IAEE INTERNATIONAL ASSOCIATION FOR ENERGY ECONOMICS

Newsletter

Published by the Energy Economics Education Foundation, Inc.

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Third Quarter 2004

President's Message

I am very happy to report on the success of two recent conferences. Despite initial setbacks, registrations at the Iranian conference held last May in Tehran exceeded 800. The organisation and facilities were excellent and a very stimulating atmosphere ensured that Majid Abbaspour and his team enjoyed the success that they thoroughly deserved. Of special note was an excellent closing debate featuring energy journalists discussing current oil market trends, concluding with active and enthusiastic audience participation.

There was almost 400 participants at the 24th Annual North American Conference of the USAEE/IAEE held in Washington from 8 to 10 July, including 27 student scholarship holders: the highest number to date at any of our conferences. Although a consistently high standard of plenary session presentations was a feature of the conference, it would be remiss of me not to mention the invited lunch address by Tom Casten, CEO of Primary Energy LLC. Entitled *Economic Growth and the Central Generation Paradigm*, Tom held the audience in rapture with his brilliantly articulated message. His presentation will be placed on the IAEE website and I encourage those who were not fortunate enough to be present to take a serious look at his message. Congratulations to Mine Yucel, her conference co-chairs, and her conference committee for assembling an excellent program.

I have already mentioned the student scholarship holders, and I would like to encourage individuals and companies to join those currently supporting this program with additional funding. We are building a broad and intellectually rigorous base for the IAEE's future through this program, and it is really delightful to see so many enthusiastic young energy economists in our midst. Many thanks to the current sponsors, the results of your generosity are very apparent. Also many thanks to those professors who are using their research grants to provide air fares for students to attend IAEE conferences.

Over the next few months I intend to devote some effort to expanding services provided to our student members. I will be writing to all Affiliate leaders asking them to nominate a student who would be willing to act as a liaison officer, or representative, for their affiliate. This will enhance the efficiency of communications between the student Council members and their colleagues around the globe and, hopefully, encourage greater student participation in the Association's activities.

At the Council Meeting held in Washington just prior to the conference, a proposal by the German affiliate to hold the 2006 International Conference of the IAEE in Potsdam was approved. Details will be made available shortly on the IAEE website.

Finally, welcome to the Spanish Association for Energy Economics whose application for IAEE affiliate status was approved at the last Council meeting.

Tony Owen

Editor's Notes

James Sweeney comments on the three issues that have always been considered in energy policy: (1) reducing the environmental impacts of energy production, distribution, etc., (2) providing security against disruption of the supply system, and (3) supplying and using energy at a reasonable cost. He then introduces molecular hydrogen as a possible new energy carrier. He reviews the similarities of this carrier and electricity and suggests that together they offer any nation the ability to harness whatever primary energy resource it

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has available.

Carol Dahl and Balázs Nagy report that Enterprise Application Integration (EAI) technologies are becoming more and more popular in energy industries. Because these applications cost in the 10s of millions of dollars to implement, the choice of the best system is an important business decision and in some cases can be a 'do or die' proposition. They provide some guidance for the choice of EAI technologies for energy companies and include a brief history of information technologies that have led up to EAI.

Petter Osmundsen, Frank Asche and Klaus Mohn examine the return on capital employed as an indicator of market value for a select group of oil and gas companies. The econometric relations established indicate a positive but somewhat fragile relation between return on capital employed and market-based cash-flow multiples, while a simple valuation model proves to have a high explanatory power for oil sector valuations.

Poul Morthorst notes that within the past ten years the global installed capacity of wind power has increased from approximately 2.3 GW in 1991 to more than 40 GW at the end of 2003, an annual growth rate of more than 25%. However, only a very few sites, with high wind speeds wind power, are economically competitive with conventional power production. He examines how the economics of wind power has developed in previous years and how it is expected to develop in the near future.

Roger Bentley and Michael Smith note that many petroleum geologists now recognise that the decline in global discovery of onshore and offshore oil reserves since the mid-1960s will lead to a period in which the world will begin to want more oil that it can produce and that this will occur in the near to medium term. They look at the supply-side of this issue, and, given the estimated resource base, identify a range of world oil production profiles allied to a realistic set of investment constraints. The study considers maximum global oil supply capacity to 2050, including the impact of supply increases in non-conventional oil, in particular that of oil (tar) sands in Canada and Venezuela.

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FUTURE USAEE / IAEE EVENTS

Annual Conferences

November 21-22, 2004	1st Annual CZAEE International Conference Prague, Czech Republic The Municipal House
June 3-6, 2005	28th IAEE International Conference Taipei, Taiwan Grand Hotel
August 28-30, 2005	8th Annual European Conference Bergen, Norway
September 18-21, 2005	25th North American Conference Denver, Colorado, USA Omni Interlocken Resort

7th USAEE/IAEE/Allied Social Science Association's Meeting, Philadelphia, PA – January 7 - 9, 2005

The IAEE annually puts together an academic session at the ASSA meetings in early January. This year's organizing committee will be Carol Dahl of the Colorado School of Mines and Fred Joutz at George Washington University.

The theme for the session will be "Volatility in Energy Markets."

Papers presented at the session will be published in the Proceedings of the next North American Conference of the USAEE/IAEE.

The program including abstracts will be posted at www.iaee.org/en/conferences by September 1, 2004.

For complete ASSA meeting highlights and pre-registration information please visit:

http://www.vanderbilt.edu/AEA/anmt.htm

28TH IAEE ANNUAL INTERNATIONAL CONFERENCE

Hosted by:

International Association for Energy Economics (IAEE)

Chinese Association for Energy Economics (CAEE)

Globalization of Energy: Markets, Technology, and Sustainability

3-6 June 2005

at the Grand Hotel, 1 Chung-Shan N. Road, Section 4, Taipei, Taiwan 104, ROC

Conference Themes and Topics

1. Prospects of Global Energy Development:
- Global and Regional Energy Demand and Supply
- New Paradigm under the World Trade Organization
- Restructuring and Deregulation
- Inter-Regional Energy Security and Reliability
- Liberalization and Market Power
- Role of International Energy Suppliers

2. Prospects of Energy Technology Development:
- Green and Renewable Energy Technology
- Conservation Know-how and R&D
- Fuel Cell and Hydrogen Technology
- Distributive Energy Systems
- Diffusion and Collaboration in Energy Technology

3. Sustainability:
- Sustainable Energy Development
- Global Warming and Energy
- Energy and Pollution Control
- Nuclear Safety and Waste Disposal
- Rationality and Energy Selections
- Policy Options and Strategies

Keynote Plenary Session Theme:
- The Future of Energy

4. Individual Energy Sectors:
- Coal
- Oil
- Natural Gas (including LNG)
- Electricity
- Renewable Energy and New Energy

5. Energy Efficiency and Energy Modeling:
- Energy Statistics and Energy Efficiency Indicators
- Energy Modeling, Simulation, and Forecasting
- Energy Conservation Program and Demand-Side Management
- Integrated Resource Planning and Demand Response
- ESCO and New Business Models

Dual Plenary Session Themes:
- The Middle East Situation and Energy Security
- Regulation vs Deregulation of the Energy Market
- The Impact of GHGs Emission Control on Energy Supply and Demand
- Rethinking Nuclear Energy
- Prospects of New Energy Technology
- The Scope and Potential of Renewable Energy

***** CALL FOR PAPERS *****

Abstract Submission Deadline: 2 December 2004

(Include a short CV when submitting your abstract)

We are pleased to announce the first Call for Papers for the 28th IAEE Annual International Conference entitled 'Globalization of Energy: Markets, Technology, and Sustainability', scheduled for 3-6 June 2005 at the Grand Hotel in Taipei. Please mark your calendar for this important conference. There will be at least 7 plenary sessions and 27 concurrent sessions, as well as 5 poster sessions. During the conference, we will also ensure that you and your spouses can enjoy the wonderful hospitality and rich content of traditional Chinese and Taiwanese culture.

Abstracts should be double-spaced and between 300-500 words giving an overview of the topic to be covered. Abstracts must be prepared in standard Microsoft Word format or Adobe Acrobat PDF format and within one single electronic attachment file. Complete contact details should be included in the first page of the abstract, which should be submitted to the CAEE conference secretariat either through the e-mail system (as an electronic mail attachment) or the postal system (in a 1.44Mb diskette) to: **Yunchang Jeffrey Bor**, Ph.D., Conference Executive Director, Chung-Hua Institution for Economic Research (CIER), 75 Chang-Hsing Street, Taipei, Taiwan 106, ROC, Tel: 886-2-2735-6006 ext 631; 886-2-8176-8504, Fax: 886-2-2739-0615, e-mail: iaee2005@mail.cier.edu.tw

General Organizing Committee

Vincent C. Siew: General Conference Chairman; Chairman of the Board, Chung-Hua Institution for Economic Research (CIER), Taiwan, ROC. **Yunn-Ming Wang**: Program Committee Chairman; Chairman of the Board, Chinese Association for Energy Economics (CAEE), Taiwan, ROC. **Neng-Pai Lin**: Organizing Committee Chairman; Chairman of the Board, Taiwan Power Company; Taiwan, ROC. **Ching-Tsai Kuo**: Sponsorship Committee Chairman; Chairman of the Board, Chinese Petroleum Corporation, Taiwan, ROC.

IAEE BEST STUDENT PAPER AWARD: US$1,000 cash prize plus waiver of conference registration fees. If interested, please contact IAEE headquarters for detailed applications/guidelines. **STUDENT PARTICIPANTS**: Please inquire about scholarships for conference attendance to **iaee@iaee.org**

The Energy Policy Triangle and Molecular Hydrogen

By James L. Sweeney*

Three fundamental issues are now and have always been explicit or implicit in energy policy – reducing environmental impacts of energy production, distribution, use; providing security against disruption of the supply system; supplying and using plentiful energy at a reasonable cost. These issues together are what I call the *energy policy triangle*.

I would like to make a few observations about the energy policy triangle and then relate my observations to the quest for a new energy carrier: molecular hydrogen, which might take a place comparable to that of electricity.

Environmental Impacts

We have learned or are learning to deal with most of the worst environmental impacts of energy use. In the U.S. we have reduced acid rain precursors from electricity generation and could choose to reduce them further. The allowable criterion pollutants from new automobiles have been reduced by orders of magnitude, so that the biggest problem now is old, super polluting vehicles. We do find environmental problems with emerging technologies, e.g., avian and bat kills from wind turbines, but we are attacking such problems. Air and water pollutants from refineries are tightly controlled.

But there is one problem we have not learned to control – carbon dioxide releases from combustion of fossil fuels. There is basically a one-for-one linkage between the amount of gasoline we use and the carbon dioxide released from combustion of that gasoline. Combustion of coal in electricity generation releases carbon dioxide basically proportional to coal use.

And the evidence is persuasive that the accumulation of atmospheric carbon dioxide can be expected to change the patterns of global heat flow, increase average global temperature, modify rainfall patterns, increase severity of tropical storms, raise ocean levels, sharply disrupt many ecosystems, and accelerate the extinction of species. Scientists have identified other risks, for example, that the ocean "conveyor belt" could be shut down, leading to a sharp decreases in European temperatures.

Internationally we have the Kyoto protocol as a response, but that has not been universally ratified and has been rejected, for good reasons, in the United States, and may not be met in some countries who have ratified the protocol. A problem is that the protocol tells us what commitments are expected by various countries but does not make such changes economically viable. Nor does it assure that the changes will happen. To meet the goals requires not simply institutional and economic changes, it needs technological advances.

Thus, the challenge is to create technologies that allow us to continue supplying plentiful energy at a reasonable cost, while sharply reducing or eliminating carbon dioxide releases into the atmosphere.

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*James L. Sweeney is Professor of Management Science & Engineering at Stanford Univestiy. This is an edited version of his talk at the 24th North American Meeting of the USAEE/IAEE held in Washington, DC, July 8-10, 2004.

This challenge will bring me to electricity and hydrogen as two energy carriers that could, in principle, meet these objectives.

We also have to broaden our focus to include the non-fossil fuel releases of greenhouse gases. We need to seriously think about adaptation to the changing circumstances in parallel to our focus on mitigation. But these are not fundamentally energy issues and I would like to focus here on energy topics.

Security Issues and Associated Disruption of the Energy Supply System

For many of us old-timers, the public policy focus of energy started with security issues. The 1973 war in the middle east, reduction in production of oil by Saudi Arabia and other middle eastern countries, coupled with inventory buildups by oil users led to a rapid jump in world oil prices, which in turn created a world-wide depression and indirectly led to world-wide inflation. Those changes were coupled with an embargo of oil exports against the U.S. and the Netherlands. Although ineffectual, the embargo showed that oil might be used as an economic weapon. The world saw that the entire world economy was vulnerable to oil supply interruptions.

In the United States that led to the call for Project Independence; to creation of the department of Energy. It led to the International Energy Agency. Our very organization – the IAEE – never would have been organized without that energy shock.

Since that time we have come a long ways. Since 1973, oil use has grown little while the world's economic activity soared, so now oil expenditures are a relatively small fraction of world gross product. The strategic petroleum reserve can provide some shock absorber against oil price spikes. Oil is produced in many more areas of the world than in 1973. And during the many years of excess production capacity, OPEC nations deliberately reduced the severity of price jumps, although they have also kept oil prices elevated above competitive levels. Natural gas has grown as an alternative to oil, creating more supply diversity.

But we now must return our attention to oil supply vulnerability. The recent and projected future growth in world oil demand, driven by the recovery in the world economy and in the growth trend of automobiles in China, implies that world oil markets may be tight for decades to come. It is not just that tight oil markets imply higher oil prices. I am more concerned that the tighter the market, the greater the price jump that would stem from an oil supply disruption and the more damaging would be the impacts on the world economy.

Second, I believe that the probability of oil supply disruptions is higher than ever. I no longer expect OPEC countries to use oil as a political weapon. But the growth of world-wide terrorism and the vulnerability of oil infrastructure suggests increasing risk. In Iraq the oil infrastructure has become a target. In Saudi Arabia, once thought to be internally secure, there are now terrorist attacks, some directed toward the oil system and its workers. The weapons of terrorist networks are becoming more powerful and more unpredictable. I personally would not be surprised to see a low-yield nuclear bomb detonated somewhere (and I hope it is low yield). Thus I believe the risk, including the risk of major disruptions to oil supply infrastructure is greater than ever. Now, maybe some of you can show that I am wrong and I fervently hope I am wrong. But, if I am right, then the combination of increased probability of disruptions and a tighter oil market implies that we are back into the high risk area so prevalent in the early 1970s.

Thus, a challenge is to reduce the vulnerability of our oil supply system. That may mean finding ways of sharply moving away from oil. It may mean hardening soft targets. It may mean development of other shock absorbers in the system. It demands out-of-the box creative thinking followed by policy choices, some of which may be costly.

But issues of security and vulnerability are not limited to the oil system. As we develop international trade in liquified natural gas, we may find that some of the same issues arise. Large concentrations of valuable resources creates economic incentives to gain control of those resources, possibly by military force. If the world economy becomes dependent on natural gas trade for a large share of its energy needs and if LNG supply becomes concentrated in unstable parts of the world, we may face similar vulnerability problems.

On a more local scale, more centralized energy systems, from which more energy must be moved, provide more attractive targets for terrorist attacks. And they can become more vulnerable to inadvertent disruptions, as the power blackout in the U.S. Northeast illustrated.

This issue of energy security will bring me to electricity and hydrogen as two energy carriers that have, in principle, the opportunity of helping to meet these objectives, if managed appropriately.

Two Energy Carriers: Electricity and Hydrogen

Superficially, electricity and molecular hydrogen are very different. First, the form is different – one is moving electrons requiring a circuit for movement, the other is a very simple gaseous molecule. Electricity is produced at the very moment it is used; hydrogen can be produced and stored indefinitely. We have developed ways of using electricity for every generic energy need – heating, cooling, lighting, mobility, communication. Many of these uses are very economical. On the other hand we have found economical ways of using hydrogen only in chemical processes, such as hydro-cracking heavy petroleum and fertilizer manufacture, purposes for which electricity cannot serve.

But at a more abstract level, there are many similarities between electricity and hydrogen. And those similarities underlie my hope in the development of hydrogen as a parallel to electricity for our energy system.

First, as we all know, neither electricity nor molecular hydrogen are primary energy sources, but are produced from primary sources. Thus I will refer to them as energy carriers. This is important: neither are in themselves energy supplies but must be produced from other energy sources.

Second, I believe that electricity and hydrogen could ultimately both be available for virtually all generic energy uses. In this vision, hydrogen and electricity would compete as energy carriers, with their differing physical properties giving one or the other a competitive advantage for particular uses. Market and policy forces would determine where electricity was used and where hydrogen was used.

This <u>does</u> require development of economical hydrogen fuel cells and the improvement of hydrogen storage. But with such fuel cells, we could convert hydrogen to electricity at the point of use. Thus hydrogen could satisfy all uses of electricity. Hydrogen could be stored and used for mobile purposes, particularly transportation. Through fuel cells, we could have rechargeable hydrogen batteries. And, direct combustion of hydrogen could provide uses of hydrogen not feasible for electricity.

