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INTERNATIONAL ASSOCIATION *for* ENERGY ECONOMICS

IAEE Energy Forum

Second Quarter 2010 International Association for Energy Economics

President's Message

The Copenhagen Climate Conference (COP 15) is over months ago. To those who had hoped for a forward-looking and binding global agreement on GHG-emissions and related climate issues, the outcome must have been disappointing. Some have even characterized it as a defeat or at least a serious setback for such negotiations, partly because the resulting document from the Copenhagen negotiations, the Copenhagen Accord, is short and vague and not legally binding on the parties, and partly because negotiations in this form and on this scale have made it evident how difficult it is to reach consensus on a complex issue as climate change.

It has been surprisingly quiet, some may even say alarmingly quiet, on the climate negotiating scene after Copenhagen. It is almost as if the air has gone out of a balloon. It is surprising in view of the intense preparations and efforts that went into the Copenhagen negotiations and it may be alarming because the Mexico negotiations are not that far away. Instead, a heated debate has arisen about the quality of the underlying foundation of the data and scientific knowledge base of the negotiations, and the relationship between science and politics in this area of policy decision-making. In particular, the IPCC has come under critique and scrutiny, partly because of its general methodological approach and working methods, and partly because of some of its specific predictions about expected effects of climate change and global warming, e.g. on the melting of ice in Himalaya.

This debate might distract from the long-term real issues of global climate change and political measures to control it, but to the extent that it can contribute to clarifying the relationship between science and politics, and create a better understanding of this relationship among parties involved in the policy decision-making process, broadly defined, it should be welcomed. These issues are also highly relevant for the IAEE in many contexts, so let me take this opportunity to comment a little on them.

As a background and example: In 1997, Mike Hulme, Professor of Climate Change at the University of East Anglia, author of the thought-provoking book, *Why We Disagree About Climate Change* (Cambridge University Press, 2009), and a leading British environmental scientist, initiated and co-signed a common statement by European climate researchers, as an input to the preparation for the Kyoto Climate Conference, in support of the EU proposal for a 15 per cent reduction of CO_2 emissions by 2010. This statement, coming from a group of climate scientists, he argued then, was to be considered as "an indisputable conclusion of our scientific work".

Between 1997 and 2009 he evidently changed his mind on these issues. Recent statements by him like e.g. "Don't use science to get round politics" and "To hide behind the dubious precision of scientific numbers, and not actually expose one's own ideologies or beliefs or values and judgments is undermining both politics and science", are examples of this change of opinion. He was really upset by the comments made by the then Danish Prime Minister, Anders Fogh Rasmussen, in an opening statement to a scientific conference in Copenhagen prior to the COP 15, e.g., ".......science should be the basis for decision-making in this field", and then he asked scientists to keep it simple, "not to provide us with too many moving targets...and not too many considerations on uncertainty and risk and things like that."

Not all political statements are, of course, like this one, but still it illustrates the basic dilemma between science and politics: Ideally, we would like political decisions to be

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Editor: David L. Williams

PRESIDENT'S MESSAGE *(continued from page 1)*

based on the best, relevant scientific knowledge available, but in the process of transforming and translating scientific knowledge to make it useful as a foundation for policy decisions, it may be distorted, taken out of its context, unduly simplified (and sometimes maybe even manipulated to fit a stated purpose), and, in the end, incompletely understood or misinterpreted by decision-makers, so that it may, in fact, sometimes do more harm than good in the policy-making process. And then we should always remind ourselves that, ultimately, the most important debate about issues like climate change, energy resource use, etc. is about policy and political choices and not about science in a narrow sense; e.g., how much resources to use to combat GHG-emissions and prevent global warming beyond acceptable limits, is basically a question of political decision-making and not a question that scientific data and knowledge can solve.

What relevance does all this have to the IAEE? As a professional association, the IAEE is, of course, politically independent in every respect. However, at IAEE conferences and other occasions we regularly meet as IAEE members from industry and business, government, consulting, and the academic and research communities to discuss energy economic issues that often border on policy. As scientists and researchers we feel, and sometimes may even get frustrated by the fact, that the wealth of data, researched-based knowledge and competence we have at our disposal are not sufficiently taken advantage of in the policy-making process, resulting in inoptimal or inferior decisions compared to what the outcome could have been if this knowledge was built properly into the process. Should we then simply leave it at that, throw up our hands, and withdraw from the process? Of course not, but we should be fundamentally aware of the consequences and the responsibility placed on us if we step outside the confines of science and become advocates of certain political solutions, without making our scientific position clear and the limitations that our data and knowledge may have in relation to specific political decisions. This may sound obvious and at the same time unduly restrictive, but again, the experience from climate research as a case in point, referred to above, may at least give us a warning signal to think about.

