consider the effect of just CO_2. A 100 $/ton tax on carbon emissions would increase electricity production costs from coal by 2.32 cents/kWhr, from 4.03 cents/kWhr to 6.35 cents/kWhr. For a gas CC plant, LCOE costs increase by 0.99 cents/kWhr, from 3.84 cents/kWhr to 4.83 cents/kWhr. The relative small change over the three pollutant example reflects the assumption that each new plant already includes SO_2 and NOx pollution control technologies.

For the nuclear option, the externality analysis is limited to consideration of dealing with the spent fuel. Currently, U.S. reactors are charged a flat fee of 1 mill/kWhr produced electricity. This charge is expected to cover the cost of the eventual emplacement of this material in a central geological repository, such as at Yucca Mountain, Nevada. GenSim

Figure 1
Nuclear Construction Time Sensitivity Analysis



allows the user to explore the impact of changing this assumption about spent fuel storage costs, or could add other externalities as well through increased storage costs. The base case assumes a 1 mill/kWhr charge.

GenSim also allows the user to consider the overall costs of pollution control. Without pollution control technologies included in the analysis, LCOE estimates for coal and natural gas decrease 0.60 and 0.04 cents/kWhr for coal and gas CC plants, respectively. These are the implied costs of the required pollution control devices.

In addition to the type of externality analysis illustrated here, GenSim allows users to conduct a wide range of more detailed externality analyses.[5]

Conclusions

The Electricity Generation Cost Simulation Model (GenSim) is a user-friendly, high-level dynamic simulation model that calculates electricity production costs over a wide range of plant and economic assumptions including capital, O&M, and fuel costs, construction times, and interest and discount rates. These electrical production costs are calculated for a variety of electricity generation technologies, including: pulverized coal, gas combustion turbine, gas combined cycle, nuclear, solar (PV and thermal), and wind. The model also permits a wide range of sensitivity and externality analysis. Its ease of use and intuitive, graphical display will help provide students of energy policy, as well as policy makers, energy executives and their staffs a better understanding of the economic viability and trade offs among power generating technologies and their emissions trade-offs.

Footnotes

[1] Sometimes referred to as busbar or production costs. Transmission and distribution costs are not included.

[2] The costs given in this paper are for newest available technologies for each option.

[3] All dollar figures in paper are in 2003 dollars.

[4] More detailed versions of this paper with relevant screen shots are available from the authors in the Sandia National Laboratories report SAND2002-3376, *Electricity Generation Cost Simulation Model (GenSim)*.

[5] Additional details are available upon request from the authors.

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Platt's Research and Consulting Group. 2002.

U.S. Department of Energy (DOE). 2002. *Assumptions to the Annual Energy Outlook 2003.*

SAND2002-3376, *Electricity Generation Cost Simulation Model (GenSim)*, November 2002.

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New Challenges for Energy Decision Makers

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Oil & Gas: Frontier Issues
Efficiency and Regulation of Electricity and Gas Distribution Companies

Volatile fuel prices, market restructuring, globalization, privatization and regulatory reform are having significant impacts on energy markets throughout the world. Most major energy industries are restructuring through mergers, acquisitions, unbundling and rebundling of energy and other services. This conference will provide a forum for discussion of the constantly changing structure of the energy industries.

At this time, confirmed speakers include the following:

Arnold B. Baker, Sandia National Laboratories
Lars Bergmann, Stockholm School of Economics
John Brodman, U.S. Department of Energy
Alfred John Boulos, Boulos International
Mary-Ellen Boyle, Clark University
J. Christensen, RISO National Lab., Denmark
Robert Eagan, Sandia National Laboratories
Robert Ebel, Center for Strategic & Int'l Studies
Jean-Pierre Favennec, IFP-ENSPM
Massimo Filippini, University of Lugano
Herman Franssen, Petroleum Economics Ltd.
Michael Grubb, Imperial College, London
Einar Hope, Norwegian Sch. of Econ. & Bus. Admin.
Tooraj Jamasb, University of Cambridge
Hoesung Lee, Council on Energy & Environment, Korea
Sang-Gon Lee, Korea Energy Economics Institute
Johannes Maters, European Commission, DG TREN
Charles McPherson, World Bank Group
John Mogford, BP, Plc.
Poul Erik Morthorst, RISO National Laboratory
Mohan Munasinghe, Munasinghe Inst for Development
Shirley Neff, Energy & Natural Res. Comm, US Senate
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Willy Olsen, Statoil
Anthony Owen, University of NSW, Australia
Miroslav Pise, EON
Robert Rios-Herran, Legal Advisor
Yoshihiro Sakamoto, Institute of Energy Economics, Japan
Jiri Schwarz, Liberal Institute, Czech Republic
Matthew R. Simmons, Simmons & Company Int'l
Nils von Hinten-Reed, CapAnalysis (Europe)
Frank Wolak, Stanford University

Keynote luncheon and dinner presentations will be given by Andrei Konoplyanik, Deputy Secretary General, Energy Charter Secretariat; Miroslav Pise, Mgr., EON Bohemia Office and Jeremy Leggett, Chief Executive, Solar Century.

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Strategic Security of Energy Infrastructure Systems in the Czech Republic

*By Ivan Benes and Monika Mechurova**

Introduction

Tragic events that meaningfully affect human society reach not only into people's privacy, but also lead to new approaches and activities among businesses and politicians, who strive for new measures, regulations and laws in order to protect persons and assets and lower the risk of repetition. The terrorist attacks on September 11, 2001 altered security situations around the world. In order to evaluate the current situation in the Czech Republic, CityPlan, Ltd., with the support of fourteen energy companies that share in these concerns, presented a *study on the strategic security of energy infrastructure systems in the Czech Republic* in April 2002. Investigation was primarily focussed on the reliability of energy supplies in the Czech Republic and the security of the population and property in the event of a terrorist attack on energy infrastructure systems.

This article is an attempt to summarize the basic analyses and concepts for defining suitable measures that should be undertaken by public institutions. An attempt was made to evaluate the essence of threats in relation to the energy infrastructure in the Czech Republic, and, subsequently, to offer rough recommendations resulting from an analysis of the possible consequences of such threats.

Critical Points of Energy Infrastructure

For the bulk of our infrastructure, the level of vulnerability or risk may be acceptable. Most power lines, pipelines and transmission facilities can be repaired within a fairly short period, although sometimes at great expense. Many parts of the energy system can easily be replaced, or kept in operation for a transition period using improvisation, postponing complete renewal to a later date.

However, certain critical components of the energy infrastructure system are at much greater risk to terrorism with serious consequences. Disruption of their operation or complete destruction could cause serious breakdowns locally, regionally, or perhaps even nationally. Such an attack would also have serious domino effects across the entire economy. Depending on how such an attack was carried out, it could also cause widespread human casualties and long-term environmental damage.