There is a third similarity. Neither hydrogen nor electricity lead to emissions of carbon dioxide at the point of use, nor do they release other criterion pollutants. Hydrogen simply releases water and heat after it combines with oxygen; electricity releases heat and possibly light. Thus, at the point of use, both electricity and hydrogen allow energy use without release of pollutants.

Fourth, both electricity and hydrogen can be produced using <u>any</u> primary energy resource. Of course, electricity can be produced using coal, natural gas, oil, hydro-power, nuclear, solar energy, wind, biomass, and geothermal energy. But so can hydrogen. We can gasify coal or biomass to produce hydrogen. We can use a steam shift reforming of natural gas. We may be able to use high-temperature nuclear to dissociate water into hydrogen and oxygen. And, using electrolysis, we can convert electricity, produced using any other resource, including the renewables, into hydrogen. So hydrogen can be produced using any primary energy resource that can be used to produce electricity. Whether this is economical or not, of course, is a different matter.

Thus, both electricity and hydrogen allow the <u>potential</u> for any nation to harness whatever primary energy resources it has available to produce energy for all uses. This may be domestically produced; it may be imported. But since the many different primary energy sources are broadly distributed around the world, either of these energy carriers have the potential of sharply reducing the security risk of highly-geographically concentrated supplies of hydrocarbons.

Although both electricity and hydrogen are carbon-dioxide free at the point of use, they either may or may not be carbon-dioxide free at the point of production. Hydropower, solar, nuclear, and wind are inherently carbon-dioxide free for hydrogen or electricity production. Thus each offers the potential, using either energy carrier, of a complete supply chain free of carbon dioxide emissions. Other primary resources, particularly coal, natural gas, and oil, include carbon. But even for these, there is the potential to separate carbon dioxide from the gas stream and sequester it permanently, in spent oil and gas reservoirs, in coal beds, or in salt water aquifers. And biomass-based hydrogen offers the possibility of fixing carbon dioxide from the atmosphere and then sequestering that carbon dioxide when the biomass is used to produce hydrogen. This would pump carbon dioxide from the atmosphere.

Here there appears to be an advantage to hydrogen over electricity. It appears that carbon dioxide separation will be easier and less costly in production of hydrogen than electricity. But technological advances may provide new methods for separation in the process of electricity generation.

In principle, then, with appropriate technological advances, at some future time we potentially could have two competing energy carriers, hydrogen and electricity, each allowing use of a broad variety of primary energy sources, each allowing abundant energy with no carbon-dioxide release at the point of production or the point of energy use. This vision may use little, if any, refined petroleum products as energy carriers.

In this vision, the different physical properties of electricity and hydrogen could help determine which of the two would be used for various energy needs. For example, electricity could be used in all-electric vehicles, but only if battery technology advances greatly. Hydrogen, since it is storable on vehicles and allows for quick refueling, could be the more attractive alternative. For heating and lighting, electricity delivered through the grid is likely to be more economical than hydrogen used to generate electricity on site. But, back up generators based on fuel cells could convert electricity to hydrogen and hydrogen back to electricity when backup power was needed. It is not obvious whether hydrogen based batteries or electrical rechargeable batteries would be more competitive for portable electronic devices.

So what is the problem with this vision? Technology and economics. For hydrogen use, fuel cells are still far too expensive and have too short lives to compete in automobiles with gasoline or diesel fuel. Proton exchange member fuel-cells need too much platinum or other noble metals. Adequate storage of hydrogen on board vehicles is a technological and safety problem. For electricity, battery technology does not yet allow long range for electric vehicles nor quick recharging time. So we still use oil for almost all our light-duty vehicles, in the U.S. and around the world. But changing technologies could make oil the less economical alternative.

I believe that production of hydrogen from biomass is apt to remain too costly, absent technologies not currently envisioned. Land constraints may also make hydrogen from biomass economically not viable. But we have all been surprised with new technologies.

Movement of hydrogen by pipeline or truck is far more expensive than movement of electricity, creating a major disadvantage for hydrogen. But hydrogen production relatively near the point of use could give hydrogen an overall cost advantage in mobile uses, even if electric battery technologies were to advance. Electrolyzers are still very far too costly to economically convert electricity to hydrogen, except for specialized non-energy purposes, but that could change. We know we can sequester carbon dioxide – we do so in the Slepner field – but we don't know whether we can do so on as broad a scale as needed. And we don't know whether we can permanently sequester the carbon dioxide.

Technologies don't just happen. They are created by scientific and engineering advances, by allocation of resources to bring technologies to fruition. By private sector organizations, by government agencies and laboratories, by universities. How we should allocate those science and technology efforts is not obvious, nor is it obvious how much this should be private sector and how much should be public sector.

So what else is the problem? Competition with the other energy carriers, natural gas and refined petroleum products. Technologies for use of these carriers will not remain stagnant. For example, hybrid electric vehicles, now rapidly growing as a technological option, allow better fuel economy and thus lower cost of gasoline than conventional vehicles. And hybrid electric mid-size vehicles and SUVs will soon be available. The greater conversion efficiency of a fuel cell may not be enough to compensate for higher capital costs of vehicles or higher costs of hydrogen, relative to gasoline. If hybrid electric vehicles remain more economically attractive than hydrogen or electric powered vehicles for driving cars and trucks and if natural gas remains more economical for heating homes, then even with technological advances in the hydrogen and electric system, we still will not get the environmental or security benefits, absent policy drivers.

And there are other problems. We need to manage safety risks for hydrogen, including standards for fueling stations, pipelines, ventilation of garages and tunnels. It will be costly to develop the appropriate infrastructure. The problem of having a dual fueling system – gasoline and hydrogen – for decades is clear. Assuring that there is enough local competition among fueling stations that retailers cannot exercise excessive market power will itself increase the cost of the system. Will there be unforeseen consumer acceptance issues – after all the grass is always greener until we get to the other side of the road.

Finally is policy. We have not seriously in the United States imposed carbon constraints or externality prices for carbon. The security costs of a tight oil market are socialized to the entire economy, not integrated into policy instruments that would push energy systems that are less vulnerable. But policy alone cannot be the answer, absent technology. We can set all the security or carbon dioxide policies we want, but without the technological advances, we will not have the two competing energy carriers envisioned here.

In short, we do not know whether we can reach this vision of two competing energy carriers, each carbon-dioxide free, each allowing a multiplicity of different primary energy sources, with sharply lower security risks, providing abundant energy around the world at reasonable costs. If we reach this vision, we do not know how quickly it can be reached. We just know that it will take many decades. Many decades seems like a long time. In some sense it is. But some of us in the room have been involved in energy policy for many decades. And if IAEE is successful as an organization, many of the students here at our conference will themselves be working in the energy field for many decades.

Thus I offer this vision to the distinguished members of the IAEE – especially the students who may well help guide evolution toward such a vision throughout their careers.

Leading Edge Information Technologies for Energy Industries

By Carol Dahl and Balázs Nagy*

History of Information Technologies

Information technologies are not new. They have evolved hand in hand with computer technology. They began over 50 years ago with mainframe computers and EFI (electronic fund transfer) and EDI (electronic data interchange) on VANs (value added networks) when banks and large corporations wanted a cheaper, safer and faster way to track and transfer funds and information. The first business packages were used for accounting in the 1960s and others soon followed. First generation office information systems included Digital Equipment's Decmail, IBM's Display Writer, and Wang's Office Information System in the late 1970s.

Supervisory control and data acquisition (SCADA) systems, which remotely controlled processes for pipelines, offshore oil and gas production, and electric utility production, transmission and distribution, were early energy applications of information systems. For example relays, which are electromechanical devices to turn on and off current, were used as early as the 1930s to control remote power stations in Sweden. Through the 1950s and beyond, systems were transformed from relays, to transistors, which had no moving parts and were faster and more reliable. Custom built SCADA systems were used to remotely measure and collect data on pressures, pump status, compressor status, temperatures, tank levels, valve status, possible leaks, and current levels among other things. Telephone lines, microwaves and radio waves were used to transmit data back to a central control station. SCADA systems could also be used to control processes through starting and stopping equipment and opening and closing valves. These central stations, often with banks of screens and dials, were monitored by humans who could then control an entire system from a central location. Early applications were run by mainframes, then minicomputers and finally microcomputers beginning in the 1980s.

With the proliferation of all these disparate computers systems each doing their own thing, communication between them became more and more complex. As a result, software companies such as SAP, which was launched in 1972, arose to provide customized business software to run on these various systems. Packages included accounting, provisioning, MRP (manufacturing resource planning), ERP (enterprise resource planning) and CRM (customer relationship management).

The apple cart was further upset when the Apple II appeared in 1977 and IBM developed its personal computer in 1981. Again disparate PC systems emerged and a need for cheap off the shelf operating systems and standard applications such as word processing, spread sheets, and data bases became a necessity. Moore's Law accentuated the problem with computing power doubling every 18 months. For example, the first computer ENIAC was 10 feet high, 150 feet wide, could do 5000 operations per second and cost millions of dollars to build. It used so much power to run its vacuum tubes that the lights in Philadelphia dimmed when it was turned on. However, by 1971, Intel had produced a 2 millimeter chip that was 12 times as powerful and cost only around $200.

As a result of increased software needs, software companies such as Microsoft, which was launched in 1975, arose to provide off the shelf business software to run on PCs. Sun Microsystems, launched in 1982, provided a replacement for the mainframes by using a modular framework that can grow as a company does. Sun provided powerful Unix based workstations, which could be connected to different classes of servers depending on the users computing needs. Landmark Graphics founded in 1982 built the first workstation for geoscientists to analyze seismic data, which had formerly been done on very large mainframes such as the Cray computer. Landmark was committed to integrated open systems for geophysical, geological and reservoir engineering analysis.

Mainframe second generation office systems beginning around 1983 evolved into third generation systems by the end of the 1980's. Digital Equipment's All in One became All in One Phase II and IBM Profs became Office Vision and both had moved to a client/server mode with PC's hooked to a centralized server. The server provides basic services and stores data for the client and might be located and maintained at the vendor's site. The client processes the data locally and may be connected to the server by the Internet or a private network.

If the client's system is very limited, it is called a thin client. In such a case, called an application service provider, the server provides the application, the data, and the computing power. Coffman (2000) lists the following services that ASPs provide to energy industries – data integration and interpretation, security, wideband network access, messaging and directories, web servers, document management, shared applications, network monitoring, and data management, storage and retrieval. An example for the oil industry is Geonet Services (www.geonet.com) started in 2000. Geonet offers almost 300 applications on their server from a range of vendors. Clients only pay for the time they use on an application.

Networks evolved in parallel with computers and provided powerful tools for connecting users to each other. Networks became ever more powerful as the number of connections increased — the value of the network increases, according to Metcalfes's Law, as the square of the number of connections. The Internet, with a burgeoning number of connections, was initially sponsored by the US and later other

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governments to enhance communication within research institutes, and speed nuclear research. It came to connect military, research, and educational institutions with commercial access allowed in 1991. The military split out onto its own network early on in the late 40's. The invention of the worldwide web (www) in 1989 at CERN in Geneva allowed people to access documents over the Internet easily.

Mosaic developed at the University of Illinois by Marc Andreasson and others in 1991, became the first commercial grade Internet browser available in 1993. With the new appealing graphical interface, the Internet became so popular that the government privatized it in 1995. Its use has mushroomed as a communication tool among businesses, consumers, and the government. By 2000, just over half of US households had a computer and just over 40% of them had Internet access. By 2001, it is estimated that over 60% of the US population had Internet access. The top 66 countries that represent over 90% of Internet connections are estimated to have an average connect rate of 10% of the population.

In the mean time at the enterprise level, so many different applications had been implemented to solve so many different problems - procurement, logistics, accounting - that communication between these applications became a critical problem. J.D. Edwards estimates that over half of Fortune 500 countries have more than 2 computer platforms that need to be linked together and to outside trading partners. Making these applications communicate with each other is called EAI (Enterprise Application Integration). One of the key events that triggered EAI was the 1996 Telecom Act. The Baby Bells were forced to open their systems and had to provide gateway solutions to enable access. The companies that required access (competitive local exchange carriers) also needed new tools to access, absorb, and use customer and telephony usage data. Companies such as Vitria, Tibco, and BEA were instrumental in providing these EAI software tools.

These same changes outlined above occurred in energy industries. Grinpelc and Siegfried (2001) outline how the transition towards using information technology has evolved in the oil and gas industry. Originally mainframe computers were employed in analyzing data and field samples. Special customized engineering applications were developed for their mainframe platforms followed by customized applications for back office activities, which include financial, human resources activities and distribution functions. Later desktop personal computers and portable field computers allowed work to be carried on independently of any central platform or even in the field. Customized software gave way to packaged software while stand-alone applications have become increasingly networked on Intranets or attached to client-server technologies. More recently there have been moves toward integration across the enterprise, data and technical platforms.

In the front office, which includes sales, marketing, and core business activities, there have been advances in seismic, engineering, geological tools, and e-commerce activities, while back office enterprise resource planning (ERP) is being used to develop enterprise wide information systems that tie front office, back office, customers and suppliers together in productive ways. ERP allows real time integration, analysis, and reporting of the enterprises activities, data and transactions.

Standardized information business packages with versions focused on the energy industry have been developed for information applications including enterprise resource planning (ERP), Customer Relationship Management (CRM), Human Resource Management (HRM), data warehousing (DW) sometimes called business intelligence (BI), and supply chain management (SCM), which provides links between the internal systems using ERP and outside suppliers and customers along the whole supply chain. Early or prominent leaders in developing these kinds of packages included SAP for ERP, Peoplesoft for HR, Siebel for CRM, CommerceOne and Ariba for E-Procurement and MicroStrategy, Cognos, and Sap BW for Data Warehousing DW. Armature, i2, and Manugistics are leaders in SCM.

As other industries such as energy industries have started de-regulation and as the Internet has become more acceptable and pervasive in enterprises, EAI is becoming even more powerful by creating a next generation EDI renamed B2B (Business to Business). However, B2B even though powerful is still a bilateral relationship. Therefore, EAI offers another level of transaction management, through Trading Partner Networks (TPN) which uses a hub or brain to connect the partners (businesses) to each other through the Internet. Only the best EAI tools can provide such an advanced infrastructure. Classic examples include ANX, which began by connecting auto-part suppliers and industrial users but has been extended into chemical, logistics, manufacturing and other industries, and Rosettanet, which connects computer part manufacturers and computer builders to each other. Transaction costs and inventories are reduced using these TPNs rather than the earlier dedicated private value added networks (VANs).

In addition to inter-application communication, a good EAI tool will provide a brain at the enterprise level that captures all the necessary business processes by controlling all the software applications. For example, Exxon hires a new geologist. The brain contains a rule based business process for new hires. It will instruct each application (e.g. accounting, HR (human resources), etc.) to perform sub processes to incorporate this employee's user data and needs into the system. Applications then communicate with each other through the brain.

The brain along with communication software are off the shelf applications designed to securely control the flow of information. Connectors, which interface between the brain and each application, translate data between the brain and the applications languages. Thus, the applications communicate through the brain. Most connectors can also be obtained off the shelf, however, for non-mainstream applications, they need to be custom designed.

These applications, which began with the telecoms, are becoming more and more popular in energy industries especially because of energy deregulation. So how are these technologies evolving and changing the way we do business? Schumpeterian notions of creative destruction suggest that the old will give way to the new. Almost ¾ of Fortune's 500 companies in 1955 no longer existed forty years later. The same thing will continue to happen with technologies as the old is absorbed, destroyed and replaced with the new. The old information technologies required writing, typing, printing, mailing and telephones with low bandwidth capacity. The new technologies require typing, electronic publishing, transfer, and customizing of products for users. They rely on the current telecommunication infrastructure, which is a mix of fiber optics, coaxial cable, copper wires, satellites, microwave and cellular spectrum with increasing moves to wider bandwidths.

It is interesting to consider how these technologies are being used, how they and their infrastructure evolve and diffuse, and how they will affect business structure in the energy industries. Technological determinism suggests that such groups of inventions influence many aspects of daily life including social change, income distribution, individual and social rights, employment, migration, privacy, sense or lack of community, and appropriate management styles. In the next section, we consider what business functions EAI will need to have.

EAI Business Functions

An EAI platform is expected to have the following three main areas of functionality:

- Internal Data Integration addresses internal data exchange. It typically involves a solution with messaging and data conversion.
- External Data Integration is mostly business-to-business integration. It typically involves a solution with messaging data conversion across the Internet, private networks or through an EDI VAN (Value-Added Network). However, Virtual Private Networks (VPNs) with strong encryption to protect the privacy of the data on the Internet are more and more replacing private networks.
- Business Process Management enables companies to manage and coordinate their business processes or procedures and must be able to perform workflow automation, that does not require decision making, as well as business process automation, which may require automated decision making. An additional aspect of business process management is to be able to analyze business data as it relates to business processes.