A recurring criticism or argument at IAEE conferences, and also to some extent with regard to IAEE publications, is that dialogue and communications between parties are made unnecessarily difficult, particularly because of academic jargon and analytical exposition in papers and studies being presented, also in relation to debate on policy-oriented issues. Dialogue is a two-way communication process and, therefore, it is not just one side that should be shot at, and then typically the scientific side. Regardless of that, every effort should be made at IAEE conferences and in other connections to remove the communications barrier between parties so that a fruitful dialogue on energy policy and related policy issues can be arrived at.

As mentioned in my previous Message, a Working Group is in the process of preparing a report to the IAEE Council on the possibility of establishing a new policy-oriented IAEE publication, tentatively named the Journal of Energy and Environmental Policy (JEEP). If this project is realized, the issues I have touched upon above will have to be faced squarely and tackled constructively to the benefit of all parties. The Council will discuss the WG report and decide on the JEEP project at its meeting in Rio in June.

The Rio International IAEE Conference is coming up soon and I hope that you have made preparations to attend. I think it will be a great conference event and I look forward to seeing you there.

Einar Hope

IAEE Mission Statement

The International Association for Energy Economics is an independent, non-profit, global membership organisation for business, government, academic and other professionals concerned with energy and related issues in the international community. We advance the knowledge, understanding and application of economics across all aspects of energy and foster communication amongst energy concerned professionals.

We facilitate:

- Worldwide information flow and exchange of ideas on energy issues
- High quality research
- Development and education of students and energy professionals

We accomplish this through:

- Providing leading edge publications and electronic media
- Organizing international and regional conferences
- Building networks of energy concerned professionals

Editor's Note

This issue of the Forum continues our look at the far east, particularly China and India. We have seven articles that look at multiple facets of energy economics in that area. Next issue we will turn our attention to Russia and the former Soviet Union.

Alan Moran notes that major emission reductions in CO_2 emissions continue to be the stated goals of most developed world countries. Yet, few countries have achieved the carbon reduction goals they accepted at Kyoto in 1997 because the costs of doing so have proven to be politically excessive. These costs will increase with each successive level of forced reduction.

Yimin Liu, Yong Yang and Erica Klampfl discuss the oil supply issue China is facing, the corresponding energy and related auto industry policy the country is implementing, the impacts of the aforementioned on the auto industry and the technological measures the Chinese auto industry is taking to address these issues.

Caleb O'Kray and Kang Wu review China's biofuel developments and policy issues of the past few years, which come with a detailed list of ethanol and biodiesel plants. They also examine obstacles for future biofuel growth. Lessons learned by China, including policy effectiveness and various limitations, can be useful for other countries wanting to develop biofuels.

José A. Orosa notes that the Indian renewable-energy program was in response to India's rural energy crisis of the 1970s. He reviews the progress of the program in India, and proposes some future corrections, with special emphasis on rural areas and low wind–speed energy converters.

Hui Su and Jerald J. Fletcher summarize the motivation for China's carbon capture and storage options and development, and then discuss the carbon capture and storage potential for Shenhua's direct coal liquefaction plant in Inner Mongolia.

Stéphane Rouhier notes that because of its heavy reliance on coal, China is severely hit by pollution which puts a heavy burden on its population. After detailing Chinese energy consumption and its environmental implications, he advocates for a price-based solution to achieve an environmentally sustainable development.

Malti Goel describes the technology focus for the mitigation of climate change through carbon dioxide sequestration. She reports on an Awareness and Capacity Building Programme on Carbon Capture and Storage held in New Delhi aimed to create scientific awareness about various aspects of research into carbon sequestration in India.

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Newsletter Disclaimer

IAEE is a 501(c)(6) corporation and neither takes any position on any political issue nor endorses any candidates, parties, or public policy proposals. IAEE officers, staff, and members may not represent that any policy position is supported by the IAEE nor claim to represent the IAEE in advocating any political objective. However, issues involving energy policy inherently involve questions of energy economics. Economic analysis of energy topics provides critical input to energy policy decisions. IAEE encourages its members to consider and explore the policy implications of their work as a means of maximizing the value of their work. IAEE is therefore pleased to offer its members a neutral and wholly non-partisan forum in its conferences and web-sites for its members to analyze such policy implications and to engage in dialogue about them, including advocacy by members of certain policies or positions, provided that such members do so with full respect of IAEE's need to maintain its own strict political neutrality. Any policy endorsed or advocated in any IAEE conference, document, publication, or web-site posting should therefore be understood to be the position of its individual author or authors, and not that of the IAEE nor its members as a group. Authors are requested to include in an speech or writing advocating a policy position a statement that it represents the author's own views and not necessarily those of the IAEE or any other members. Any member who willfully violates IAEE's political neutrality may be censured or removed from membership