An attack against critical components of the Czech energy infrastructure must, therefore, be perceived as one of the greatest threats to the nation, which must be duly considered and resolutely minimized. Efforts to better protect this infrastructure against terrorist attacks should be an essential political priority.

It is essential to pinpoint the weak spots in the energy infrastructure, whose destruction or damage could result in the collapse of the entire energy system. Likewise, we must prepare procedures, which will enable at least temporary emergency operation. Although crisis plans based on the assumption of technological or human error have been elaborated for all energy facilities, substantial changes must be implemented in the private sector. At present, most of these plans (with the exception of nuclear power plants) do not consider the possible consequences of terrorist attacks on such facilities. Pure patriotism aside, private energy companies have considerable business interest in the protection of their facilities and employees. Moreover, prudent companies take steps to limit their liability.

Some of these steps, which companies should try and implement, are relatively simple and low-cost, such as better-trained guards and tighter operational security for sensitive information. Nonetheless, with respect to some relatively vulnerable critical components in the energy infrastructure, the demands for real security go far beyond simply employing more security guards. The Czech Republic has neither the technological nor financial means to solve this situation by interconnecting satellite monitoring of the energy infrastructure with land and air forces; this solution is being considered in the USA. For our nation, it is far more reasonable to resort to short-term measures, while long-term development of the energy infrastructure would ensure limited local effects of terrorist attacks and avoidance of the collapse of the system as a whole on a regional or national scale.

Apparently, no energy company in the world has sufficient means to protect itself against the type of "suicidal" attack that occurred in New York on September 11. The public and private sectors must cooperate during development of new security regulations for the creation of energy concepts and construction of energy facilities. This process is akin to the manner in which environmental issues were introduced in the planning of energy infrastructures. However, because it concerns the co-responsibility of politicians for citizens' security, it must effectively increase the security of energy supplies, without being been just another regulatory burden on the private sector. In order for the energy sector to adequately confront the threat of global terrorism, it will need substantial help from the public sector. In the current liberalized competitive environment, it can hardly be expected that individual private players will be capable of building the necessary infrastructure redundancies into the energy systems without the active support of the Czech government.

The weak point in the world's energy infrastructure is the unequal distribution of international resources and primary energy supplies, in particular crude oil and natural gas. Ensuring access to drilling and transport of these commodities (to ports, terminals, national consumption) is among the most important geopolitical goals of today's superpowers.

Process chains for all types of energy supply are composed of facilities for mining and acquisition of primary energy (coal and uranium mines, wells for drilling oil and gas, hydroelectric, wind and solar power plants, biomass), energy distribution facilities (oil and gas pipelines, heating networks, power lines), storage facilities (coal supplies, liquid fuel tanks, gas tanks), technologies for energy transformation (refineries, power plants, heating plants, transformer stations), technological systems for final energy consumption, and finally power plant waste storage units (ash storage, burned nuclear fuel storage units).

It is clear that terrorist attacks on certain components of the energy infrastructure could have not only economic consequences, but are equally dangerous to life and health.

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Human lives and health can be directly threatened by extensive catastrophes, such as the destruction of a refinery, nuclear power plant or accumulation hydroelectric plant. Such accidents may have long-term effects on the environment (air, water and land pollution), which may in turn threaten the lives and health of people and render entire territories useless.

Although it is important, the protection of human lives and health is not the only aspect of the consequences of such an accident that must be considered. Long-term disruption of energy infrastructure systems may cause both economic and political destabilization and collapse in extensive areas.

Critical Points Evaluation

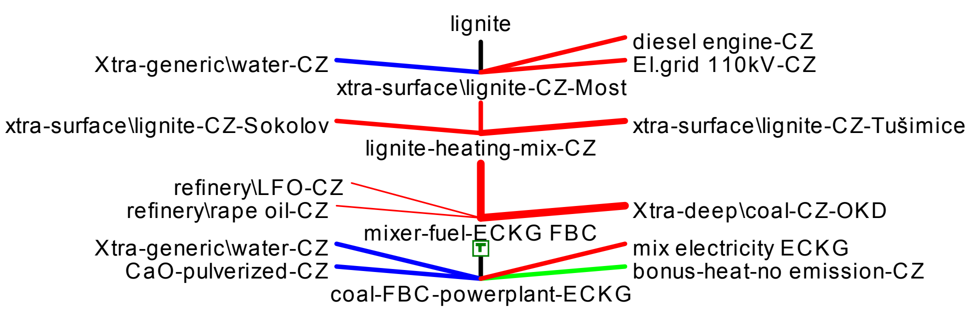
CityPlan provides critical infrastructure evaluation using the GEMIS model. GEMIS (Global Emission Model for Integrated Systems) was originally intended for life-cycle analysis (LCA). In 1987, Öko-Institute (Institute for Applied Ecology) in Germany developed GEMIS as a publicly available, cost-free software and database. In the 90s CityPlan, in cooperation with the Austrian and Czech governments, enlarged the database with Czech data. Utilization of GEMIS in the Czech Republic is now financially supported by the Czech Energy Agency and is used mostly as a Regional Energy Planning tool.

Life-cycle is a concept used in life-cycle analysis and material flow analysis to determine the environmental burdens of products and services from “cradle-to-grave”, i.e., from the source (raw material or primary energy extraction) through the use phase to the “sink” (e.g., waste treatment, or recycling.) It includes the materials needed for the construction, all transports and auxiliary inputs as well. The links of all processes, which contribute to a life-cycle, are called the process chain. The most important part of LCA analysis is the Life-Cycle Inventory.

For critical infrastructure assessment it is also important to describe the entire process chain that is necessary for the critical infrastructure function. We can give an example of how the Life-Cycle Inventory is effectively utilized to track energy supply security.

Near to Prague is located the most modern new Czech coal fired power plant, ECK Generating (ECKG). The coal part process chain of the plant is shown in Figure 1.

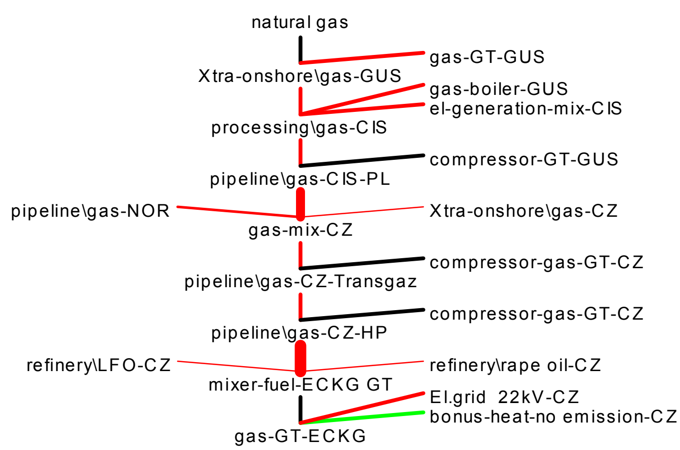
Figure 1
Fluid Bed Circulating Process Chain



As it is shown, operating fuel for the power plant can be supplied either from coal mine (OKD) or from three lignite mines (Tusimice, Sokolov, Most). Light fuel oil (LFO) or rape oil can serve as an ignition fuel. The pulverized limestone (CaO) is needed to capture sulphur from coal; technological water for cooling is also needed. The power plant needs auxiliary electricity for starting and auxiliary consumption (mixed electricity ECKG). Once it is started, the power plant can operate an island grid without external connection. The heat bonus means that the plant also produces heat (as a byproduct) used for the municipal district heating system.