Companies typically first start looking into EAI solutions when they have a simple data conversion problem to solve. For example, an electric utility company may want to look at a data-oriented EAI solutions to consolidate information from some of their internal systems into a full view of their electricity provisioning capabilities and supply for customer service purposes. Or a utility may want to look at internal data integration solutions for sending provisioning orders to a power generator. Ideally, as companies see their business requirements becoming more complex, they want to be able to extend the integration work they've already done for their simple integration problems. Companies thus require platforms that scale well — in terms of both complexity and raw performance — as their business environment changes.

An energy company can use an EAI platform to integrate its software applications within their network, integrate with the supply side and demand side partners outside their network, and automate the business processes across the enterprise. With a successful EAI implementation, an energy company may realize the following benefits:

- Seize new business opportunities and create entirely new categories of businesses, such as trading hubs and electronic exchanges.
- Respond to change rapidly-before competitors.
- Form closer, more profitable relationships with partners and customers.
- Increase the efficiency of operations and lower operating costs by automating and analyzing business processes in real-time.
- Model and automate the business process to bring new products and services to market quickly.

Successful energy companies of the future are those who can integrate and automate their supply and demand chain globally. Companies that embrace eBusiness face unprecedented opportunities as they define new markets, unearth expanded revenue opportunities, as well as achieve higher levels of efficiency, customer loyalty, and customer satisfaction. EAI enables energy companies to capitalize on these opportunities.

The tools discussed below allow automation of manual processes within the organization or with trading partners. They allow legacy (previously installed) systems that did not talk to one another to now communicate. Reshaping or encapsulating the data into customized business objects enables legacy applications to communicate with the EAI infrastructure. In fact the whole legacy application can be encapsulated and integrated into the new system. Reshaping also provides a robust set of common services that guarantee business transactions, security, and data integrity.

EAI Software Components

To perform the previous EAI functions, the following software categories are used

1. Middleware.
2. Application Integration Software.
3. B2G Gateways and Trading Partner Networks.

Middleware is a piece of software that allows different software applications within a company to talk to each other. It involves mostly data conversion and data transfer. A benefit of middleware is that two different applications can behave as one from the user's perspective.

Application Integration Software uses middleware to create a live link between different applications within a company to ensure that transactions are completed successfully (transaction integrity). Components of this software include middleware, message brokers, applications servers, remote data-shapers and other integration software. A benefit is a smarter link that is in charge of data conversion, data integrity, and assures that the transactions "commit" in all integrated systems. Another benefit that these tools present besides letting internal applications talk to each other is to web-enable those same applications in the same effort.

B2B Gateways and Trading Partner Networks process business transactions between companies and take electronic interconnection to a whole new level. More than simply making connections, they provide a framework for establishing and enforcing industry standards that allow understanding the data that is being exchanged. Further, they allow agreement on the process that will be used to perform the transaction or to process the data being exchanged. For example, an oil trading TPN will contain data elements such as price, quantity, and grade and process elements such as how to convert currencies and or grades.

B2B Gateways and a central hub, both with similar software technology, form a TPN. TPNs generally follow two business models. In one model, a single company owns, operates and controls the business rules (standards, processes, legal environment, etc.) governing the transactions on the hub. For example, Dynegy has a TPN for energy trading.

In another model, an alliance of companies forms a trading community that operates through a hub. It differs from the first model because the alliance jointly determines the rules of conducting business and the owner of the hub merely operates according to the defined rules. With TPNs, the partners have the infrastructure for electronic connectivity and process automation among all market participants, including entities along the supply chain, to enhance operations and speed performance.

There are numerous benefits of TPNs. For example, they allow energy companies:

- to offer new services through aggregations of services,
- to reach new markets,
- to automate the energy supply chain (forming internal and external eCommunities), and
- to facilitate outsourcing of selected functions.

Utility.com provided a practical application of a TPN. Through its membership in Vitria's TPN, Utility.com was able to bond electronically with its key partners and suppliers, as well as other pre-existing e-Communities. Thus, it could bring new products and services to market faster, streamline its delivery chains, and lower its transaction costs. Alternately, Dynegy, mentioned above uses a TPN to streamline its supply chain from upstream oil and gas exploration to the distribution of electricity.

Comparison Criteria to Evaluate and Choose Technologies

Choosing an EAI technology can be done in house or by relying on a trusted consulting company, for whom references have been checked and who has a portfolio of similar successful implementations. Remember that bigger is not always better in this case.

Your first step in implementing your EAI project is to define requirements. Once you define your requirements you will need to select a vendor and a product. You derive a set of minimum benchmarks from your requirements that the vendor's product will have to meet. These benchmarks are based on the following:

- Vendor Expertise in EAI software technology as well as in the technology and structure of your industry segment.
- Maintenance and Cost of Ownership:
- the resources required to keep your system running,
- the resources required to keep adding features and functionality.
- Technology:
- support for XML is compulsory, as XML has become a de facto inter-application communication standard
- internal architecture based on CORBA, which is a sophisticated communication framework developed and maintained by the Object Management Group (OMG), may lead to higher efficiency,
- for legacy EDI connectivity, external CORBA support is required.

Having selected a short list of vendors using the above benchmarks, the final decision should be based on the following criteria. The technology should

- be flexible with the capacity to adapt to complex situations. For example, the more platforms an EAI tool can effectively support, the more valuable and flexible it is likely to be,
- be popular with a reasonable level of penetration for interoperability and support,
- minimize complexity of implementation for your given requirements,
- maximize expected success rate.

Some of the more prominent vendors that you might consider are: Vitria Technologies, BEA Weblogic, Tibco, and Web Methods. Also some smaller companies have good products which might perform better for some needs. They include Linguateq, Orchid Systems, Inc. and Jacada.

EAI Implementation Guidelines

For the implementation, you have the choice of in house staff versus outside consultants. In general, the staff required for the implementation stage is from 10 – 50 people. After implementation during the maintenance stage a smaller staff will suffice typically from 1 – 10 people. Typically in house implementation is cheaper but takes longer. Therefore, most of the EAI solutions are done with the help of a consulting company. Prominent examples of such companies include Accenture, AMS, BusinessEdge, CGEY, J.D. Edwards, KPMG, and PWC. All have major IT consulting branches that are capable of handling up to turnkey EAI integrations.

Whatever you do, we recommend that the main expertise should come from the vendor, who should provide training and provide senior subject matter experts that validate design decisions, check in at the milestones, and provide continuous mentoring. If you have hired consultants to perform the implementation you should still make sure that the consultants follows the guidance and design suggestions of the vendor's experts. However, if you believe that the vendor did not send a senior enough person, feel free to send that person back and request a more senior person.

Pitfalls of EAI Integration Learned from Telecoms

The uses of EAI in the energy industry have a lot of similarities with the Telecom industry. Although the details of the requirements of the information systems used by the utilities are different, the high level requirements stay the same:

- Provisioning
- Order Management
- Billing
- ERP
- CRM
- HRM

Therefore, it is no surprise that the major EAI vendors for the telecom industry also have a significant role in the electricity industry.

The Telecoms were at the forefront of the EAI experiment beginning with the Telecom Deregulation Act of 1996. This act started a process that entirely changed the telecom market. With the provisions of the Telecom Act, Competitive Local Exchange Carriers (CLEC) could form. The main need of a CLEC was a streamlined provisioning system that tied in with a billing system capable of rating usage in sophisticated ways, abide by complex taxation rules, and communicate with an order management system. Very soon after a new piece was added, customer relationship management (CRM).

The telecom experiments showed that new information technologies may require reengineering of processes. You may need to step back and take a look at your processes. Ask yourselves "Do we really need EAI now?" "Are we solving the right question?" "Can our processes be simplified?" There are also some cautions to consider. If processes are broken into too many pieces, no one can see the big picture. There may be too many hand offs resulting in too many potential failure points. If processes are broken into too few pieces, you may lose the effects of specialization and may not be able to take advantage of parallel rather than sequential tasking. Note whether information can be better used at any point in the process chain. Since opportunity cost is still an essential piece of information, you will need to understand cost trade offs at all levels. For more information on re-engineering your business in the information age, see http://www.speed-of-thought.com.

The first and perhaps most important of the above questions is "Do we really need EAI now?" The most prevalent mistake made at this point is that the total cost of EAI integrations is underestimated. One reason for such underestimation is that the initial requirements are incomplete or poorly defined. In addition vendors have a vested interest in making costs appear lower in order to sell you the project. As a rule of thumb, you need to expect such an integration to cost more than $10 million dollars. Related to the underestimation problem is an overestimation of the financial benefits. Here natural optimism and vendors interest in making the projects appear attractive add to the over estimation. All the hype surrounding information technologies add to their glamour, while fears of being left behind may inflate their attractiveness.

An example of underestimating costs and overestimating benefits comes from FirstWorld, which filed Chapter 11 in March of 2002. Initially they wanted to be a CLEC and an ISP along the lines of what today is Qwest. FirstWorld started by building an EAI infrastructure including a billing system, a CRM tool, and a provisioning system even though at the time they had no customers. As their marketing did not go according to their projections, they acquired other companies for their customers. However, those companies had their own infrastructure. These new systems added additional requirements to FirstWorld's EAI infrastructure changing the scope of the effort considerably. At that point they had already spent on the order of $10 million with no functioning system. Accenture, which was in charge of the project, made recommendations that would have resulted in roughly an additional $10 million even though FirstWorld still had very few customers. Shortly after Accenture's recommendation, FirstWorld cancelled the whole project. To recover, FirstWorld decided to only be an ISP. Even being an ISP, however, was more than they could manage given their remaining finances. They further consolidated into a data center provider role. However, both these recovery decisions came too late to save FirstWorld from bankruptcy. The truth is that FirstWorld had not yet needed the heavy duty EAI framework chosen because their client base and revenue base had not justified it.

So what can energy companies learn from FirstWorld's example? New energy startups as a result of deregulation should be careful that their IT infrastructure expenses are aligned with real revenues and not wishful thinking. EAI is not necessarily a panacea for all ills. As with any business decision, especially expensive ones, basic business principles still prevail. Careful up front analysis of the costs and benefits of the technology must be made to determine whether the cost of the project and the cost savings will provide an acceptable rate of return.

Another lesson that can be learned from the telecoms comes from one of the cornerstones of the Telecom Act. This cornerstone was the obligation of the Incumbent Local Exchange Carriers (ILEC) to allow CLECs to resell telco services. Hence, the need for a streamlined communication process between the ILEC and the CLECs. Companies like Quintessent created gateways to talk more efficiently with the ILECs legacy ordering and provisioning systems. However, the high complexity of the telco products and standards makes the integration with these gateways extremely difficult. A similar challenge might face the energy industry while trying to integrate these new systems into established systems, which currently use mostly EDI and have very rigid operating rules. What happened in the telecom industry is that vendors overstated their interoperational capabilities, which mislead IT managers and caused significant unforeseen expenses that could be measured in millions of dollars.

One of the pitfalls in creating TPNs can be derived from another telco example. A TPN requires a strong driving force that will entice its partners to active trading. Active trading will provide the liquidity that a successful market needs. Given the nature of the basic telecom products (phone line, services through phone line such as voice mail) trading partnerships had no driving force behind them. Since it wasn't practical to trade such basic services, TPNs could not be successful if they were relying on trading them. However, as the telecom world turns towards new media more and more, and data transmission prevails, bandwidth trading will be a new driving force to create trading communities. Similarly energy industry companies seeking to form TPNs need to ensure that there are strong driving forces behind the products chosen for trade and that there is room in the market for them.

Besides the physical costs, every investment in information technology has human and organizational costs. The physical costs are the hardware and the software. The human costs are for training and other adjustment costs. In neoclassical economics, we assume that consumers maximize utility and producers minimize cost and maximize profits. In a complex systems approach, we consider the psychological, social, and institutional factors that go into decision-making. With the new information technologies, neoclassical assumptions may not be enough and we may need to consider complex systems. Users may not be able to make the psychological adjustment in the same amount of time that technology has changed. Human psychological costs include stress from feelings of helplessness, never getting anything done, always being busy, having a lack of control, being acted on by the system, and responding rather than initiating.

The organizational costs of new technologies are the costs of reengineering. For a business process reengineering effort brought on by EAI to be effective, it is imperative to include the end-users of the system at every milestone and design decision. If end users don't buy into the changes, the integration may be doomed from passive or even active resistance. A problem that occurs often is the development of unreasonable requirements (also known as overkill) by the marketing team or the IT staff, that leads to a disconnect between marketing people using the technology and the IT people who implement the solution. Having the client (usually the marketing/sales department) and the provider (usually the IT staff or outside consultant) meet often and discuss the root problems that need to be solved is the only way to arrive at a reasonable set of requirements. Also, both parties have to be prepared to compromise. This will result in the senior marketing and technical staff being on the same page and ensuring that the client gets what they really need, not what they think they need.

The following examples illustrate the above points.

- A Chevron-Ariba alliance was originally announced in April 1998 as a procurement portal for the entire energy industry. Named Petrocosm, it was launched in January of 2000. Texaco joined the alliance in March of 2000. However, the driving forces were not there and Petrocosm folded just over a year later from a lack of liquidity.
- Shell partnering with BP Amoco, Conoco, Dow, Mitsubishi, Occidental, and Phillips Petroleum and using CommerceOne as a key technology provider built TradeRanger to link its purchasing people with the partner's many suppliers. These founding partners have subsequently allowed other players to join them. In so doing, they are providing a liquid marketplace for buying and selling anything that energy developers or providers need leading to the success of this TPN so far.
- Peace Software has built Energy™ Version 6 using BEA's WebLogic Server. The solution is designed to streamline customer and commodity management for the retail energy industry. BEA WebLogic also powers Energy B2C (business to consumer) communication and transactions for Internet self-service, providing customers with online access to account information and other data. Currently several major energy players such as Xcel Energy use this platform. Peace, in business since 1984, has been able to leverage their knowledge of the energy market to succeed by creating the appropriate EAI tools for the retail energy market.
- Enron deployed a new credit management and Power Trading System (PTS), a Gas Management System (GMS) and a Risk Management System (RMS) using Vitria as their EAI backbone. This implementation was a success and would likely have still been in production had Enron's executives followed better business practices.
- Utility.com, founded in 1998 and subsequently named the Best-Performing Utility Web Site in the World by Accenture, wanted to change the utilities marketplace by offering a range of energy and telecommunications services for consumers and small businesses. Its information technology (IT) platform included several disparate systems. They also needed to easily communicate with customers and partners. Leveraging Vitria's EAI tools, Utility.com wanted to improve customer service, generate additional sales, and strengthen relations with its partners. This was their business strategy at the height of the EAI hype. When this strategy turned out to be a failure, they jumped onto the next hype in late 2000, which was the ASP model spending an additional 6 million dollars. Their goal was to provide their services and software tools to other utilities. Little did they know at that time that they had only 6 months to live. Their's is a classic example of hopping from hype to hype and investing in overrated technologies. This example is sadly similar to that of FirstWorld.

These five examples show that the new complicated and expensive EAI technologies may be enabling when handled well, but disabling when handled poorly. Further, basic economic and business principles that were thrown out with the euphoria of a new world order, need to be brought back – the sooner, the better.

Conclusions

Electronic information technologies have been changing ever since the advent of the telegraph. What is different now is that the pace of change seems to have quickened requiring rapid adjustment to new technologies. Also the information age revolution brought new technologies that enable us to handle business problems that were not possible before. As bricks and mortar give way to clicks and mortar, business models are changing to take advantage of the increasing ease of connecting and transferring information. To integrate across systems initially software systems were linked to each other. Now more and more internal systems are being linked backwards to suppliers and forward to customers blurring the boundaries between firms. These systems need to be able to manage business processes in an efficient way as well as integrate data across and within companies.

Enterprise Application Integration is the technology that provides such interconnectivity allowing the digital transfer of information. It requires middleware to allow internal applications to talk to each other, application integration software to verify the integrity of the transactions and trading partner networks to allow the transfer, security and understanding of data across companies. EAI when done properly may allow businesses to decrease costs, create new businesses such as trading hubs, allow companies to beat their competitors off the mark, decrease product cycle times, and allow companies to form better customer relationships. However, care must be taken in choosing these expensive technologies as the recent dotcom meltdown has shown.

Usually expensive consulting companies are used to help pick these multimillion dollar technologies in conjunction with expertise from the vendor. However, even then success is not assured. Many a company has been parted from its dollars and been disappointed with the EAI system they have acquired. As with any business project to truly get what you need, you must carefully define what you need. Avoid the hype and make sure the latest and greatest product satisfies your particular needs within your budget. Otherwise don't get it. Pick technologies that are flexible, are popular enough to ensure the interoperability and connectivity that you need, are not overly complex to implement and operate, and maximize your expected success rate.

Examples from the Telecom industry and increasingly from the energy industries demonstrate the pitfalls that have been encountered. First you must make sure you need the EAI now. The most common mistakes that companies make at this point is to underestimate the costs of the project due to poor requirement specification or to overestimate the benefits. These big and expensive projects are complicated and as Murphy has so aptly pointed out, if things can go wrong they will. Even with carefully thought out requirements and the correct choice of systems, the physical and human dimensions of the implementation and operation of the project must still all come together to ensure a successful project. Further, information projects and technology are like any other projects or technologies and should be subject to fundamental economic and business principles.

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Valuation of Oil Companies - The RoACE Era

By Petter Osmundsen, Frank Asche and Klaus Mohn*

Introduction

Being a successful stock market analyst can be very rewarding, but is indeed also demanding. One single person often has to keep track of a wide range of companies, and provide superior advise and consistent investment recommendations to exacting investors with no concerns but to maximise their returns and to outperform their benchmarks. No wonder, therefore, that both analysts and investors have to relate to some simplified indicators that can help them in developing relative valuations and investment rankings.

For the international oil and gas industry, the most common financial indicators and valuation benchmarks in the oil industry are Return on Average Capital Employed (RoACE), unit cost, production growth, reserve replacement rate, and average tax rates. These indicators can be perceived as an implicit incentive scheme presented to the oil firms by the financial market. In responding to these incentives, the companies need to strike a balance between short-term goals of rentability and medium- to long-term goals of reserve replacement.

First, some basic definitions. RoACE, or return on average capital employed, is usually defined as net income adjusted for minority interests and net financial items as a percentage ratio of average capital employed, where capital employed is total capital minus net interest-bearing debt. DACF, or debt-adjusted cash flow, normally reflects after-tax cash flow from operations plus after-tax debt-service payments; where after-tax cash flow is the sum of net income, depreciation, exploration charge and other non-cash items.

Given the data that is available for external analysts, it is common to use market comparative metric analyses. Cash-flow multiples stand out as especially important in this respect, and one widely used indicator is the relation between enterprise value (EV) and debt-adjusted cash-flow (DACF) – or EV/DACF. An estimate for the value of a company, P, is thus found by taking the mid-cycle *DACF* for company *i* and multiplying it with the metric for the comparable companies (peer group), *EV/DACF* . Thus, $P_i=(EV/DACF)xDACF_i$. Positive investment recommendations are awarded to "cheap" companies, where valuation estimates go beyond current market capitalisation. On the other hand, caution is usually recommended for the more "expensive" companies, where simple valuation estimates fall short of their market capitalisation.

In their *Global Integrated Oil Analyzer*, UBS Warburg states: "Our key valuation metric is EV/DACF". The key arguments are that it is an after-tax value (important in an industry with substantial resource rent taxes) and that it is independent of capital structure (thus facilitating comparisons between companies with different capital structure).

UBS Warburg also appreciates the influence of oil price volatility on their analysis. For valuation purposes, they, therefore, concentrate on what they call mid-cycle conditions. Given the considerable volatility in oil and gas prices, this is clearly important for the international oil and gas industry. For a given year, UBS Warburg identifies a clear relationship between RoACE and the EV/DACF multiple, and conclude:

> "Each of the stocks which we rate a 'Buy' is trading below the average level relative to its returns. EV/DACF versus RoACE provides the key *objective* input into the process of setting our target prices."

Similar statements about valuation, multiples and return on capital are made in Deutsche Bank's publication *Major Oils*.

In presentations of their valuation techniques, investment banks often picture the relationship between market capitalisation (or EV/DACF) and a single financial indicator (like RoACE) in a diagram. They typically show this relationship for different companies at a given point of time. We take this approach a big step further, by including the time-series dimension in a rigid econometric framework for a panel data set. Thereafter, we compare our findings with common analyst perceptions.

Previous Research

McCormack and Vytheeswaran (1998) point out particular problems in valuation of oil companies, since the accounting information in the upstream sector gathered and reported by oil and gas concerns, "does a distressingly poor job of conveying the true economic results". There are measurement errors in petroleum reserves. There is an asymmetric response to new information; bad news is quickly reflected in the reserve figures whereas good news takes more time to be accounted for. Moreover, reserves may be exposed to measurement errors since they are noted in current oil price (and not the mid cycle price), and since they do not include the value of the implicit real options. Finally, McCormack and Vytheeswaran claim there is a bias, as the large and profitable oil companies are more conservative in their reserve estimates. The latter assumption is perhaps open for questions after the recent reserve write-down in RD/Shell.

As for depreciation, with the successful efforts method, initial depreciations are too high. The unit of production method also has the effect of depreciating the assets too quickly. The effect may easily be to punish new activity and reward passivity. Other measurement challenges specific to the oil business are cyclical investment patterns and long lead times, which may exacerbate the measurement errors. We may have similar effects from the fact that discoveries are discontinuous and stochastic.

McCormack and Vytheeswaran (1998) perform econometric tests on financial relations for the largest oil com-

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See footnotes at end of text.

panies for the period 1997-2001. Change in shareholder wealth is tested against EBITA, RONA, after-tax earnings, ROE, and free cash flow. The relations between valuation and financial indicators were found to be very weak or non-existent. Stronger relations were established by introducing Economic Value Added (EVA[1]) and reserves.

Antill and Arnott (2002) address the issue of rentability versus growth in the petroleum industry. They claim that current RoACE-figures of some 15 per cent are due to the fact that the companies possess legacy assets that have low book values but still generate a considerable cash flow. If market values of the capital employed were applied, they estimate that the rate of return would fall to approx. 8-9 per cent, being more consistent with the cost of raising capital. One problem of RoACE, they add, is that it reflects a mixture of legacy and new assets, i.e., it does not adequately reflect incremental profitability. Thus, it falls short of being a good measure for current performance. Antill and Arnott (2002) argue that the oil companies should accept investment projects with lower IRR, as the growth potential would give added value to the companies.

Chua and Woodward (1994) perform econometric tests for the American oil industry, 1980-1990. They test P/E-figures for integrated oil companies against dividend payout, net profit margin, asset turnover, financial leverage, interest rate, and Beta. However, they fail to uncover robust relations in the data set. The estimated interactions are weak, and some of them even have different signs than expected. Chua and Woodward do not find support for the P/E-model. They, therefore, go on to test the stock price against cash flow from operations (following year and preceding year), dividend payout, net profit margin, total asset turnover, financial leverage, interest rate, beta, and proven reserves. Future cash flow and proven reserves are statistically significant explanatory factors, thus offering support to a fundamental approach to valuation. An increase in proven reserves of 10% produced an increase in the stock price of 3.7%, in the model estimated by Chua and Woodward.

Empirical Specification and Data

Out objective is to evaluate the current valuation techniques among stock market analysts and professional investors. Standard analyst reports usually illustrate/compute correlations obtained from a cross-section of companies for one year only. We expand the analyses by making use of time series data for a panel of companies. Our econometric approach also allows for a variety of explanatory factors in a simultaneous model. It is, e.g., interesting to test how market capitalisation is affected both by rentability (RoACE) and the reserve replacement rate (RRR). Traditional bilateral correlation studies of EV/DACF may not give the full picture of value generation if there for instance is a negative correlation between RoACE and RRR

A word of precaution is at this stage appropriate. This is the first output from a new, long-term research programme. Our findings are indicative, not final, and should be interpreted with caution. As researchers, we still have a long way to go in the area, in developing high-quality data sets – and to uncover the underlying data-generating processes.

For this study, UBS Warburg have kindly provided us with a panel data for the period 1997-2002, and it includes the following companies[2]:

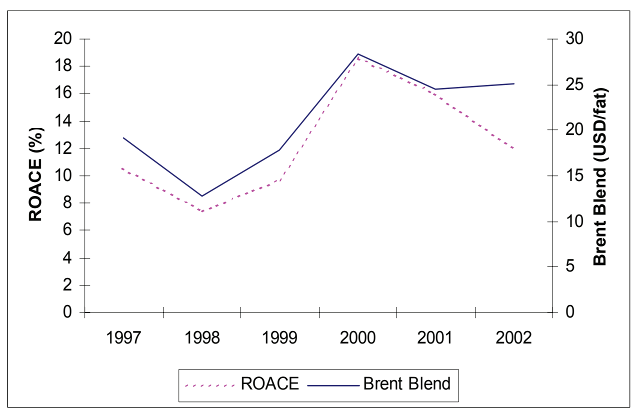
Amerada Hess
BP
ChevronTexaco
Eni
ExxonMobil
Marathon Oil
Norsk Hydro
Occidental
Petro-Canada
Repsol YPF
TotalFinaElf

The exact model specifications and detailed results are given in Osmundsen, Asche and Mohn (2004). In the following, the main findings are presented.

Lack of Normalisation

In a time series setting, performance evaluation of oil companies would have to adjust for the volatility of oil and gas prices. If a company is performing well, it is vital to know whether it is merely due to a favourable oil market sentiment, or if superior stock market performance can be attributed to real improvements in the company's underlying operations. Such normalisation is crucial also in a cross sectional setting, since normalisation is necessary for comparing companies with different portfolios. Companies are not to the same extent exposed to refinery margins and price fluctuations for oil and gas.

Figure 1
Arithmetic Average RoACE versus Brent Blend, 1997-02.[3]



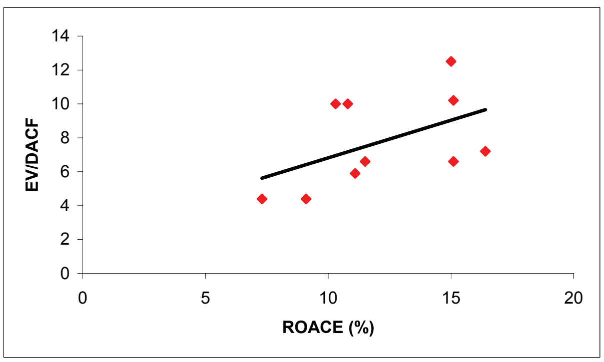
Some oil companies do publish normalised RoACE-figures. One example is Norwegian Statoil, who publishes details of normalisation related to oil price, gas price and refinery margins when communicating their RoACE targets. However, most valuation analyses are based on non-normalised data. It is probably hard for independent analysts to calculate normalised returns for different companies in a consistent manner. To account for the effect of price cycles, they instead emphasise mid-cycle market conditions, which may be seen as a related concept.

Figure 1 indicates that non-normalised RoACE-figures have quite limited information value. Non-normalised RoACE does not seem to provide much beyond the oil price, in this particular time period. Mid 2001, however, the two figures depart and this has continued into 2003. Similar departures might have occurred under previous price cycles. Note also that the diagram is on an aggregate basis, implying that the non-normalised return from individual companies might provide more information. Still, the benefits of normalised return figures should be obvious.

Empirical Results

The metric EV/DACF versus the rentability indicator RoACE is essential to today's standard valuation reports from stock market analysts. As a basis for valuation, they claim to identify a clear, positive relationship between RoACE and the EV/DACF multiple. This relationship is illustrated for the year 2002 in Figure 2. UBS Warburg is unlikely to recommend investing in an oil company unless it is located above the solid line in Figure 2.

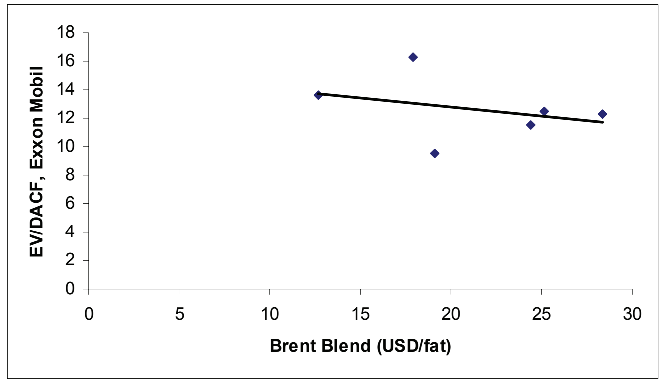
Figure 2
EV/DACF versus RoACE, 2002



Our data set offers support to this relationship for most of the individual years 1997-2002. However, the annual relationship between EV/DACF and RoACE is only weakly significant in the dataset. The relationship is clearest for 2002. This is shown in Figure 2.

We would like to take this further, to see if the relationship between EV/DACF and RoACE prevails over time, and in a setting with multiple explanatory factors. With straightforward testing on time series data, we cannot establish any correlation between EV/DACF and RoACE. But here we need to take one step back and reflect on the input data we use. As explained above, we would have liked normalised RoACE-figures. Having only non-normalised rentability figures at hand, we have to address the issue of oil price fluctuations. With oil companies being priced at mid-cycle oil prices, one would have to assume a strong relationship between the metric EV/DACF and the oil price, as revealed in Figure 3. When the oil price is very high, the market does not expect it to prevail (mean reversion) and, accordingly, a low metric is the result. The reverse is the case at very low prices.

Figure 3
Oil Price Sensitivity. EV/DACF versus Brent Blend, ExxonMobil, 1997-2002



Consequently, we need to single out oil price volatility to isolate the true effect on valuation from underlying profitability, i.e., the effect of normalised RoACE. One way of achieving this is simply to include oil price in the regression. The coefficient pertaining to RoACE will then reflect the effect on valuation from *normalised* rentability on average capital employed. Since all the oil companies more or less face the same oil price in a given year, due to an efficient world market for oil, inclusion of oil price in the regressions is analogous to including a year dummy across the panel.

Introducing year dummies in addition to RoACE, we find from regression analyses on the panel data set that the year dummies (reflecting oil price) are strongly significant whereas RoACE is weakly significant in explaining the metric EV/DACF. However, the overall explanatory power is still relatively poor.

Note that we find significant year effects in the panel data testing, i.e., EV/DACF responds negatively to oil price, as in Figure 3. This supports the perception that oil companies are priced at mid cycle oil prices.

We would like to examine the eternal trade-off between short-term return (RoACE) and growth (reserve replacement rate, RRR). We find that the explanatory power of this basic model is poor. RoACE is weakly significant. RRR has the sign we would expect, but is not significant in explaining valuation. Hence, the classical short-term, long-term trade-off is not sufficient to generate a valid valuation model in the oil industry for the relevant period. One possible explanation to the fact that RoACE is only weakly significant, would be that the strong focus on RoACE in the years 1997-2002 has been at the expense of organic reserve replacement. The valuation metric, therefore, has not responded considerably in response to high RoACE figures, since the investors have not perceived the higher rentability to be sustainable. This explanation, of a stock market primarily concerned with long term potential, however, is not supported by our tests.

Company size plays an important part in pricing of international oil companies. Various practical and theoretical reasons have been provided to explain this fact. We will mention some of them. Larger companies may have a larger growth potential in their portfolios. Size may have a positive effect on governments' discretionary licensing decisions for oil and gas deposits. Large and prospective operatorships, which also are skill and resource demanding, are often awarded the largest companies. A larger opportunity set in terms of geological deposits may allow large firms to pursue a cream-skimming strategy. The largest international oil companies also have the best opportunities to pursue tax shifting. On the other hand, large companies may face higher co-ordination costs, and may miss out on benefits of focusing strategies and specialisation.

We now check for the effect of size on oil company pricing in our dataset, using oil and gas production (Q&G) as a proxy for size. We find that size is a highly significant explanatory factor in the pricing of oil companies. Note that the sign of RoACE now is negative. This may be due to a likely correlation between RoACE and O&G, to be explored below.

Thereafter, we proceed by including other explanatory factors, like finding & development costs (F&D) and unit of production costs (UPC). The explanatory power of the model now improves substantially. Notably, the perceived relationship between EV/DACF and RoACE now disappears. When additional explanatory factors are introduced, the parameter on RoACE actually becomes negative and significantly so. This is perhaps not surprising. The figures F&D, O&G, RRR, and UPC, affect rentability and can be controlled by the companies. They are therefore likely to be correlated with RoACE, and hence the effect of RoACE on EV/DACF may be crowded out. In the following, the relation between RoACE and these underlying factors is examined.

We find that size, represented by O&G, is a highly significant explanatory factor. F&D, UPC and RRR are not statistically significant.

We now run EV/DACF against the various explanatory factors, excluding RoACE, but including company dummies. The explanatory power is now very high. In this regression each company has its own constant term, where a large constant term indicates a higher EV/DACF for that company that cannot be attributed to any of the other factors. This ranking of company effects deviates from traditional EV/DACF rankings, where the largest companies tend also to have the highest multiples. Occidental has the highest company effect in our regression, and a company like Hydro outperforms Exxon. By including O&G in the regression, we have accounted for the effect of size, and by this isolated reputation effects beyond size.

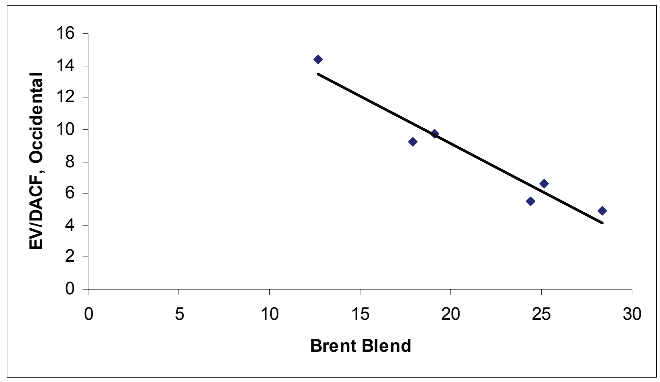
By excluding O&G in the regression, however, we get the traditional result that the largest firms have the most significant company effects. BP and ExxonMobil have by far the highest scores. That is, all things equal, ExxonMobil and BP trade at a premium. Notably, that this simplified regression, containing only year dummies (accounting for oil prices) and company dummies, have a very high explanatory power.