The external electricity can be substituted by electricity from a gas turbine that is the gas-part of the ECKG plant. This gas turbine can burn natural gas (from Russia or Norway), or conventional light fuel oil even rape oil. But as is shown in Figure 2, the weak point of the plant from a critical infrastructure point of view is that the gas turbine is not able to start without external electricity. To enable a black-start of the power plant there is the possibility of equipping the gas turbine with a diesel generator.

Figure 2
Gas Turbine Process Chain

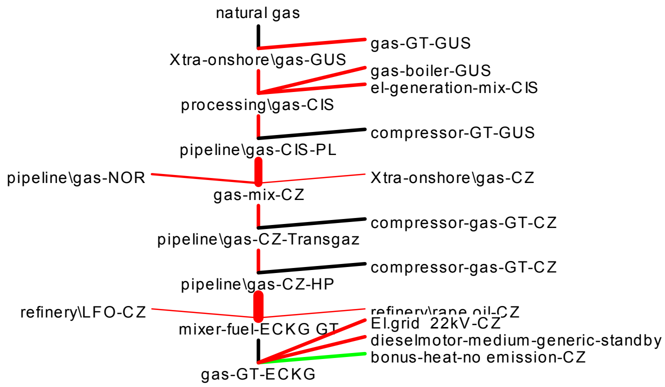


It means that a small investment of about US $100,000 in a diesel generator can provide a relatively large source of power independently on the external grid when necessary (Figure 3). The power plant, ECKG, is than able to cover about 40% of Prague consumption as a critical infrastructure source during a transmission system crisis. The problem is that independent power producer will not invest in a diesel generator if there is no assured market during crises. Public sector involvement is then needed.

Conclusion

Ensuring the general security of the population and property, and defending them against criminal activity, which an organized terrorist attack undeniably is, is a basic responsibility of the state and all components of the public sector. For this reason, the security of the Czech energy infrastructure at all levels against terrorist attack is undoubtedly a leading political priority, because energy is the foundation of political and economic stability in the nation. This responsibility is also one of the most important activities of all parties, which are linked by the obligation to ensure security against criminal terrorist attacks.

Figure 3
Gas Turbine Process Chain Equipped By Standby Diesel Generator for Black Start



The security of citizens and property cannot be part of one party's policy, because it is a compulsory service, which all levels of state government are ordered to perform by the Constitution of the Czech Republic. It should, therefore, be included in the election programs of all democratic political parties, for both parliamentary and particularly community elections.

The analyses indicate that increasing the security of the Czech energy infrastructure against terrorism, and reliably supplying households and other sectors of the national economy under crisis conditions, aside from general planning of considered technological or human errors, exceeds the capabilities of individual energy companies.

Measures, which may contribute to increasing the security of energy supplies in the Czech Republic include:

- In the long-term, it is necessary to take terrorist attacks into account. In order to be able to prevent and confront them, cooperation between the public and private sectors is necessary to strengthen the protection of sensitive parts of the energy infrastructure.
- In the event of worsened security situations in the state, it is necessary to use the assistance of armed forces (police, army) to ensure priority protection of facilities, an attack on which could threaten human lives and have long-term consequences on the environment. Such facilities include nuclear power plants (which was the case for a short time following September 11), chemical factories and oil refining facilities, oil and natural gas drilling equipment, natural gas, oil and petroleum product and dangerous chemical substance storages, overground parts of gas pipelines, including compressor stations, overground parts of oil pipelines and transmission lines, and hydroelectric accumulation plants.
- Increase the security of all systems of the Czech economic infrastructure, including securing of their emergency operation, by amending regulations on territorial planning.
- Ensure an increase in security of sensitive consumer system facilities (hospitals, selected office, banks, large shopping centers, selected industrial facilities, etc.) against long-term electricity blackouts by amending building regulations and project recommendations.
- Special attention must be paid to power systems, because most of its equipment is located on the surface and is easy to find and attack.
- Ensure controlled access to information from GIS (geopolitical information systems) concerning underground components of the energy infrastructure. In combination with the available GPS (global positioning system), such information can enable easy targeting and attacks on important underground elements of the energy infrastructure (pipeline systems, telecommunication systems).
- Increase the capabilities of local public CHP plants and industrial power plants to supply electricity and heat to apartments and other important buildings in cities in cooperation with local distribution companies.
- If necessary, ensure rapid mobilization of mobile substitute resources for emergency electricity supplies to rural populations.
- Ensure the publication of information materials for citizens and companies about procedures in crisis situations and the possibilities of diversification and substitution of individual types of energy.
- In the future, sustain the capability of the coal industry to ensure sufficient independent primary energy supplies in the Czech Republic.
- Support the reduction of specific energy consumption, and support repair of the existing building stock and support the construction of low-energy and passive buildings.
- Support increased use of renewable energy resources.
- Reflect security criteria when solving energy concepts for regions and major cities.
- Reflect security criteria in the performance of energy audits.
- Create security-oriented thinking among government employees and citizens.

The system for increasing the security of the Czech energy infrastructure against terrorism should also be continually tested and improved pursuant to ISO 9001 (quality management) principles.

The following steps will be necessary to create a new security strategy against the threat of terrorist attacks:

- Formulation of the main purpose of increased security of energy supplies in the Czech Republic (security concept from the aspect of global terrorism)
- Formulation of the desirable state (security vision from the aspect of global terrorism)
- Perform analyses of all external factors (including international), which significantly affect energy companies during their fulfillment
- Perform evaluations of the individual parts of the energy infrastructure on the level of specific energy companies
- Analysis of the strong and weak points with external opportunities and threats (SWOT analysis) for fulfillment of the security vision, feasibility study and identification of the main problems
- Definition of strategic areas for increasing resistance of the energy infrastructure against terrorist attacks (definition of areas of key importance for fulfillment of the security vision, specifiction of the importance of individual areas and definition of their mutual relations)
- Formulation of strategic aims (key long-term development

tendencies in individual strategic areas, on which efforts for fulfillment of the security vision will be focussed)

- Formulation of partial goals of increasing security of the energy infrastructure against terrorist attacks (specification of individual strategic aims into the form of interim steps)
- Elaboration of action plans for increasing security of the energy infrastructure against terrorist attacks (specifiction of tasks necessary for the realization of partial goals, including deadlines, responsibilities and conditions necessary for their fulfillment)
- Specification of strategic indicators for assessment of security of the energy infrastructure (selection of criteria for evaluation of the course and results of fulfillment of strategic goals)
- Fulfillment of action plans (performance of practical steps within the framework of fulfillment of individual partial goals and tasks)
- Creation of a surveillance system for monitoring, measuring and evaluating the course and results of fulfillment of strategic goals according to strategic security indicators for the energy infrastructure
- Adaptation (modification of action plans, strategic goals and partial goals of the overall vision in relation to the course and results of realization of the actions plans, development of the security situation and changes in the external environment)
- The result should be achievement of a state that will considerably complicate and limit attacking of the energy system, and make it an unsuitable target for economic and political destabilization of the nation.

The study on the strategic security of energy infrastructure systems in the Czech Republic has been presented to the Ministry for Territorial Development, the Ministry of Interior and the Ministry of Industry and Trade. The study recommended the following:

- analyses of all possible catastrophes (not only terrorist attacks, but also accidents and disasters)
- analysis not only of the energy sector but also of other parts of critical infrastructure

These suggestion have been included in the study and in September 2002 a team of experts under the leadership of Dana Prochazkova, PhD. (Department of Crisis Planning, Ministry of Interior) developed the key principles and approach to evaluation of vulnerability of sensitive parts of critical infrastructure.

Currently CityPlan is preparing a pilot study: *Prevention of the threat of terrorist attack on the energy sector in the Middle-Bohemian and South-Bohemian Regions*. After the floods in August that affected the Czech Repulbic, this study will also extend to prevention of all types of catastrophes. These two regions have specific security concerns because the capital of Czech Republic, Prague, is situated in the center of Middle-Bohemian Region and there is a nuclear power plant, Temelin, in the South-Bohemian Region as well as several dams and hydropower plants on the Vltava river.

Hubbert's Peak *(continued from page 12)*

Footnotes

[1] Fred Guterl (2002). "When wells go dry", *Newsweek* 139(115): 32B.

[2] Deffeyes (2001). Princeton: Princeton University Press.

[3] M. King Hubbert (1965). National Academy of Sciences Report on Energy Resources: Reply. Bulletin of t he American Association of Petroleum Geologists 49(10): 1720-1727.

[4] John M. Ryan (1965). National Academy of Sciences Report on Energy Resources: Discussion of the Limitation of Logistic Projections. Bulletin of the American Association of Petroleum Geologists 49(10): 1714.

[5] Hubbert, op cit., 1723.

[6] Ibid. 1722, Fig. 1.

[7] Ibid. 1724-25

[8] Guterl, op cit.

[9] Op cit., 1723.

[10] Op cit.

[11] National Fuels and Energy Study Group (1962). *Report to the Committee on Interior and Insular Affairs, United States Senate,* 87th Congress, 2d Session, Document No. 159, 354-357, 380. The study group also strongly rejected the argument of impending shortages of crude oil.

Uzbekistan, an Expanding and Capital-Hungry Economy

Specific Interrelated Opportunities in Energy, IT and Agriculture

*By Malika Saidkhodjaeva**

Uzbekistan has a strong and vibrant economy. It is fortunate to be rich in mineral resources, self-sufficient in energy and endowed with a wide variety of human skills. The demographic profile of its youthful population and degree of technical education indicate considerable potential dynamism.

The location of the capital, Tashkent, at the heart of the five Central Asian Republics (see Table 1) gives the city a co-ordinating role in the wider region and as a key stepping-stone between Europe and China. Uzbekistan also has a secondary and potentially rewarding part in the ancient and reviving North-South flow of goods, services, capital and people emanating from Russia and Northern Europe towards Afghanistan, Pakistan and India and in a developing trade in the reverse direction. As a key trading, communications and energy hub, Uzbekistan will, therefore, begin to attract much more foreign investment. The challenge will be to use that valuable inflow to derive optimum long-term national benefit.

Following the break-up of the Soviet Union in 1991, the newly independent Uzbekistan government found itself faced with many intractable economic problems. Subsidies from Russia and neighbouring FSU states had been withdrawn; capital inflow had been virtually halted and current income from cross-border trade declined sharply. Lack of continuing investment and markets led to declining industrial and agricultural output and high domestic inflation.

The new economic policy targeted:

- continuing self-sufficiency in energy
- self-sufficiency in food-grains
- diversion of key exports such as cotton and gold to international hard-currency buyers
- restriction of inessential and luxury imports

As a result, Uzbekistan's sensible response in very difficult circumstances resulted in a much shallower economic recession than that experienced by its neighbours. In comparison, for example, with the other large Central Asian republic, Kazakhstan, which since that time has been experiencing the tumultuous and de-stabilizing effect of high capital-inflow into the oil and gas-sector, the Uzbekistan government was able to pick a more cautious strategy and a step-by-step approach to economic reform and the opening-up of the economy to international interest and support.

This opening-up process continues. There have been the first privatisation projects in the electricity and banking sectors. Invitations to leading Western universities to set up outreach academic and technical training centres in Uzbekistan have been readily taken up: a number are already in full operation in Tashkent and Samarkand and others are planned in Urgench and the Fergana Valley.

High priority has had to be placed on social issues:

- Health
- Education
- Provision for the aged
- Improvements in urban water supply
- Improvements in transport infrastructure

This leaves many major economic opportunities still to be tackled:

Agriculture: Diversification

Further rationalisation of the cotton and cereals industries will give higher per capita yields and will release resources for a gradual switch to other high-value export cash crops in which Uzbekistan has some accumulated experience. As external export markets again begin to develop and thrive under private sector stimulus and with much cheaper air freight both to key markets in Western Europe and Southeast Asia, as well as to neighbouring states, exchange restrictions can be gradually lifted and external competitiveness enhanced.

A Sound Energy Mix

Uzbekistan's continuing energy self-sufficiency is a source of great economic strength. In 2001 consumption rose by 7.8% to 54.8 mtoe after sluggish growth over the previous five years. Oil production which had slumped 33.6% over the previous decade plays only a small role (11.9%) in the energy mix (see Table 3). Coal (1.1 mtoe) and hydro (1.3 mtoe) barely count for anything in this mix. There is no nuclear and no significant alternatives (solar, wind, geo-thermal etc).

A Modern Gas Economy

Taking an overview, Uzbekistan today is predominantly a modern expanding natural gas economy. Natural gas production has risen 36.9% over the decade to 46.0 mtoe (82.9% of total energy consumption) and is still capable of expanding strongly (see Table 2). The level of gas production puts Uzbekistan in first place among the five Central Asian states, although Turkmenistan at 43.1 mtoe is not so far behind. A decade ago Turkmenistan gas production was double that of Uzbekistan. What is more significant, however, is that Uzbekistan's natural gas consumption is four times that of Turkmenistan and five times that of Kazakhstan. In other words Uzbekistan is far ahead of the other Central Asian states in the modern distribution and utilization of natural gas, a very useful economic under-pinning to kick-start the Uzbekistan economy into a period of high industrial growth and agricultural diversification.