Oil Price Sensitivity

By spreading their activities over the entire value chain, integrated oil and gas companies reduce their exposure to oil price volatility. An oil price fall that hurts the upstream portfolio is often perceived to benefit the downstream activity. (This is not necessarily so, as the refinery industry is a margin business.) This is one of the reasons given to explain that supermajors have high valuation metrics However, there are a number of mid-sized companies that are integrated, without gaining the same level of stock market multiples. Again, size seems to be important.

For other companies, having a stronger upstream focus, the Figure 3 type curve is steeper. This is the case, e.g., for Occidental, see Figure 4.

Figure 4
Oil Price Sensitivity. EV/DACF Versus Brent Blend, Occidental, 1997-2002



The relationship between E&P exposure and oil price volatility could be skewed by other factors. One example is Statoil. Having the same upstream exposure as Occidental we should perhaps expect a slope similar to the one in Figure 4. However, what we probably would find is a a slope similar to ExxonMobil in Figure 3. Unfortunately, lack of sufficient market data prior to the listing of Statoil prevents us from drawing this diagram. However, Table 1 lists some interesting key figures for the three companies.

Table 1
Oil Price Sensitivity, 2000-2002

	E&P assets, % of total, last 2 years	E&P profits % of total last 2 years	Oil price sensitivity profits	Oil price sensitivity, DACF
Statoil	69	74	4.9	2.3
ExxonMobil	44	75	5.2	2.7
Occidental	75	95	11.9	5.0

Table 1 suggests a rather similar risk pattern for Statoil and ExxonMobil, There may be several reasons for this. First, and not surprisingly, the oil price and the NOK/USD exchange rate show a pattern of negative correlation, thus generating a hedge for Statoil's NOK profits. Second, considerable tariff revenues from ownership in pipelines generate a fixed revenue element for Statoil, but this is hardly material enough to explain the relatively low oil price sensitivity in Table 1. Finally, and most important, the tax system for the Norwegian Continental Shelf shifts much risk from the companies to the Norwegian state. The Norwegian petroleum tax system mimics a cash flow tax, and is fairly close to being symmetric. The government take is high at high oil prices, but is reduced to a large extent when prices fall. Most petroleum tax systems do not have the same risk reducing features for the companies.

Conclusion

We have undertaken regression analyses on market and accounting data from oil companies for the years 1997-2002. The objective is to ascertain key valuation drivers. The valuation metric EV/DACF is tested against a number of financial indicators and dummy variables. Making use of year dummies in addition to RoACE, we find from regression analyses on the panel data set that the year dummy (reflecting the oil price) is strongly significant, i.e., EV/DACF responds negatively to oil price. This supports the perception that oil companies are priced at mid cycle oil prices. The effect of RoACE on the valuation metric, however, is only weakly significant. We obtain strongly significant company effects, which to a large extent coincide with company size. A simplified valuation model that includes only year dummies (accounting for oil price) and company dummies proves to have a very high explanatory power.

As indicated above, this paper is an early attempt to substantiate the links between market valuation and financial and operational indicators in the international oil and gas industry. The results are inspiring, but preliminary. We still have a long way to go, developing high-quality data sets – and to uncover the true data-generating processes. Future research should be directed at the development of broader panels for a longer time-horizon. More degrees of freedom would allow for more sophisticated modelling, without loss of quality in the results. This modelling should also take us well beyond the statics of our simple first-cut models. The significance of dynamics should not be neglected, at least not in the stock market.

Footnotes

[1] EVA is a trade mark of Stern Stewart & Co.

[2] We are currently working on establishing a larger dataset, based on Deutsche Bank's *Major Oils*.

[3] RoACE is in the UBS dataset defined excluding goodwill amortisation charges from the returns, but goodwill is included in capital employed.

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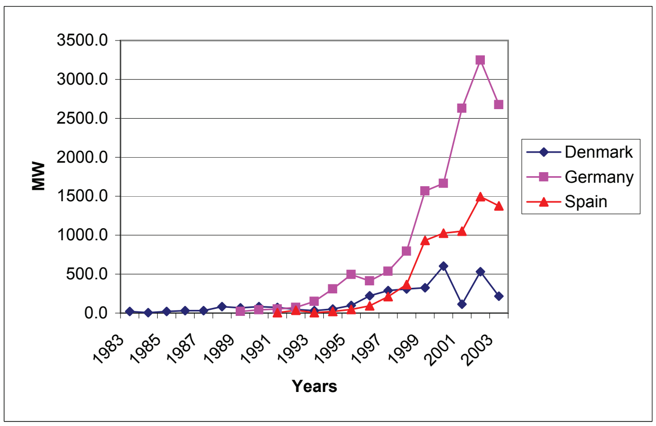
The Economics of Wind Power

*By Poul E. Morthorst**

Within the last 10 to 15 years wind power, globally, has developed incredibly fast. In 1990 total installed capacity of wind power in the world amounted to approximately 2.0 MW – by the end of 2003 this capacity has increased to more than 40 GW, equalling an annual growth rate of more than 25%. And the rate of growth is still high - in 2002 global installed capacity increased by 30% and by approximately 26% in 2003. European countries dominate the wind power scene. In 2003 approximately 65% of total installed wind turbine capacity was established in Europe, and the only major contributors outside Europe were the United States with a total installed capacity of approximately 6.4 GW and India with 2.1 GW (BTM-consult, 2004).

Figure 1
Annual Increase of Installed Wind Power Capacity in Germany, Spain and Denmark



But even within Europe, a few countries denominate: Germany, Spain and Denmark accounted for more than 75% of the growth in European installed wind turbine capacity in 2003, and correspondingly these three countries together have installed more than 80% of the total accumulated capacity in Europe. Germany has had an especially rapid development. In 1991 total accumulated capacity in Germany was approximately 100 MW; today the annual capacity increase is approximately 2700 MW and total installed wind power capacity is almost 15 GW. Similar developments are found in Denmark and Spain, although not to the same extent. Denmark had a total installed capacity of almost 3.1 GW and a growth rate of approximately 8% in 2003, while Spain had installed 6.4 GW with a growth rate of more than 25% in 2003. Other contributors in Europe worthy of mention are the Netherlands (0.9 GW), Italy (0.9 GW), UK (0.8 GW), Greece (0.5 GW), Sweden (0.4 GW) and Austria (0.4 GW), (BTM-consult, 2004).

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Policy Conditions for Wind Power

The main reason behind the development in Germany, Spain and Denmark is a fast improvement in the cost-effectiveness of wind power during the past ten years (Redlinger et.al.,1998), combined with long-term agreements on fixed feed-in tariffs (at fairly high levels), altogether making wind turbines one of the most economically viable renewable energy technologies today. The national policies of fairly high buy-back rates and substantial subsidies from governments to a certain extent reflect the need for a development of renewable energy technologies to cope with the greenhouse gas effect. According to the Kyoto protocol the European Union has agreed on a common greenhouse gas (GHG) reduction of 8% by the years 2008-12 compared with 1990. All the three above-mentioned countries have adopted a policy of GHG-limitation in accordance with the agreed burden sharing in the EU.

That the development of renewable energy resources is expected to play an important role in the implementation of these GHG-targets is reflected in EU policy as well. In its White Paper on a strategy for the development of renewable energy the EU Commission launched a goal of covering 12% of the European Union's gross inland energy consumption by the year 2010 by renewable sources; that is mainly by biomass, hydro power, wind energy, and solar energy. Next to biomass, wind energy is seen as the main contributor (European Commission, 1997). Moreover, the European Commission has agreed on the promotion of renewable energy technologies, including a proposal on the share of renewables in the individual member states in 2010, based on the percentage of each country's consumption of electricity (European Commission, 2000). Although not binding these targets are generally accepted by the EU member states. Thus the directive signals the need to include renewable energy technologies as one of the serious options in achieving the targets for GHG-reductions.

In parallel with the implementation of the Kyoto GHG-commitments a number of countries are liberalising their electricity industry. The cornerstone in liberalisation is opening of the electricity markets for trade, within the country and among countries. To generate efficient competition unbundling of the power industry might be necessary: splitting existing companies into independent ones for production, transmission and distribution of electricity. Finally, to handle dispatch of electricity an independent systems operator is needed, and establishing a power exchange might facilitate and increase transparency in trading.

This process towards liberalised electricity markets has been going on for some years. The EU-directive on common rules for the internal market in electricity, states that each member state has the right of access to the electricity and distribution grids, thus opening the concept of free electricity trade in Europe. A number of countries already have or are in the transition phase of liberalising their electricity industry. Electricity exchange markets are being developed to facilitate electricity trade and now exist in several countries, among them England, Germany, Norway, Sweden, Finland

and Denmark. In 1996 Norway and Sweden established the first inter Nordic electricity exchange market (NordPool). Through collaboration with the existing Finnish electricity exchange, El-Ex, in 1998, Finland was included in the market. In the summer of 1999 the western part of Denmark joined the exchange, while the eastern part became a member in 2000.

How wind power is to be integrated into the competitive electricity market is still an open question. At present most renewable energy technologies are not economically competitive with conventional power producing plants. Thus it can be expected that if renewables must compete on pure market conditions this will halt the development of new renewable capacity. One model of generating additional payments to renewable technologies is to develop a separate green market. This model will facilitate the integration of renewables into the liberalised market and at the same time make it possible for these technologies to be partly compensated for the environmental benefits they generate compared to conventional power production.

A number of EU member states, Holland, Belgium, the UK, Italy and Sweden, already have or are presently aiming at introducing tradable green certificate systems (TGC's). The main objective of a TGC-scheme is to increase the penetration of renewable electricity production into the electricity market by stimulating demand. Green certificates are generated by renewable producers, which receive a certificate for each unit of production sold to the electricity grid (Voogt et.al., 1999). The TGC-systems in the EU appear to be quite different, however. For example, Holland has a voluntary scheme, Italy places the obligation on the power producers, while Sweden sets a quota on electricity consumers. Thus, no common EU TGC-system seems to be underway.

In 1999 the Danish Parliament agreed to phase out the existing feed-in tariff system and replace this with a green certificate market (Morthorst, 2000). Uncertainty about how the new certificate system would work stalled the development of Danish wind power in 2001 (only 115 MW was established), Finally the government decided to postponed the certificate market until 2004-5, mainly due to resistance from Danish wind organisations and wind manufacturers. Whether a green certificate system will ever be put in place in Denmark is doubtful, This will probably happen only if a common European-wide system is established. But as mentioned, there are at present no signs within the EU of developing a common green market for renewables. Germany and France have chosen to continue with the well proven feed-in tariff system.

Economics of On-land Sited Wind Turbines

Wind power is used in a number of different applications, including both grid-connected and stand-alone electricity production, as well as water pumping. This section analyses the economics of wind energy, primarily in relation to grid-connected turbines which account for the bulk of the market value of installed turbines.

The main parameters governing wind power economics include the following:

- Investment costs, including auxiliary costs for foundation, grid-connection, etc.
- Operation and maintenance costs
- Electricity production / average wind speed
- Turbine lifetime
- Discount rate

Of these, the most important parameters are the turbines' electricity production and their investment costs. As electricity production is highly dependent on wind conditions, choosing the right turbine site is critical to achieving economic viability.

The following sections outline the structure and development of land-based wind turbines' capital costs and efficiency trends. Offshore turbines are gaining an increasingly important role in the overall development of wind power, and thus an overview is given in a separate section.

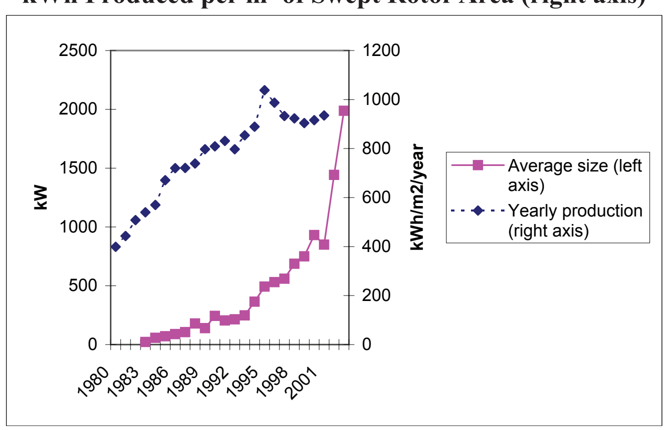
In general, two trends have dominated grid-connected wind turbine development:

1) The average size of turbines sold on the market has increased substantially
2) The efficiency of production has increased steadily.

Figure 2 shows the average size of wind turbines sold each year using the Danish market as a proxy. As illustrated in Figure 2 (left axis), the average size has increased significantly, from less than 50 kW in 1985 to almost 2 GW in 2003. In 2003 the best-selling turbines in the world market had a rated capacity of 750-1500 kW and more than a 50% share of the market. But turbines with capacities of the 1.5 MW and up had a share of 35% and are increasing in market share. At the end of 2003 turbines with a capacity of 2 MW and above were getting increasingly important, even for on-land sitings.

Compared with other countries, the Danish market is at the upper level in the development of the average size of turbines sold. The average size sold in Denmark in 2003 was almost 2 MW; influenced to a high degree by the development of a large offshore farm equipped with 2.2 MW machines. Germany was a little below with an average size of 1650 kW,

Figure 2
Development of Average Wind Turbine Size Sold in the Danish Market (left axis) and Efficiency, Measured as kWh Produced per m² of Swept Rotor Area (right axis)



while the average in the UK was almost 1.8 MW and Sweden was approximately 900 kW. In Spain the average was 870 kW and in the United States approximately 1400 kW.

The development of electricity production efficiency is also shown in Figure 2, measured as annual energy production per swept rotor area (kWh/m^2 on the right axis). Measured in this way, efficiency has increased by almost 3 percent annually over the last 15 years. This improvement in efficiency is due to a combination of improved equipment efficiency, improved turbine siting, and higher hub height. The decrease in efficiency shown in Figure 2 is due to a lower average wind speed at those sites available for the latest established turbines[1].

Capital costs of wind energy projects are dominated by the cost of the wind turbine itself (ex works)[2]. Table 1 shows a typical cost structure for a 1 GW turbine in Denmark. The turbine's share of total cost is approximately 82 percent, while grid-connection accounts for approximately 7 percent and foundation for approximately 5 percent. Other cost components, such as control systems and land, account for only minor shares of total costs.

Table 1
Cost Structure for a 1 GW Wind Turbine (year 2001 €)

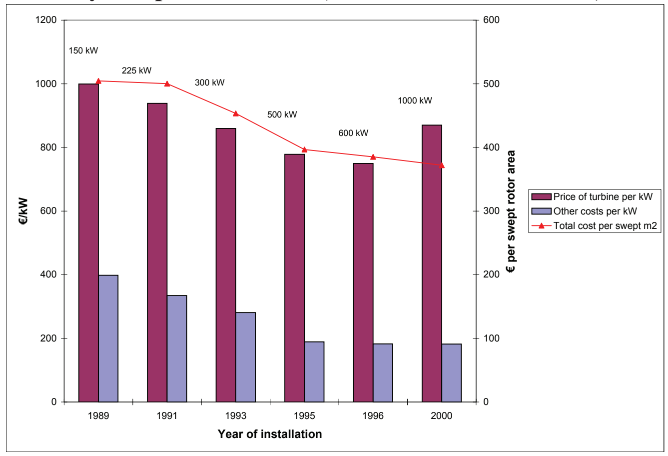
	Investment (1000€)	Share (%)
Turbine (ex works)	748	81.9
Foundation	44	4.8
Electric installation	10	1.1
Grid-connection	60	6.6
Control systems	2	0.2
Consultancy	8	0.9
Land	27	2.9
Financial costs	8	0.9
Road	7	0.7
Total	914	100.0

Note: Based on Danish figures for a 1 GW turbine, using average 2001 exchange rate 1€ = 7.45 DKK.

Figure 3 shows changes in capital costs over the years. The data reflect turbines installed in the particular year shown. All costs at the left axis are calculated per kW of rated capacity, while those at the right axis are calculated per swept rotor area. All costs are converted to 2001 prices. As shown in the figure, there has been a substantial decline in per-kW costs from 1989 to 1999. In this period turbine costs per kW decreased in real terms by approximately 4 percent per annum. At the same time, the share of auxiliary costs as a percentage of total costs has also decreased. In 1987 almost 29 percent of total investment cost was related to costs other than the turbine itself. By 1999 this share had declined to approximately 20 percent. The trend towards lower auxiliary costs continues for the last vintage of turbines shown (1000 kW), where other costs amount to approximately 18 percent of total costs.

A little surprisingly, investment costs per kW have increased for this last-mentioned machine compared to a 600 kW turbine. The reason is to be found in the dimensioning of the turbine. With higher hub heights and larger rotor diameters the turbine is equipped with a relative smaller generator

Figure 3
Left axis: Wind Turbine Capital Costs (ex works) and other costs per kW Rated Power (€/kW in constant 2001 €). Right axis: Investment Costs Divided by Swept Rotor Area (€/m2 in constant 2001 €)



although it produces more electricity. This is illustrated in Figure 3 at the right axis, where total investment costs are divided by the swept rotor area[3]. As shown in this figure, the cost per swept rotor area has decreased continuously for all turbines considered. Thus, overall investment costs per swept rotor area have declined by approximately 3 percent per year during the period analysed.