Rich Petroleum Resources

In geological terms, Uzbekistan is a strategic centre of the semi-ring extending from the Persian Gulf through the Caspian and Tarim basins, an area which comprises:

- some 85% of proven global crude oil reserves
- a vast reservoir of natural gas much of which has been only superficially explored and evaluated

The country has a total of 155 oil, condensate and natural

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The Statistical Sources for this article are: IMF, World Bank, BP, IEA and OGJ.

gas fields which the international industry rates to be of high prospectivity.

It would be unwise to burden the national budget with such development, when the international oil industry is demanding relatively minor improvements in participation and taxation terms.

Access to the Latest Technology

The major prize to be achieved in the petroleum sector is the adjustment of terms for foreign participation to permit a strong inflow of advanced technology and external capital. This does not imply any selling off of national assets, merely a more practical working relationship between the public sector and the new outsiders. Energy self-sufficiency, as in the UK, Netherlands and Canada, often gives cause for a misguided and dangerous government complacency. In the case of Uzbekistan, slowness in this policy area would be like abandoning the fast-track to sustained economic growth and high-levels of prosperity.

Abundance of Minerals

The rich mineral resources of Uzbekistan include 900 identified areas with proven reserves valued at $970 bn and probable resources put at $3.3 trn.

Reserves of uranium are sufficient to sustain production at current (1990-99) levels for the next 60 years. Gold production and reserve statistics, estimates and forecasts are not easily obtained but anecdotal evidence suggests buoyancy. New discoveries of other minerals include more large and accessible deposits of marble, granites and gabbros.

Tashkent As a Regional/International IT Hub

Various efforts have been made to establish Tashkent as the key communications hub for the Central Asia region. There are very many sound economic and commercial reasons for such a development. Yet the critical mass of computing resources and the level of penetration of IT use in Uzbekistan still falls below the levels considered as essential in industrialised countries – not far below but still below.

To make this jump is not a difficult one and, if managed properly, can be achieved swiftly with little charge to the government budget. Countries such as India, Japan and Malaysia may be able to supply the most appropriate model; a competent analysis of the relative backwardness in IT of Kazakhstan, Turkmenistan, Tajikistan and Krygyzstan compared with Uzbekistan may also be helpful.

Without doubt, agricultural diversification, oil and gas production acceleration, minerals development and a consumer-led period of high economic growth would benefit sharply from stronger communication links and local IT trading facilities. An example within the energy sector would be to build on the daily co-operation and quarterly meetings of the region's five energy ministers to go beyond energy supply issues of mutual concern to the introduction of advanced IT and Western market mechanisms to manage and regulate peak levels of energy demand.

Summary

The Uzbekistan economy is quite close to the point of economic take-off. Resource- and skills- and people-rich, Uzbekistan has many advantages over its neighbours. The national economic priorities are now being focussed on strengthening external trading links, communication infrastructure and a strong inflow of capital and technology.

Table 1
The Five Central Asian Republics

	Population (millions)	**Area** (sq. miles)
Uzbekistan	25.0[1]	175,000
Khazakhstan	17.8[2]	1,050,000
Tajikistan	6.2[3]	55,000
Kyrgustan	4.8[4]	75,000
Turkmenistan	4.7[5]	190,000
Total (5)	58.5	1,545,000

[1] of which 69% Usbeks; 10% Tajiks
[2] of which 36% Kazakhs
[3] of which 60% Tajiks; 23% Usbeks
[4] of which 52% Kyrgyz
[5] of which 72% Turkmen

Statistics provided by PTA London from UN Sources.

Table 2
Uzbekistan Oil Sector
Mtoe

	1991	**1996**	**2001**
Production	2.8	7.6	7.3
Oil Reserve/Production Ratio 2001: 11.2 years			
Consumption	11.0	7.4	6.5
Oil Self-Sufficiency 2001: 112.3%			

Source: PTA London from International Oil Industry Sources

Table 3
Uzbekistan Natural Gas Sector
mtoe

	1991	**1996**	**2001**
Production	35.2	41.1	48.2
Gas Reserve/Production Ratio 2001: 33.2 years			
Consumption	33.4	39.0	46.0
Gas Self-Sufficiency in 2001: 104.8%			

Source: PTA London from International Gas Industry Sources

Author Note

This paper, covering the broad aspects of current research, has been written for presentation to the 26th Annual International Conference of the International Association of Energy Economists in Praha, Czech Republic on 4-7 June 2003 and supplements more detailed information presented to IAEE-24 in Houston, USA in June 2001 and to IAEE-25 in Aberdeen, Scotland in June 2002.

Erratum

In the article on *Mexico's Energy Scene* in the First Quarter 2003 issue, the Crude Oil Reserves figure in Table 1 should be $38.29x10^9$ b not $8.29x10^9$b as shown.

Electric Energy Sector in Poland

*By Zbigniew Mantorski **

The Way Toward A Modern Energy Sector

Since the beginning of the transformation in Poland, that is from the beginning of the 1990s, it was obvious, that the energy sector, including electric energy, had to be completely reconstructed. In 1990 this sector was divided into 3 sub-sectors: generation, transmission and distribution and the Polish Grid Company (PSE SA) founded with 100% state treasury ownership. In 1993, 33 distribution companies were separated from the transmission network and became joint stock companies also with 100% state treasury ownership, while still managed by PSE SA. The next important step in the energy sector modernisation was the connection of the Polish energy network to the West European network UCPTE in 1995, but the most important changes started in 1997 when the Polish Parliament passed the Energy Act, which became the force of law. Concurrently with the implementation of the new law, the Energy Regulation Office (URE) was founded. These measures facilitated the commencement of privatisation – the first energy company Heat and Power Plant in Cracov, was privatised the following year. Electricity prices are no longer set by the Finance Ministry, but prepared by distribution companies; while still subject to the approval of the President of URE. The basis for privatisation were determined in "The Strategy of Privatisation Distribution Sub-sector in Poland" (with amendments), a document prepared by the State Treasury Ministry. In 1999 the Polish Power Exchange was founded and in 2001 an hourly-based market opened up. The last power plant was transformed into a state treasury joint stock company the same year. Now it can be said that from a legislation point of view, nearly all the measures enabling the reconstruction and privatisation of the electric energy sector have been implemented.

Current Situation

As mentioned above, the Polish energy sector is divided into three sub-sectors: generation, transmission and distribution.

The generation sub-sector has 17 system power plants, all fuelled by hard coal and lignite, several big heat and power plants and industrial power plants mostly fuelled by hard coal. Hydro-power plants work mainly as peak-load plants. There are no nuclear power plants in Poland. In 2000 the total installed capacity was 34,552 MW and total energy production was 144,417 GWh (142 TWh predicted for 2002). The outlook for installed capacity is presented in Figure 1 and for energy production in Figure 2. With total installed power of over 34 GW, the peak loads are between 15 and 23 GW and there is still a substantial power margin.

PSE SA, the national grid operator of the highest voltage networks, is responsible for transmission, and purchases electricity from system power plants, selling it to distribution companies. It has 8116 km of 220 kV lines, 4660 km of 400 kV lines and 114 km of 750 kV lines.

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Figure 1
Installed Capacity (2000) by Type of Plant [MW]

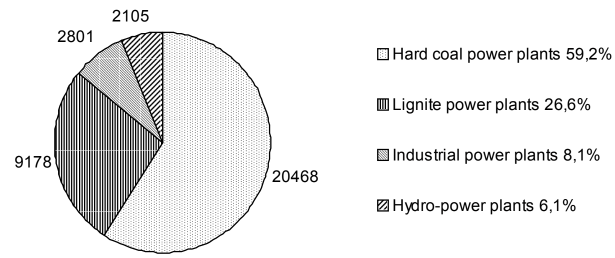
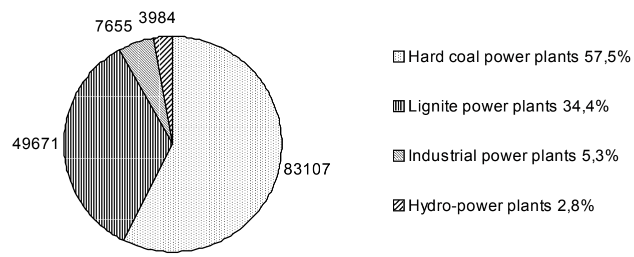
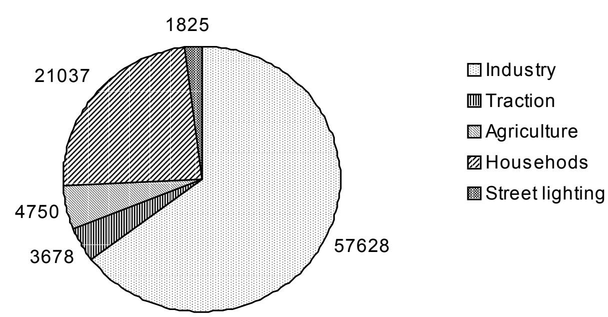


Figure 2
Electric Energy Production (2000) by Type of Plant [GWh]



The 33 distribution companies are operators of a 110 kV, medium and low-voltage network. In 2000 they supplied above 15 million customers and sold them 100,239 GWh. Figure 3 presents the structure of electricity consumption in Poland. In February 2002 the Ministry of Economy issued a document concerning the evaluation and correction of energy policy up to 2020. Two variants (base and high) predict 1.2% and 1.3 % increase, respectively, in annual energy consumption up to 2005.

Figure 3
Structure of Electricity Consumption (2000) [GWh]

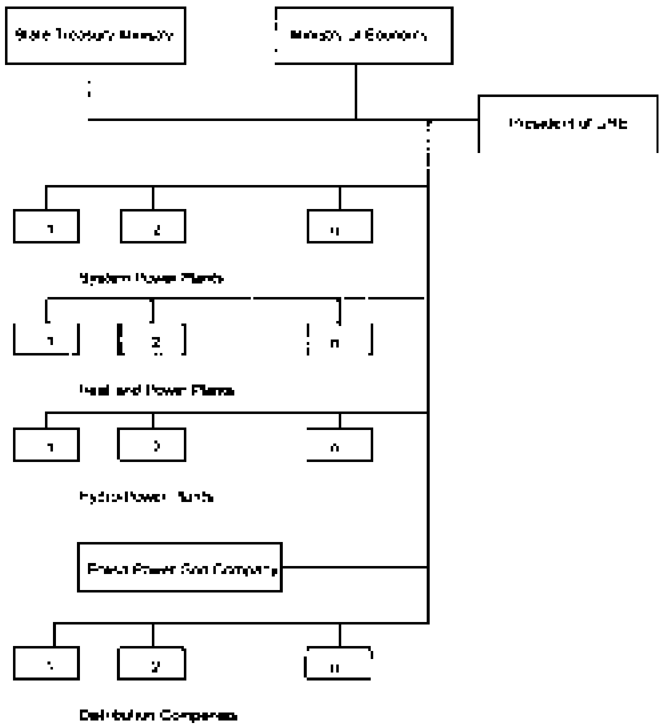


The current structure of the Polish electric energy sector is presented in Figure 4.

Privatisation

The foundations for the privatisation strategy were laid down in "Privatisation of Energy Sector, Assumption and Implementation", a document prepared in 1999 by the Ministry of State Treasury. It assumes that power plants shall be privatised individually by strategic investors. Lignite fuelled power plants have to be privatised alongside mines. Heat and power plants will also be privatised individually, by strategic investors, financial investors, public offer or flotation. So far, 5 heat and power plants have been privatised, with Electricite

Figure 4
Structure of the Electric Energy Sector



de France as the main shareholder; as well as three large power stations: PAK – 2 GW, Rybnik – 1.7 GW, Polaniec – 1.8 GW.

The distribution companies were divided into the groups in which they are to be privatised with preferences for strategic investors. Only the largest of these companies (GZE in Upper Silesia) was privatised in 2001 with Swedish Vattenfall as the strategic investor.

PSE SA – the national grid operator will be privatised when the privatisation of the other sector companies is completed, but the State Treasury shall remain the owner of the majority of shares.

The privatisation of the energy sector had initially been planned to be completed by 2002, but the process was delayed. The change of government in 1999 and the ensuing changes in the posts of ministers responsible for energy sector privatisation resulted in different concepts of privatisation. The lack of an effective solution to the long-term contracts made it difficult to find strategic investors. Additionally, some cases of poor privatisation practices in other sectors of the Polish economy have created an unfavourable social climate for the privatisation of all strategic enterprises.

Barriers to Electric Energy Sector Development

There are several barriers hindering the growth of the electric energy sector: these are legal, political, organisational, technical and social, including:

- Imperfection in the Energy Act,
- Lack of correct methodology in tariffs construction,
- Lack of equal market opportunities for electricity produced with low and high emission of pollutants,
- An obligation to purchase electricity in Minimum Electricity Amounts – long-term contracts cover most of energy trade, power exchange transactions are not concluded by PSE SA,
- Concentration of wholesale energy trade in one company,
- The mechanism of price construction for end users is not working correctly,
- The regulatory policy of URE,
- A negative influence by the present ownership of the sector (the state treasury is the majority owner),
- A technical infrastructure that is undeveloped (metering, telecommunication, IT),
- A lack of operating experience in competitive markets,
- Development trends in the energy sector are difficult to predict; there are discrepancies between different forecasts,
- A misunderstanding and lack of knowledge about changes in the energy sector,
- Social disapproval of privatisation and the ensuing changes, evoked by mistakes made in the course of privatisation in other sectors as well as negative propaganda made by some populist politicians.