The total cost per produced kWh (unit cost) is calculated by discounting and leveling investment and O&M costs over the lifetime of the turbine, divided by the annual electricity production. The unit cost of generation is thus calculated as an average cost over the turbine's lifetime. In reality, actual costs will be lower than the calculated average at the beginning of the turbine's life, due to low O&M costs, and will increase over the period of turbine use.

Figure 4 shows the calculated unit cost for different sizes of turbines based on the above-mentioned investment and O&M costs, a 20 year lifetime, and a real discount rate of 5 percent per annum. The turbines' electricity production is estimated for roughness classes one and two, corresponding to an average wind speed of approximately 6.9 m/s and 6.3 m/s, respectively, at a height of 50 meters above ground level.

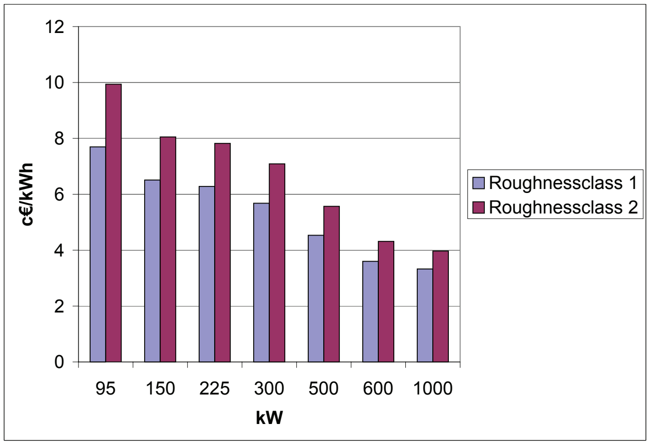
Figure 4 illustrates the trend towards larger turbines and improved cost-effectiveness. For a roughness class one site (6.9 m/s), for example, the average cost has decreased from over 7.7 c€ /kWh for the 95 kW turbine (1985) to under 3.4 c€ /kWh for a new 1000 kW machine, an improvement of more than 50 percent over a time span of 15 years (constant 2001 prices).

The discount rate has a significant influence on electricity production costs and hence on wind projects' financial viability. For a 1000 kW turbine, changing the discount rate from 5 to 10 percent per year (in real terms) increases the production cost by a little more than 30 percent.

Future Development of the Economics of On-land Turbines

In this section the future development of the economics of wind power is illustrated by the use of the experience

Figure 4
Total Wind Energy Costs per unit of Electricity Produced, by Turbine Size. (c€/kWh, constant 2001 prices)



curve methodology. As is well known, the experience curve approach was developed back in the 1970s by the Boston Consulting Group. The main feature is that it relates the cumulative quantitative development of a product with the development of the specific costs (Johnson, 1984). Thus, if the cumulative sale of a product is doubled, the estimated learning rate tells you the achieved reduction in specific product costs.

The experience curve is not a forecasting tool based on estimated relationships. It is merely pointing out that if the existing trends continue then we might see the proposed development. It converts the effect of mass production into an effect upon production costs, other casual relationships are not taken into account. Thus changes in market development and/or technological break-throughs within the field might considerably change the picture.

In a recently EU-project, EXTOOL, with the participation of Lund University in Sweden, ISET in Germany, and Risø National Laboratory in Denmark, the concept of the experience curve was investigated and applied to wind power. The following section is essentially based on the results from this project as presented at a workshop in Paris (Extool, 2003).

For Denmark an experience curve using data from the beginning of the 80s until now has been estimated. Using the specific costs of energy as a basis (costs per kWh produced) progress ratios in the range of 0.83 to 0.87 are found, corresponding to learning rates of 0.17 to 0.13. That is, when total installed capacity of wind power is doubled the costs per produced kWh for new turbines are reduced between 13 and 17%. In this way both the efficiency improvements and embodied and disembodied cost reductions are taken into account in the analysis.

The consequences of applying the above-mentioned results for wind power are illustrated in Figure 5. At present the cumulative installed capacity of wind power world-wide is increasing by almost 30% per annum. Thus, within three years time the total installed capacity is expected to double, and according to the experience curve, the costs per kWh wind produced power could fall by approximately 13-17% in that period. If growth in installed wind power continues, within 5-7 years the costs of wind produced power should, according to the experience curve approach, be within a range of approximately 2.3 c€/kWh to 3.0 c€/kWh.

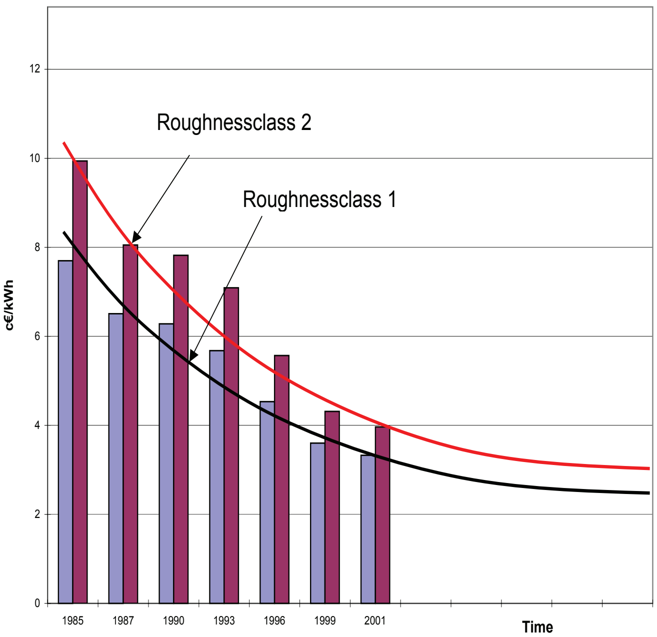
What then are the production costs of the competing conventional power producers? At present the price of power at the Nordic power market, NordPool, has an average of approximately 3.0 c€/kWh. However, at the Nordic market no major new investments in power capacity have been undertaken in the time period when Denmark has taken part in the market. And the Nordic organisation for TSOs, Nordel, expects a shortage of power capacity within the next 3-4 years (H.H.Lindboe, 2002). Thus, it is expected that the price will rise to induce new investments in conventional power plants. According to Danish power companies, the most promising technology to chose is a natural gas fired combined cycle power plants, which will produce at a cost of 3.3 c€/kWh to 4 c€/kWh[4] (ELSAM, 2002).

As shown in Figure 5 this implies that within 5-7 years wind power should be fully competitive with new conventional produced power, if the existing trends continue.

Development of Offshore Wind Turbines

In a number of countries offshore turbines are playing an increasingly important role in the development of wind power, particularly in the north-western part of Europe. Without doubt the main reasons are that on-land sitings are limited in number and the utilisation of these sites, to a certain extent, is exposed to opposition from the local population. This, seen in relation to an unexpected high level of energy production from offshore turbines compared to on-land sitings (based on the experiences gained until now), has paved the way for a huge interest in offshore development.

Figure 5
Using Experience Curves to Illustrate the Future Development of Wind Turbine Economics



At present a number of offshore wind farms are in operation in the northern part of Europe, the largest ones in Danish waters. The worlds largest offshore wind farm is situated on the West Coast of Denmark; Horns Reef, situated approximately. 20 km west of the coast of Jutland was established in 2002 and has a total capacity of 160 MW, consisting of 80 2 MW turbines. The Nysted project at Rødsand, close to the isle of Lolland in Denmark, was finalised in 2003. Nysted has a total capacity of approximately 160 MW consisting of 72 2.2 MW turbines. Middelgrunden (Denmark) east of Copenhagen was put in operation in 2001. The total capacity is 40 MW consisting of 20 2 MW turbines. Finally, Samsø offshore wind farm (Denmark) situated south of the isle of Samsø was put in operation in 2002 and consists of 10 2.3 MW turbines.

Moreover, in a number of countries offshore wind power projects are in the planning and implementation phase. Notable among these are Germany, Ireland, the Netherlands, and UK.

An important concern for the Danish Government is to ensure that the future offshore development is based on market conditions in an economically efficient way. The government, therefore, has investigated the possibilities and conditions of tendering future offshore wind farms in Danish waters. By applying a tendering procedure, competition among bidders will be ensured and the most cost-effective offshore turbine developments will be undertaken. As part of the governmental investigations a scenario was worked out for the future development of a new offshore wind farm at Horns Reef consisting of 3 Mw turbines compared with the 2 MW turbines, which are utilised at the existing Horns Reef wind farm. The economic consequences of this scenario is summarised below:

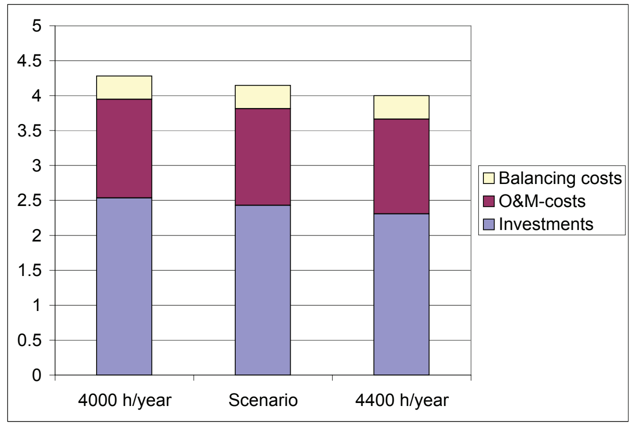
In the scenario, the number of full load hours is assumed to be 4190 h/year and investment and O&M-costs are modified to a 3 MW-farm, using cost data from the existing 2 MW farm as a starting point. As shown in Figure 6, in the scenario total production costs are calculated to approx. 4.2 c€/kWh, including 1.4 c€/kWh as O&M-costs and 0.3 c€/kWh for balancing the power production at the market. Not unexpectedly the assumption on full load hours is important. If the assumed utilisation time is reduced to 4000 h/year, costs will increase to 4.3 c€/kWh, while a utilisation time of 4400 h/year corresponds to a cost of only 4.0 c€/kWh.

The above costs are calculated as simple national economic ones using a real discount rate of 5% p.a. and, therefore, they will not be the costs of a private investor, who will have higher financial costs, require a risk premium and eventually a profit. How much a private investor will add on top of the simple costs will depend, among other things, on the perceived technological and political risk of establishing the offshore farm and, finally, on the competition in the bidding process for such an offshore farm.

Conclusions

Wind power is one of the most promising new renewable technologies, undergoing a rapid technological development

Figure 6
Calculated Production Costs in the Scenario Based on 3 MW Turbines, including Sensitivity Analyses on Numbers of Full Load Hours.



and possessing environmental characteristics that make it well suited to contribute to a future sustainable development. This paper has addressed the market and economic development of wind power. The following issues are highlighted:

- On a global scale wind power is developing rapidly, showing growth rates of installed capacity of more than 25% annually. Nevertheless, the development is vulnerable, because it is dominated by a few countries: Germany, Spain, United States and Denmark. A number of EU members states have established green markets, but still there are no signs of a common EU green certificate market.
- The size of the average turbine sold at the market place is continually increasing. In 2001 the best-selling turbines had a rated capacity of 750-1500 kW and a market share above 50%. At the end of 2002 turbines with a capacity of 2 MW and above were getting increasingly important, even for on-land sitings.
- Within the last 15 years there has been a continuous trend towards larger and more optimised turbines and thus towards more cost-effective machines. For a coastal location, for example, the average cost has decreased from over 7.7 c€ /kWh for the 95 kW turbine (1985) to under 3.4 c€ /kWh for a new 1000 kW machine (2001), an improvement of more than 50 percent over a time span of 15 years (constant 2001 prices).
- If growth in installed wind power continues, within 5-7 years the costs of wind produced power should, according to the experience curve approach, be within a range of approximately 2.3 c€/kWh to 3.0 c€/kWh. At the Nordic power market a natural gas fired combined cycle power plants to be constructed and on-stream within 5-6 years will produce at a cost of 3.3 c€/kWh to 4 c€/kWh. This implies that with in 5-7 years on-land sited wind turbines should be fully competitive with new conventional produced power, if the existing trends continue.
- Offshore wind power is getting an increasingly important role in the development of wind power and a future offshore farm equipped with 3 MW turbines could

produce at a cost of approx. 4.2 c€/kWh, including 1.4 c€/kWh as O&M-costs and 0.3 c€/kWh for balancing the power production at the market.

Footnotes

[1] The efficiency measure is based upon Danish turbine statistics and sites available for new turbines are increasingly getting more limited in number.

[2] 'Ex works' means that no site work, foundation, or grid connection costs are included. Ex works costs include the turbine as provided by the manufacturer, including the turbine itself, blades, tower, and transport to the site.

[3] Swept rotor area is a good proxy for the turbines' power production.

[4] Depending on the number of full load hours the plant is expected to produce. At the high cost an utilisation time of 4000 hours is assumed, while the low costs implies an utilisation time of approximately 6500.

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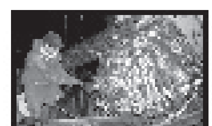


World Oil Production Peak - A Supply-Side Perspective

*By Roger W. Bentley and Michael R. Smith**

Introduction

An increasing number of petroleum geologists, particularly those who have worked internationally outside Europe and the United States, are beginning to recognise that the quite dramatic decline in global discovery of new reserves of conventional oil since the mid-1960s will result in oil, and thus energy, supply difficulties in the near to medium term - that is over the next 10 to 20 years.

Assuming a framework of existing demand trends, the analytical requirement is to identify when shortfalls in oil production will most likely occur, and to quantitatively assess by how much a 'business-as-usual' demand forecast will exceed supply. It is a complex challenge since increasing supply tightness pushes up price, which suppresses demand, and encourages more difficult and expensive resources to the market.

The information in this paper is based on two distinct sets of analyses:

a. Work carried out since 1995 by the ‘Oil Group’ at the University of Reading[1] drawing heavily on the work of A. Perrodon, J. H. Laherrère, G. Demaison, and C. J. Campbell. Their analyses have been published in consultancy reports,[2] and in the open literature.[3] The Reading ‘Oil Group’ has checked aspects of these in detail, and additionally carried out its own research.
b. More recent detailed study by Michael R. Smith (an author of this paper) of EnergyFiles Ltd. who has developed a bottom-up model of historic and forecast global oil production constrained by OPEC supply, assuming different future demand levels. The author has long-term field experience as a geologist, oil exploration manager and consultant in a range of locations across the world. His report is published by international energy analysts Douglas-Westwood Ltd.[4]

The data sets supporting the analyses are drawn from a wide variety of sources. A primary source for the Reading Group has been the data set of IHS Energy/Petroconsultants providing information on most oil and gas fields in the world and giving wildcat histories, allowing regional discovery trends to be determined.

M. R. Smith’s work has been derived from public domain production data and from independently determined reserves analyses derived from his experience and personal contacts with oil companies and governments. The various data sets have been subject to considerable comparison, checking and adjustment.

Mainstream Calculation of oil Peaking

Various opinions on the timing of oil peaking have been presented in the literature since the 1970s. Some of these forecasts are given in Table 1, all of which are founded on estimates, at the time, of the world’s original conventional oil endowment (its ultimates reserves, or ‘ultimate’).[5]

Table 1
Forecasts of the Date of Global Conventional Peak Oil Production

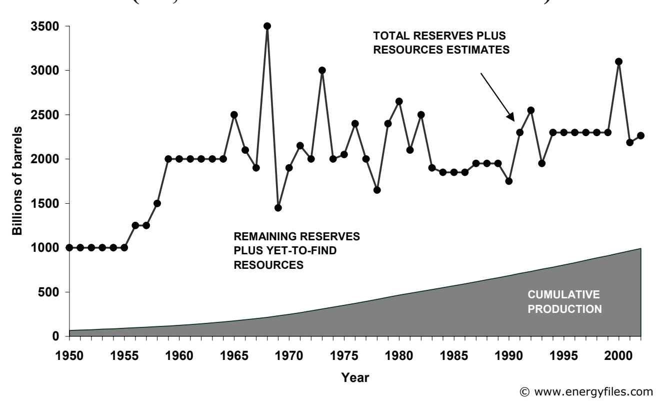
Year	Source	Forecast Date of Conventional Peak	Ultimate (Gb)
1972	ESSO	“oil to become increasingly scarce about the year 2000”	2100
1976	UK Dept. of Energy	“about 2000”	n/a
1977	M.K. Hubbert	1995	2000
1979	Shell	“plateau within the next 25 years”	n/a
1981	World Bank	“plateau around the turn of the century”	1900
1995	Petroconsultants	2005	1800
1997	Ivanhoe	2010	~2000
1997	Edwards	2020	2836
1998	IEA: WEO 1998	2014	2300
1999	USGS (Magoon)	around 2010	~2000
1999	Campbell	around 2010	2000
2000	Bartlett	2004/2019	2000/3000
2000	IEA: WEO 2000	“beyond 2020”	3345
2000	US EIA	2016/2037	3003
2001	Deffeyes	2003-2008	n/a

NB: Gb (billion barrels); Ultimate recoverable oil reserves; Various definitions of conventional oil.

The majority of such mainstream calculations are based on the following methodology:

- Conventional oil is differentiated from non-conventional oil.
- Estimates are generated for the world’s original endowment of conventional oil. Such estimates have generally lain in the range 2000 to 3000 billion barrels. There have been perhaps 100 such estimates, with the majority lying fairly close to the 2000 billion barrel level as shown in Figure 1.
- Oil production from a sedimentary basin reaches a

Figure 1
A Succession of Estimates Since 1950 of the World’s Original Endowment of Conventional Oil (i.e., the Total Recoverable Resource)



Source: The World Oil Supply Report 2003-2050, Douglas-Westwood Limited.

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physical peak, and then declines, when roughly half the original endowment has been produced. The physical explanation for this is straightforward, as falling output from large, early fields cannot be replaced by production from smaller, later fields coming onstream. It is empirically confirmed by the production profiles from depleting basins in the USA and Europe.

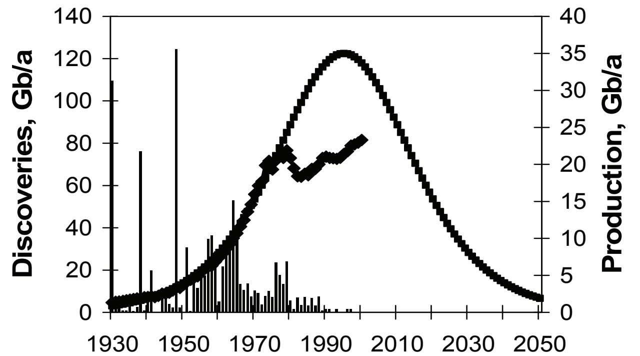
- The majority of estimates of the world conventional oil endowment of about 2000 billion barrels give a global peak in production of conventional oil occurring about 2010.
- The calculations yield a peak date for the production of *conventional* oil only and they may or may not include natural gas liquids (NGLs).
- Forecasts of peak are mostly not demand constrained. They do not account for OPECs efforts to restrict output, which have, for periods, held back demand. And, of course, other energy sources have progressively substituted for oil (especially gas, hydroelectricity and nuclear power for electricity generation), which also holds back demand.

It has also long been known that the world contains large amounts of non-conventional oil - extra-heavy oils, oil (tar) sands and oil shales - that need special extraction and refining techniques to make them useable. In the last decade non-conventional oil extraction and refining costs have fallen as technology has improved and experience has increased.

For prime sites in the Venezuelan Orinoco Belt and the Canadian Athabasca oil (tar) sands, production growth is large, but these oils remain intrinsically more expensive to produce because they require significant energy for extraction. Moreover such oils have higher CO_2 emissions, and are slow to bring onstream. For these reasons, it is estimated that their rate of production growth will be insufficient to offset most of the decline in global production of conventional oil.

The mainstream view is thus summarised by Figure 2, which shows oil discovery history (left-hand scale), a hypothetical mid-point peaking curve and the world's actual production (right-hand scale). The high prices of the two oil shocks in the 1970s curbed demand and delayed the anticipated date of peak.

Figure 2
The Mainstream View of Oil Global Peaking



Source: C.J. Campbell, discovery data (vertical bars, left-hand scale) exclude deepwater & polar oil. Hypothetical production curve corresponds to global original endowment of 1800 bn bbls; diamonds indicate actual production (both right-hand scale).

The Petrocounsultants'/C. J. Campbell Calculations

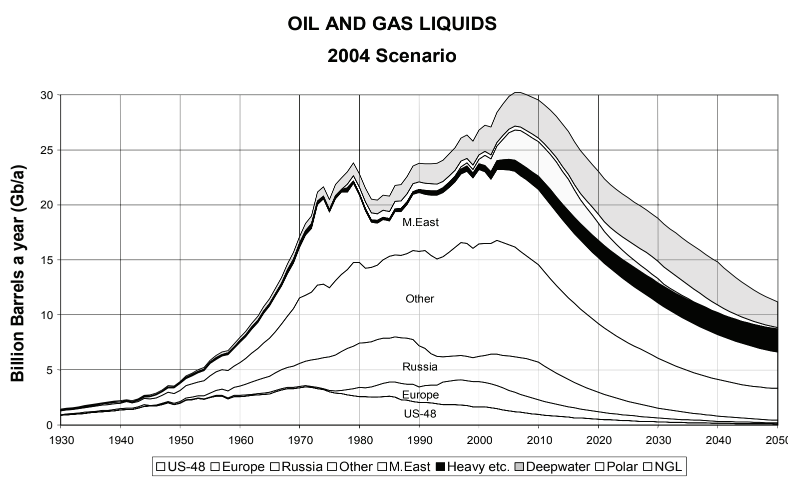
Figure 3 shows a calculation of global oil production based on the 1995 Petroconsultants' report (Campbell & Laherrère), as subsequently modified by Campbell.

In this Figure, the production of conventional oil holds close to maximum until around 2010, and then enters decline, driven by the limit of the world's resource of this type of oil. The combined production of deepwater and polar oil also peaks around this date. Production of extra heavy and tar sands oil expands, but is not sufficient to offset declining output of conventional and related oils.

The methodology used to generate this Figure was as follows:

a. Estimation of 'P50' oil reserves, by country. ('P50' reserves are those with a notional 50% probability, i.e., being equally likely to see downward as upward revision with time). The estimates were generated by taking reserves data from the Petroconsultants' database, but adjusting in the light of geological knowledge and on the basis of reasonableness tests. A key test is to plot field production vs. cumulative production. For most fields in decline this plot gives a good check of the field's likely ultimate recoverable reserves. For example, the approach shows that many field reserves in the former Soviet Union are significantly over-reported.
b. Generation of estimates of oil yet-to-find. This analysis was by basin where appropriate, and mostly used a range of statistical approaches, essentially based on discovery data to-date, to estimate the quantities of conventional oil likely be found within a reasonable exploration timeframe (for example, from twice as many wildcats as already drilled in the basin).
c. Addition of cumulative production, P50 reserves, and

Figure 3
Forecast of Oil Production, By Region and By Type.



Source: ASPO Newsletter No. 27, March 2003. (www.isv.uu.se/iwood2002) to yet-to-find, to give an estimate of each country's ultimate (i.e. ultimately recoverable reserves).

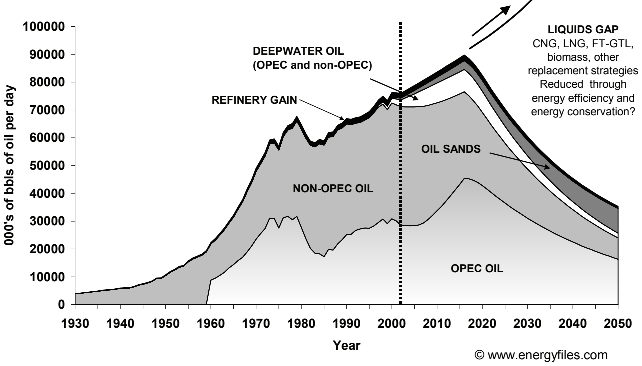
d. Modelling each country's future production. For a country already past peak, this was by declining production at the existing decline rate (fixed percentage of the remaining recoverable resource). If prior to peak, this was by increasing production at an assumed growth rate until cumulative production equals half that country's ultimate, and thereafter declining production at the then-existing decline rate. In the case of the Middle-East swing producers, their production was calculated, subject to their own resource limits, using a number of 'geo-political' scenarios.

Figure 4 shows a calculation of global oil production by M. R. Smith from the 2003 edition of the World Oil Supply Report.[4]

It was concluded that the world's known and estimated yet-to-find reserves and resources cannot satisfy the present level of production of some 74 million barrels per day beyond 2020. Any growth in global economic activity only serves to increase demand and bring forward the peak year. In Figure 4, 1% demand growth brings the year to 2016, when production is expected to peak at around 85 million barrels per day. With 2% growth, peak production of around 90 million barrels per day occurs in 2012.

Non-OPEC decline is expected to begin around 2007 whatever the demand. Even with the Middle Eastern countries producing as much as they can - inevitably requiring major foreign investment - forecasts of demand requirements of anything over 90 to 100 million barrels per day are not achievable.

Figure 4
World Oil Production 1930 to 2050
Assuming 1% Demand Growth to Peak



Source: The World Oil Supply Report 2003-2050, Douglas-Westwood Limited.

The methodology, although generally similar to the previous modelling above, used differing estimates of OPEC restrictions in the years to peak to determine four demand growth scenarios (zero, 1%, 2% and 3%). All existing and potential oil producing countries were subjected to a bottom-up analysis of known and 'yet-to-find' oil reserves and resources, including conventional, deepwater, gas substitutes and oil (tar) sands. A production profile was created based on potential productive capacity and depletion history. The data were combined to give views on the limits of global oil production, and alternatives were analysed to assess how energy mix and pricing levels might develop over coming years.

There are ninety-nine countries in the world formerly, actually or forecast to be capable of producing significant oil volumes (above 1000 bbls per day). Of these, forty-nine are already well past their resource-limited oil production peak. They include Germany (peaking in 1968), USA (1970), Romania (1976), Russia (late in the Soviet era), and Indonesia (1991). Eleven countries are just past peak, including Malaysia (1998), UK (1999) and Norway (2002). Twelve countries are at or near peak, including Algeria, Australia, China and Mexico. The remaining twenty-seven will reach peak within 25 years.

Under a 1% demand growth scenario, OPEC's share of oil production will have to substantially increase within five years if demand is to be met. If so, significant capital investments within OPEC countries, particularly Saudi Arabia, Iraq and Iran, will be required to raise gross production by around 2 mm bbls per day every year to offset declines elsewhere.

The Economists' Arguments

It is appropriate in this paper to discuss the views of many of the economists who study world energy resources. The general lack of communication between petroleum geologists and engineers, who study world oil supply, and the energy economists, who tend to focus on demand, has led to a lack of understanding about oil depletion.

At the heart of the controversy is the economists' view that human ingenuity has always kept ahead of resource depletion, and that there is no reason to expect this to change. More specifically, the economists accuse geologists of omitting the effects of price and technology from their models (and hence badly underestimating the future oil resource), and of not understanding the market mechanisms whereby supply and demand equilibrate.

Conversely we argue that the economists are misled by unreliable publicly-announced reserves volumes,[6] ignore evidence for mid-point peaking (and hence are reassured that there is 'at least 40 years of oil remaining') and do not fully understand oil industry conventions on reserves reporting (believing that fields show 'technology gain' when in fact only the reporting has changed).

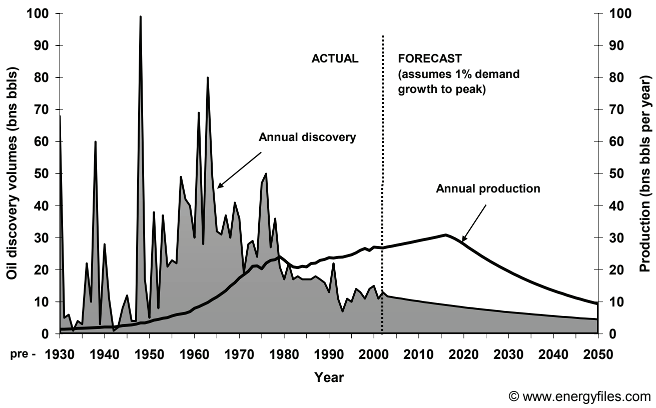
In particular, energy economists see higher price as:

a. Encouraging exploration. High prices do encourage exploration, but the creaming curves of most countries (showing cumulative oil discovery versus cumulative exploration wells) are now almost flat, pointing to a dearth of exploration opportunities. Indeed the 1970s oil shocks only temporarily reversed the decline in discovery rates (as offshore regions began to be exploited), as shown in Figure 5, and led to a decline in exploration well success rates.

b. Bringing in currently uneconomic fields. Although marginal fields do become commercial, their contribution is also marginal. Around 65% of world reserves are contained in a little over 500 giant (greater than 500 million barrel) fields.

c. Raising the recovery factor. Theoretically, there is large scope for increased recovery, however, such techniques have already been used in numerous older fields; are already accounted for in most younger, especially offshore, fields; cannot be applied everywhere; and many of the giant fields are already fully exploited by intense drilling. Most growth in the reserves of existing fields is in their reporting.

Figure 5
World Oil Discovery Volumes 1930 to 2050



Source: The World Oil Supply Report 2003-2050, Douglas-Westwood Limited.

d. Giving adequate warning. Not only can production costs fall as supplies are drawn down, but also OPEC production restrictions have meant that higher cost reserves are being depleted faster than lower cost reserves. As cheaper Middle East oil becomes more important in the supply mix, prices could decrease. In fact price signals in the USA before the 1970s oil shocks were small, and ignored.

e. Correcting imbalances in the market, by curbing demand and bringing on new types of supply. Of course new types of energy will attempt to alleviate oil supply shortfalls, but the key questions are: at what cost, and at what rate?

Oil price will certainly have effects both on global demand, and on supply, but it is also a driver that will lead to severe disruption to economic growth. It should not be used as an excuse to dismiss the oil depletion problem.

Gas

This paper does not consider gas resources or supply. However the decline in the discovery of conventional gas since the late 1960s, allied to growth in gas demand and continued replacement of oil by gas in electricity generation, will also lead to gas supply difficulties in the medium-term. See, e.g., www.oildepletion.org for a model of global 'all-hydrocarbons' production.

Conclusions

Global conventional oil production will reach a resource-limited peak, and subsequently decline, between 2011 and 2020, with the actual year depending on the rate of demand increase. The global non-OPEC resource-limited conventional oil peak will occur probably within 5 years, triggering price increases that will dampen demand.

The resource base of non-conventional oil and oil substitutes, especially oil (tar) sands in Canada and Venezuela, will be tapped to an increasing degree, but energy-cost, investment and pollution constraints are likely to keep production increases significantly below the corresponding conventional oil shortfall. The global production of all-oil will, therefore, also decline.

Acknowledgements

We acknowledge the advice of many people in the oil industry, but especially Dr. George Leckie, formerly of IHS Energy/Petroconsultants, Mr. L. F. Ivanhoe of the M. K. Hubbert Center for Petroleum Supply Studies, Colorado School of Mines, USA; Dr. C. J. Campbell, Ireland; and M. J. H. Laherrère, France. In addition, a particular debt is owed to the pioneering work of Mr. H. R. Warman of BP, and Dr. M. K. Hubbert of Shell.

Notes and References

[1] The 'Oil Group' at the University of Reading, UK, consists of Professors M. L. Coleman and B. W. Sellwood of the Postgraduate Research Institute for Sedimentology; Dr. J. D. Burton, Mr. R. H. Booth, Dr. R. Mayer and Professor P. D. Dunn of the Dept. of Engineering; Dr. G. R. Whitfield, and R.W. Bentley of the Dept. of Cybernetics. Publications include: R.W. Bentley. *Global Oil and Gas Depletion: An Overview*. Energy Policy, Vol. 30, No. 3, February 2002, pp 189-205. Elsevier, 2002; and R.W. Bentley, R.H. Booth, J.D. Burton, M.L. Coleman, B.W. Sellwood, G.R. Whitfield. *Perspectives on the Future of Oil*. Energy Exploration and Exploitation, Vol. 18, Nos. 2 & 3, pp 147-206, Multi-Science, 2000.

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[3] E.g.: C.J. Campbell and J.H. Laherrère. *The End of Cheap Oil*. Scientific American, March 1998, pp 60-65.

[4] *The World Oil Supply Report 2003-2050* 2^{nd} Edn., author Michael R. Smith (e-mail: glow@lineone.net, Web: www.energyfiles.com), published by Douglas-Westwood Ltd.

[5] For a more detailed table and commentary see: R.W. Bentley. *Oil Forecasts, Past and Present*. Proc. Int'l Workshop on Oil Depletion 2002, Uppsala University. (www.isv.uu.se/iwood2002).

[6] Public-domain proved oil reserves data are very misleading. The data are generally either very conservative (e.g., the U.K.), or conservative (many countries); although some countries (such as the FSU) are over-reported. The data can change suddenly (e.g., OPEC 'quota wars', or Mexico). But, worst of all, the data are simply not updated for the majority of countries.

IRAEE Conference A Success

The position of NGO's has recently been significantly elevated on the world scene. They enjoy an increasingly greater role to play in the process of globalization, advancement of human capital and creation of new channels of communication among peoples. The Iranian affiliate (Iranian Association for Energy Economic-IRAEE) has proved itself to be exceptionally capable of providing what is expected of an active NGO. IRAEE's recent success in organizing the 2004 IAEE affiliate international conference in Tehran is an excellent evidence of the said capabilities.