Conclusions

In last few years, the Polish electricity sector has taken some very important steps:

- The Polish power system has been connected to the West European system,
- The new Energy Act has been implemented, establishing the framework for new energy policy,
- A new market system has been created,
- The privatisation of the electric energy sector has started and is in progress,
- More rational use of electricity, motivated by the new pricing system,
- Successful pollution reduction measures have been undertaken by energy enterprises.

Despite barriers to the electric energy sector development and some unsolved problems, the Polish energy sector is moving towards liberation. Several solutions implemented in Poland as well as problems that accompany the transition, are worthy of consideration by other countries that are transforming their energy sector.

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Mantorski Z. (1998). Is There any Electricity Market in Poland? Proc. of the 21st IAEE Annual International Conference, Quebec, pp. 465-472.

Mantorski Z. (1999). Polish Electricity Sector on the Way Towards European Union. Proc. of the 22nd IAEE Annual International Conference, Rome, pp. 303-307.

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Swiss Association for Energy Economics (SAEE) and Centre for Energy Policy and Economics (CEPE)

Modelling in Energy Economics and Policy

Swiss Federal Institute of Technology Zurich (ETH) – Zurich – Switzerland
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Sessions and themes of the Conference will be structured along the following topics:

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Abstracts should be between 300-600 words. All abstracts should clearly address the themes of the conference listed in the invitation. The deadline for submission of abstracts: January 31, 2004. All papers accepted and returned in time will be included in the conference proceedings. At least one author from an accepted paper must pay the registration fee and attend the conference to present the paper.

Abstracts, papers and inquiries should be submitted to the SAEE conference secretariat:
Centre for Energy Policy and Economics (CEPE), Attn: Marianne Schindler, ETH Zentrum WEC C 12.1 CH-8092 Zurich, Switzerland.
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Please mark your calendar for this important conference. Some of the key selected themes and sessions for the conference are listed below. The plenary sessions will be interspersed with concurrent sessions designed to focus attention on major sub-themes. Ample time has been reserved for more in-depth discussion of the papers and their implications.

North American Energy Security and Reliability
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- Interdependence
- Opportunities
- Vulnerabilities

Continental Trade and Transportation: Forward or Reverse?
Session Co-Chairs: Joseph M. Dukert, Energy Consultant and
Shirley J. Neff, Goldwyn International Strategies
- Competitive economics or dated policies
- Transparency and regulatory harmonization
- Corporate interests versus political realities

Gas and Power–Convergence or Divergence?
Session Co-Chairs: Michelle Michot Foss, University of Houston and
Javier Estrada, Consultant
- Midstream issues: affiliate, market power
- LNG: myth or reality?
- What if low gas prices really were the excuse for power restructuring?

Environment and Energy in North America
Session Co-Chairs: Rafael Fernandez, PEMEX-Mexico and
Jean T. Bernard, Universite Laval
- Present energy/environmental state of affairs under NAFTA
- U.S. energy policy and growing environmental concerns
- Looming regional environmental challenges

Oil and Gas in Mexico
Session Co-Chairs: José A. Ceballos, PEMEX and
Roberto Osegueda, PEMEX
- Oil and gas reserves
- Natural gas supply-demand balance
- PEMEX strategic plan 2003-2011

Role of State Owned Utilities in North America
Session Co-Chairs: Andre Plourde, University of Alberta and
Daniel Reséndiz, CFE
- Present role of state owned utilities (SOUs)
- Obstacles/opportunities created by SOUs
- SOUs' role vis a vis private enterprises

There are 24 planned concurrent sessions. The abstract cut-off date is June 13, 2003. Given the location of the meeting in Mexico City, we anticipate a good draw to our concurrent sessions. The conference organizers strongly suggest that you get your abstract in early so that prompt follow-up can be given.

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Integrating the Energy Markets in North America: Issues & Problems, Terms & Conditions

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Interns should be inquisitive, internet literate, goal oriented, able to meet a deadline, group compatible, visualize the big picture, cost of service minded and neutral. All disciplines, especially non energy trained, are welcome. The energy model will be in U.S.$, btu's and English.

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Interns, please forward you interest and expertise to Houston Energy Chamber of Commerce, Box 820228, Houston, TX, 77282 Telephone 713 467 4732, fax 281 497 4128 email: dalesteffes@houston.rr.com.

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The IAEE annually puts together an academic session at the ASSA meetings in early January. This year's session will be structured by Professor Fred Joutz of The George Washington University.

The theme for the session will be "*The Value of and Role for Government/Strategic Inventories in Petroleum Markets*." If you are interested in presenting a paper, please send an abstract of 200-400 words to Fred Joutz at bmark@gwu.edu by May 23, 2003. If you are willing to be a paper discussant, email your interest by that date as well.

Preliminary decisions on papers to be presented and discussants will be made by July 1, 2003. The program including abstracts will be posted at www.iaee.org by September 1, 2003. Papers and comments will be published with those for the North American meeting of the USAEE/ IAEE that follows the January meeting. Please send abstracts in electronic format that is easily converted into program information. (e.g. WORD, WP, or text file).

For complete ASSA meeting highlights and pre-registration information please visit: http:// www.vanderbilt.edu/AEA/index.htm.

Publications

The Earth Policy Reader, Lester R. Brown (2003). Price: $16.00. Contact: Earth Policy Institute, 1350 Connecticut Ave., NW, Ste 403, Washington, DC 20036. Phone: 202-496-9290. Fax: 202-496-9325. Email: epi@earth-policy.org URL: www.earth-policy.org

Energy Industry Almanac 2002-203. 570 pages. Price: EUR 214. Contact: Plunkett Research, Ltd. Fax: 353-1-4957318 URL: www.researchandmarkets.com/reports/6762

Annual Oil Market Forecast and Review 2003. Price: #650.00 cd/print. Contact: Marketing Department, Centre for Global Energy Studies, 17 Knightsbridge, London, SW1X 7LY, United Kingdom. Phone: 44-20-7309-3610 Fax: 44-20-7235-4338 Email: marketing@cges.co.uk URL: www.cges.co.uk

Testing Times: The Future of the Scandinavian Electricity Industry. Price: NOK 600. Contact: ECON Centre for Economic Analysis, PO Box 6823 St. Olavs pl., N-0130 Oslo, Norway. Phone: 47-45405000. Email: econ@econ.no URL: www.econ.no

Calendar

5-7 May 2003, Environmental Progress in the Petroleum and Petrochemical Industries at Bahrain. Contact: Conference Secretariat, Bahrain Society of Engineers, PO Box 835, Manama, Bahrain. Phone: 727100. Fax: 729819 Email: bseng@batelco.com.bh URL: www.mohandis.org