The conference named "Energy and Security in the Changing World" was initially approved in the year 2000 in Sydney, Australia and later on confirmed during the Prague gathering in the summer of 2003. The success in Tehran can be seen from the list speakers and attendees (including current and three past presidents of IAEE), quality of presentations, exceptionally professional organization, the number of well known financial and media sponsor, large participation of women, responses received from participants and the hospitality of the organizers and Iranians as a whole. The reports indicate that 810 energy economists (including 129 Women and 182 non-Iranians,) from 31 countries representing 280 universities and companies and 69 media executives participated in the Tehran gathering.

This three-day conference was sponsored by fourteen energy producing companies from six different countries and fifteen media organizations from twelve countries including USA, UK and Iran.

The 83 high quality presentations of the conference (selected from 201 candidate papers) were organized and put together in four plenaries, six dual plenaries, twelve concurrent sessions and one well-attended workshop. Among the lead speakers of this gathering were two Iranian cabinet ministers (Petroleum and Energy), four distinguished editors of world famous energy journals and the current and three past presidents of IAEE (F. Fesharaki, P. Davies and A. Nystad.). IAEE congratulates the IRAEE's success and looks forward to greater interaction among the affiliates.

The conference was held at a time of exceptional strength in energy markets, which added to the pertinence of the conference's main theme. A number of speakers reviewed the long- and medium term prospects for adequate and affordable energy supplies and their relationship with international politics and stability. Former IAEE president, Peter Davies of BP, was one of several presenters underlining that the current strength in oil prices was attribtuable to certain short- and medium term imbalances, and not to any long-term global shortage of energy.

The Iranian perspective was presented by the Minister of Petroleum, Mr Zangeneh, the Minister for Energy, Mr Bitaraf, as well as by several academics including Professor Abbaspour, the conference chair. Iran's role was highlighed not only as an exporter of energy, but also the challenges of its domestic market and supply system. On the background of strong consumption growth particularly in China, much attention was received by several presentations on market developments in Asia.

A broad array of energy sectors and issues was covered in concurrent sessions. There were sessions on electricity, natural gas including LNG, downstream including refining, renewables, emissions trading, finance and taxation. The conference concluded with a journalists' panel, which notably included a discussion on the quality of the supply and demand data which are often used as a basis for market analysis and decision making.

Most papers and presentations from the conference were made available to participants on a well-organized CD-ROM

Reza Farmand and Erik Jarlsby

Iranian Conference delegates enjoy the meeting.

Fueling the Future:
Prices, Productivity, Policies, and Prophesies

September 18-21, 2005 Omni Interlocken Resort Denver, Colorado - USA

25th USAEE/IAEE North American Conference

United States Association for Energy Economics International Association for Energy Economics
Denver Chapter, USAEE

General Conference Chair: Marianne Kah
Program Co-Chairs: Dorothea El Mallakh & Carol Dahl
Concurrent Session Chair: Wumi Iledare

Conference Objective

Energy is forefront in the news again! Will coming years take us to clean, cheap, stable, and secure energy supplies with ever-increasing prosperity? Concentrated plenary sessions combined with diverse concurrent sessions and ample networking opportunities will provide the backdrop for exploring a wide-range of issues within energy markets while enjoying a view of the Rocky Mountains in a congenial atmosphere.

Plenary Session Themes

Fossil Fuels Reliance & Reserves
Environmental Issues: Past Approaches - Future Concerns
Electricity Reliability: Boom to Bust & Back AgainEnergy:
Oil & Natural Gas Market Volatility
Energy Security in the 21st Century
International Commodities
Non-Conventional Energies: Probable to Proven

Possible Concurrent Session Topics

Concurrent sessions will be developed from the papers selected for the program. Among the possible topics are: Electricity markets; geopolitics of energy; international energy markets; global LNG; Kyoto Protocol revisited & emissions trading policies; transport sector challenges; forecasting, modelling & scenario developments; energy efficiency & renewables; avoiding bottlenecks & blackouts; nuclear power revisited; sustainable development; private vs. public ownership & use; energy supply & demand; energy policy discontinuities and the climate change debate.

All topic ideas are welcome and anyone interested in organizing a session should propose the topic and possible speakers to:
Wumi Iledare, Concurrent Session Chair (p) 225-578-4552 (f) 225-578-4541 (e) wumi@lsu.edu

**** CALL FOR PAPERS ****

Abstract Submission Deadline: April 29, 2005
(Please include a short CV when submitting your abstract)

Abstracts for papers should be between one to two paragraphs (***no longer than one page***), 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. Authors will be notified by May 20, 2005, of their paper status. Authors whose abstracts are accepted will have until June 29, 2005, to return their papers for publication in the conference proceedings. While multiple submissions by individuals or groups of authors are welcome, the abstract selection process will seek to ensure as broad participation as possible: each speaker is to present only one paper in the conference. No author should submit more than one abstract as its single author. If multiple submissions are accepted, then a different co-author will be required to pay the reduced registration fee and present each paper. Otherwise, authors will be contacted and asked to drop one or more paper(s) for presentation. 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

Students: Please submit your paper for consideration of the USAEE Best Student Paper Award ($1,000 cash prize plus waiver of conference registration fees). If you are interested, please contact USAEE Headquarters for detailed applications / guidelines. Students may also inquire about our scholarships for conference attendance. Visit www.iaee.org/en/conferences for full details.

Travel Documents: All international delegates to the 25th USAEE/IAEE North American Conference are urged to contact their consulate, embassy or travel agent regarding the necessity of obtaining a Visa for entry into the United States. If you need a letter of invitation to attend the conference, contact USAEE with a fax request to 216-464-2768 or email to usaee@usaee.org The Conference strongly suggests that you allow plenty of time for processing these documents.

Interested in touring Denver? Visit http://www.denver.org/visitors/index.asp
Interested in touring Boulder? Visit http://www.bouldercoloradousa.com

Conference Proceedings on CD Rom
23rd North American Conference
Mexico City, Mexico, October 19-21, 2003

The Proceedings of the 23rd USAEE/IAEE North American Conference of the held in Mexico City, Mexico are available from IAEE Headquarters on CD Rom. Entitled **Integrating the Energy Markets in North America: Issues & Problems, Terms & Conditions**, the price is $100.00 for members and $150.00 for non members (includes postage). Payment must be made in U.S. dollars with checks drawn on U.S. banks. Complete the form below and mail together with your check to Order Department, IAEE, 28790 Chagrin Blvd., Suite 350 Cleveland, OH 44122, USA.

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Publications

Energy Security, Managing Risk in a Dynamic Legal and Regulatory Environment. B. Barton, C. Redgwell, A. Rinne, D. Zillman, Eds. (2004). Price: £79.50. Contact: Oxford University Press, Great Clarendon St, Oxford OX2 6DP, United Kingdom. Phone: 01865-556767.

Energy-Efficient Motor Systems: A Handbook on Technology, Programs, and Policy Opportunities, 2nd Edition. S. Nadel, R.N. Elliott, M. Shepard, S. Greenberg, G. Katz, A. deAlmeida. (2002). 488 pages. Price: $40.00. Contact: ACEEE, 1001 Connecticut Ave, NW Ste 801, Washington, DC 20036. Phone: 202-429-0063. Fax: 202-429-0193. Email: aceee_publications@aceee.org URL: www.aceee.org

Oil Politics – A Modern History of Petroleum. Francisco Parra. (2003). 456 pages. Price: £45.00. Contact: I.B.Tauris & Co. Ltd, 6 Salem Road, London W2 4BU, United Kingdom. Phone: 44-20-7243-1225. Fax: 44-20-7243-1226. Email: sales@ibtauris.com URL: www.ibtauris.com

Crude Power Politics and the Oil Market. Oystein Noreng. 288 pages. Price: £45.00. Contact: I.B.Tauris & Co. Ltd, 6 Salem Road, London W2 4BU, United Kingdom. Phone: 44-20-7243-1225. Fax: 44-20-7243-1226. Email: sales@ibtauris.com URL: www.ibtauris.com

Forthcoming Blood and Oil – America's Quest for Energy Security. Ian Rutledge. (2004). 256 pages. Price: £24.50. Contact: I.B.Tauris & Co. Ltd, 6 Salem Road, London W2 4BU, United Kingdom. Phone: 44-20-7243-1225. Fax: 44-20-7243-1226. Email: sales@ibtauris.com URL: www.ibtauris.com

Iran and the Gulf – A Search for Stability. Jamal S. Al-Suwaidi, Ed. 425 pages. Price: £39.50/£22.50. Contact: I.B.Tauris & Co. Ltd, 6 Salem Road, London W2 4BU, United Kingdom. Phone: 44-20-7243-1225. Fax: 44-20-7243-1226. Email: sales@ibtauris.com URL: www.ibtauris.com

Gulf Security in the Twenty-First Century. C. Koch and D. Long, Eds. 384 pages. Price: £39.50/£19.50. Contact: I.B.Tauris & Co. Ltd, 6 Salem Road, London W2 4BU, United Kingdom. Phone: 44-20-7243-1225. Fax: 44-20-7243-1226. Email: sales@ibtauris.com URL: www.ibtauris.com

Politics of the Black Sea – Dynamic of Cooperation and Conflict. Tunc Aybak, Ed. 240 pages. Price: £45.00. Contact: I.B.Tauris & Co. Ltd, 6 Salem Road, London W2 4BU, United Kingdom. Phone: 44-20-7243-1225. Fax: 44-20-7243-1226. Email: sales@ibtauris.com URL: www.ibtauris.com

The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate. Joseph Romm (2004). 256 pages. Price: $25.00. Contact: Island Press, 1718 Connecticut Avenue, NW, Suite 300, Washington, DC, USA. Phone: 202-232-7933 x 26. Fax: 202-234-1328. Email: ssoldavin@islandpress.org URL: www.islandpress.org

The Future of the Russian LPG Market. (2004). 150 pages. Price: $300.00. Contact: RPI, Inc. Fax: 7-095-967-0117 Email: vsevolodp@rpi-inc.com

Calendar

2-3 September 2004, 6th IAEE European Conference 2004 - Modelling in Energy Economics and Policy at Zurich, Switzerland. Contact: Susanne Munch, Conference Secretariat, ETH Zentrum WEC, CH - 8092 Zurich, Switzerland. Phone: 41-1-632-06-50. Fax: 41-1-632-16-22 Email: s.muench@cepe.mavt.ethz.ch URL: www.saee.ch/

5-9 September 2004, 19th World Energy Congress and Exhibition at Sydney, Australia. Contact: Tour Hosts Pty Limited Email: energy2004@tourhosts.com.au URL: www.touhosts.com.au/energy2004

9-9 September 2004, 2nd Annual Global Petroleum Industry Upstream Awards at Carlton Tower Hotel, Knightsbrige, London. Contact: Babette van Gessel, Group Mananging Director, Global Pacific & Partners International, 264 Groot Hertoginnelaan, The Hague, Netherlands. Phone: +31 70 324 6154. Fax: +31 70 324 1741 Email: info@glopac.com URL: www.petro21.com/events

12-15 September 2004, Hydrogen and Fuel Cell Futures at Perth, West Australia. Contact: Congresswest Email: hydrogen@congresswest.com.au URL: www.congresswest.com.au/hydrogen

13-15 September 2004, Water Middle East 2004/Power-Gen Middle East 2004 at Manama, Kingdom of Bahrain. Contact: Conference Coordinator, Nurnberg Global Fairs, Messezentrum, Nurnberg, 90471, Germany. Phone: 49-911-86-06-86-97. Fax: 49-911-86-06-86-94 Email: frank.venjakob@nuernbergglobalfairs.com URL: www.water-middle-east.com

20-21 September 2004, 6th Renewable Energy Finance Forum at London. Contact: Alastair MacDonald, Sales Manager, Euromoney Energy Events, Nestor House, Playhouse Yard, London, EC4V 5EX, United Kingdom. Phone: +44 20 7779 8945. Fax: +44 20 7779 8946 Email: amacdonald@euromoenyplc.com URL: www.euromoneyenergy.com

21-22 September 2004, Energy Credit Risk at New York. Contact: Tracey Huggett Email: thuggett@riskwaters.com URL: www.incisive-events.com/ecr

22-24 September 2004, World Energy Engineering Congress at Austin, TX. Contact: Conference Organizor, Association of Energy Engineers, USA URL: https://www.aeecenter.org/Shows/

22-23 September 2004, The Regulation of The Internal Energy Market in The European Union at Barcelona, Spain. Contact: Xavier Vives, Conference Scientific Director, IEB, Spain URL: www.pcb.ub.es/ieb/confeneg

27-30 September 2004, MINexpo International 2004 at Las Vegas, NV. Contact: Conference Coordinator, MINexpo International, PO Box 590, Frederick, MD, 21705, USA. Phone: 301-694-

(continued on page 33)

5243. Fax: 301-694-5124 Email: min041attendee@expoexchange.com URL: www.minexpo.com

28-30 September 2004, Metering, Billing & CRM/CIS Europe 2004 at Berlin, Germany. Contact: Ms. Maureen de Graauw-Odijk, Project Manager, Synergy, PO Box 1021, Maarssen, 3600 BA, The Netherlands. Phone: +31 346 590 901. Fax: +31 346 590 601 Email: maureen@synergy-events.com URL: www.metering.com/events

28-29 September 2004, Green Power Central & Eastern Europe at Budapest, Hungary. Contact: Mr. Nadim Chaudhry, Event Director, Green Power Central and Eastern Europe Email: nadim.chaudhry@greenpowerconferences.com URL: www.greenpowerconferences.com

30 September, 2004 - October 2, 2004, Third International Symposium - Energy and Environment 2004 at Sorrento, Italy. Contact: Secretariat, Fondazione Megalia, Via Orazio, 86, Napoli, 80122, Italy. Phone: 39-081-66-58-15. Fax: 39-081-240-42-19 Email: megalia.eco@tiscalinet.it URL: www.megaliafoundation.it

4-8 October 2004, World Economics for Oil and Gas at London, UK. Contact: Norrie Hernon, Mr, CWC Associates, 3 Tyers Gate, London, E14 6JG, England. Phone: +44 207 089 4181. Fax: +44 207 089 4201 Email: nhernron@thecwcgroup.com URL: http://www.thecwcgroup.com/train_detail_home.asp?TID=5

4-4 October 2004, 8th Annual Africa Downstream 2004 at Arabella Sheraton, Cape Town, South Africa. Contact: Babette van Gessel, Group Mananging Director, Global Pacific & Partners International, 264 Groot Hertoginnelaan, The Hague, Netherlands. Phone: +31 70 324 6154. Fax: +31 70 324 1741 Email: info@glopac.com URL: www.petro21.com/events

5-6 October 2004, 3rd Black Sea Energy Summit at Hyatt Regency Thessaloniki, Greece. Contact: Brindusa Vladutu, Mrs., The Forum for Regional and Interregional Development, Bd. Unirii 66, Bl. K 3, Ap. 9, sector 6, Bucharest, Romania. Phone: +40 21 326 48 29/30. Fax: +40 21 326 48 32 Email: bvladutu@forum.ro URL: www.forum.ro/energy3/index.htm

5-7 October 2004, Project Finance World Africa 2004 at Gallagher Estate, Johannesburg, South Africa. Contact: Saret Britz, General Manager, Terrapinn Limited, Private Bag X65, Bryanston, Johannesburg, Gauteng, 2021, South Africa. Phone: +27 11 463 2802. Fax: +27 11 463 6000 Email: saret.britz@terrapinn.com URL: www.terrapinn.com

5-5 October 2004, Third Scramble for Africa: Strategy Briefing 2004 at Victoria & Alfred Hotel, V&A Waterfront, Cape Town, South Africa. Contact: Babette van Gessel, Group Mananging Director, Global Pacific & Partners International, 264 Groot Hertoginnelaan, The Hague, Netherlands. Phone: +31 70 324 6154. Fax: +31 70 324 1741 Email: info@glopac.com URL: www.petro21.com/events

6-8 October 2004, 11th Africa Upstream 2004 at BMW Pavilion & IMAX Theatre, Cape Town, South Africa. Contact: Babette van Gessel, Group Mananging Director, Global Pacific & Partners International, 264 Groot Hertoginnelaan, The Hague, Netherlands. Phone: +31 70 324 6154. Fax: +31 70 324 1741 Email: info@glopac.com URL: www.petro21.com/events

7-8 October 2004, Electric and Natural Gas Conference at Atlanta, Georgia. Contact: Conference Coordinator, Bonbright Center Energy Conference, Terry College of Business, 110 E Clayton St, Bank of America Bldg, Ste 602, Athens, GA, 30602, USA. Phone: 706-425-3051. Fax: 706-369-6078 URL: www.terry.uga.edu/bonbright/

IAEE Newsletter

Volume 13, Third Quarter 2004

The *IAEE Newsletter* is published quarterly in February, May, August and November, by the Energy Economics Education Foundation for the IAEE membership. Items for publication and editorial inquiries should be addressed to the Editor at 28790 Chagrin Boulevard, Suite 350, Cleveland, OH 44122 USA. *Phone:* 216-464-5365; *Fax*: 216-464-2737. Deadline for copy is the 1st of the month preceding publication. The Association assumes no responsibility for the content of articles contained herein. Articles represent the views of authors and not necessarily those of the Association.

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