8-9 May 2003, Coaltrans Americas 2003 Conference & Exhibition at Sheraton Bal Harbour Beach Resort. Contact: Sonia Gomm / Judith Storr, Coaltrans Conferences Ltd, London, EC4 5EX, UK. Phone: +44 20 7779 8945. Fax: +44 20 7779 8945 Email: coaltrans@euromoneyplc.com URL: www.coaltransconferences.com/show.asp?id=ECK76

10-11 May 2003, 4th National Energy Conference Spring 2003 at Tehran, Iran. Contact: Marjaneh Etemadi, International Affairs Department, World Energy Council, PO Box 14665-415, Tehran, IRAN. Phone: 98-21-8084595. Fax: 98-21-8084687 Email: IRNEC2003@iranenergy.org.ir

12-23 May 2003, "New Era in Oil, Gas & Power Value Creation" at Houston, TX. Contact: Ms. Aisha Hanif. Phone: 713-743-4634. Fax: 713-743-4881 Email: energyinstitute@uh.edu URL: www.energy.uh.edu/new_era.asp

12-13 May 2003, Distributed Generation at San Francisco, CA. Contact: Conference Coordinator, The Center for Business Intelligence, Registration Department, 500 W Cummings Park, Ste 5100, Woburn, MA, 01801, USA. Phone: 781-939-2438. Fax: 781-939-2490 Email: cbireg@cbinet.com URL: www.cbinet.com

15-16 May 2003, 3rd Annual Bolivian Energy Summit: Leading the Southern Cone Gas Market at Santa Cruz, Bolivia. Contact: Naheed Sharmin, Marketing Manager, CWC Associates Limited, 3 Tyers Gate, London, SE1 3HX, United Kingdom. Phone: +44 207 089 4100. Fax: +44 207 089 4201 Email: nislam@thecwcgroup.com URL: www.thecwcgroup.com/conferences

15-16 May 2003, GTL World Forum at London. Contact: Elina Watson, Marketing Executive, CWC Associates Limited, 3 Tyers Gate, London, SE1 3HX, United Kingdom. Phone: +44 207 089 4100. Fax: +44 207 089 4201 Email: ewatson@thecwcgroup.com URL: www.thecwcgroup.com/conferences

15-16 May 2003, Contract Risk Management in the LNG Supply Chain at The Café Royal, London, UK. Contact: Customer Services, Oil & Gas IQ (A division of IQPC), Anchor House, 15-19 Britten Street, London, SW3 3QL, UK. Phone: +44 (0) 20 7368 9300. Fax: +44(0) 20 7368 9301 Email: enquire@iqpc-oil.com URL: www.iqpc-oil.com/GB-1982/ediary

15-16 May 2003, Flow Assurance: A Holistic Approach at The Hyatt Regency Hotel, Houston TX. Contact: Customer Services,

(continued on page 36)

Calendar *(continued from page 35)*

Oil & Gas IQ (A division of IQPC), 150 Clove Road, PO Box 401, Little Falls, New Jersey, 07424-0401, USA. Phone: (1) 973 256 0211. Fax: (1) 973 256 0205 Email: enquire@iqpc-oil.com URL: www.iqpc-oil.com/NA-1997/ediary

18-21 May 2003, The Hydrogen Economy: Challenges and Strategies for Australia Including The Tidal Energy Link at Broome, Australia. Contact: Rebecca Emery, Hartley Management Group, Dept of Industry, Tourism and Resources, Australia. Phone: 618-8363-4399 Email: hydrogen@hartleymgt.com.au URL: www.hartleymgt.com.au/hydrogenbroome

20-24 May 2003, World Fiscal Systems for Oil and Gas at London. Contact: Victoria Watt, Head of Marketing, CWC Associates Limited, 3 Tyers Gate, London, SE1 3HX, United Kingdom. Phone: +44 207 089 4100. Fax: +44 207 089 4201 Email: vwatt@thecwcgroup.com URL: www.thecwcgroup.com/conferences

20-22 May 2003, 78th Annual Intl School of Hydrocarbon Measurement at Oklahoma City, OK. Contact: Leon Crowley, ISHM Arrangements Chairman, 1700 Asp Avenue, Norman, OK, 73072, USA. Phone: 405-325-1217. Fax: 405-325-7698 Email: lcrowley@ou.edu URL: www.ISHM.info

26-28 May 2003, Renewable Energy Sources for Islands, Tourism and Water Desalination at Hersonissos, Crete, Greece. Contact: Jolanda Crettaz, EREC - European Renewable Energy Council, The Renewable Energy House, 26, rue du Trône, Brussels, 1000, Belgium. Phone: + 32 2 546 1933. Fax: + 32 2 546 1934 Email: erec@erec-renewables.org URL: www.erec-renewables.org

26-28 May 2003, Maghreb & Mediterranean Oil & Gas 2003 at Mansour Eddanhbi & Palais Des Congres, Marakech, Morocco. Contact: Babette Van Gessel. Phone: 27 11 778 4360 Email: babette@glopac.com URL: www.petro21.com

27-30 May 2003, Extreme Events & Energy, Agricultural and Natural Resource Management at Boston, MA. Contact: Conference Coordinator, Global Warming Intl Center, PO Box 5275, Woodridge, IL, 60517, USA. Fax: 630-910-1561 URL: www.globalwarming.net

28-30 May 2003, Using Real Options to Value & Manage Natural Resource Projects at Colorado School of Mines. Contact: Graham Davis, Colorado School of Mines, Golden, CO, 80401, USA. Phone: 303-273-3321. Fax: 303-273-3314 Email: gdavis@mines.edu URL: www.mines.edu/outreach/cont_ed

29-30 May 2003, Central American Energy: Opportunities & Investments at Houston, TX. Contact: Conference Coordinator, Strategic Research Institute, 236 W 27th St 8th Flr, New York, NY, 10001, USA. Phone: 888-666-8514. Fax: 646-336-5891 Email: info@srinstitute.com URL: www.srinstitute.com

4-5 June 2003, 5th Annual Conference: Oil and Gas in the Gulf of Guinea at London. Contact: Elina Watson, CWC Associates. Phone: +4420 7089 4200. Fax: +4420 7089 4201 Email: ewatson@thecwcgroup.com URL: http://www.thecwcgroup.com/conferences/welcome.epml?confmaster.REF=81

4-7 June 2003, 26th Annual IAEE International Conference - New Challenges for Energy Decision Makers at Prague, Czech Republic. Contact: Jan Myslivec, General Chair, Czech Association for Energy Economics, Odboru 4, 120 00 Prague 2, Czech Republic. Fax: 420-2-2492-2072 Email: jan.myslivec@wo.cz URL: www.iaee2003Prague.cz

8-10 June 2003, CERI 2003 Petrochemical Conference - Framing the Future at Kananaskis, Alberta, Canada. Contact: Deanne Landry, Conference Division, Canadian Energy Research Institute, 150, 3512 - 33 St NW, Calgary, AB, T2L 2A6, Canada. Phone: 403-220-2380. Fax: 403-289-2344 Email: conference@ceri.ca URL: www.ceri.ca

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