IAEE's Rio 2010 International Conference

InterContinental Rio – Rio de Janeiro – Brazil

06–09 June 2010

Dear Energy Professional
We kindly invite you to the wonderful city of Rio de Janeiro, Brazil, to attend the **33rd IAEE International Conference**, entitled *"The Future of Energy: Global Challenges, Diverse Solutions"*, which will be held at the Intercontinental Rio Hotel, on 06-**09 June 2010**.
Rio de Janeiro – considered by many the energy capital of Brazil – will be the perfect setting for professionals from academia, business and government to debate solutions to the common global challenges in a highly uncertain energy future. The focus of the conference will be to discuss possible changes in energy policies, technologies and markets, taking a careful look of the diversity of solutions currently available.
We invite you to visit our conference website where you will find all the latest information about the event including the conference program and travel details.
Please contact us at rio2010@ab3e.org.br in case you need any assistance.
We are looking forward to welcoming you for an unforgettable conference in Rio de Janeiro, the stage for the 2014 FIFA's World Cup final and the site for the 2016 Olympic Games.

REGISTRATION

Registrations are currently being accepted through **01 May** (speakers) and **01 June** (others). Registration fees are payable in advance.
Submit the registration form online here. Alternatively, you can download the conference registration form – just follow the instructions contained there. Conference registration fees may be paid by credit card; other payment options will be offered to you if you register online. Hotel and related travel costs are not included in registration fees. Registration fees include: registration materials, online conference proceedings, opening reception, gala dinner, off-site cultural event at the Sugar Loaf, three lunches and coffee breaks. Students: submit a letter stating that you are a full-time student and are not employed full-time; the letter should provide the name and contact information for your main faculty supervisor or your department chair and a copy of your student identification card – AB3E reserves the right to verify student status.

REGISTRATION FEES

	Received on or before			Onsite fee
	15 April	*06 May*	*04 June*	*05–09 June*
Speakers	R$ 1,155	R$ 1,350	R$ 1,350	R$ 1,450
IAEE/AB3E/IBP members	–	R$ 1,350	R$ 1,540	R$ 1,640
Non-members	–	R$ 1,540	R$ 1,830	R$ 1,930
Students	–	R$ 685	R$ 875	R$ 975
Accompanying persons	–	R$ 770	R$ 865	R$ 965
Voluntary contribution to student fund	–	R$ 195	R$ 195	R$ 195

(R$ (real) is the Brazilian currency – in March 2010, R$ 1 is worth approximately US$ 0.57 or € 0.41)

CONFERENCE VENUE AND ACCOMMODATIONS

The conference venue is InterContinental Rio hotel, conveniently located at the heart of the city within short walking distance to wonderful shopping, eating, entertainment and cultural sites, including a golf course and a hang-gliding facility. We encourage early reservations as hotel rooms are likely to sell out.
Special room block at the following group rate is available: single/double room at US$ 155.00 per night (exclusive of 15% taxes). Please note that you MUST make your reservations prior to 17 May to receive these special rates.
For reservations please fax the reservation form to **+55 21 3323-2295** or send it to the following email address: grupos@inter-rio.com.br. Identify yourself as being with IAEE's Rio 2010 International Conference.

TECHNICAL TOURS

- **05 June** – ethanol distillery in Ribeirão Preto, state of São Paulo, world's sugarcane capital
- **05 June** – oil platform shipbuilding yard in Ilha da Conceição, Niteroi (across the Bay of Guanabara from Rio de Janeiro)
- **10 June** – three research centers in Rio de Janeiro: Cepel (Eletrobrás), Cenpes (Petrobras) and Coppe (Federal University of Rio de Janeiro)
- **10 June** – ONS, Brazil's electric grid operator, in downtown Rio de Janeiro
- **11 June** – Itaipu, the second largest hydropower plant in the world, in Foz do Iguaçu, state of Paraná

You will find more information about technical tours here.

CONFERENCE OVERVIEW

Energy is a key driver of economic growth, something the world is desperately looking for in the current crisis. At the same time, traditional energy supply is reaching its limits. Many energy sources have to be developed to meet the 21st century environmental, social and economic challenges.

How can unconventional hydrocarbons (oil sands, shale gas and others) and carbon sequestration help bridge the gap between conventional oil, gas, coal and nuclear power and the most promising renewable energy sources – biomass, hydro, wind, geothermal, and solar? Furthermore, how can market reforms promote more energy efficiency?

This conference will bring together key players in the North American energy sector to address these questions and many others in plenary and concurrent sessions.

Those interested in organizing sessions should propose a topic and possible speakers to Pierre-Olivier Pineau, Concurrent Session Chair (p) +1 514-340-6922, (e) *pierre-olivier.pineau@hec.ca*

This conference will also provide networking opportunities through workshops, public outreach and student recruitment.

HOSTED BY: CAEE – Canadian Association for Energy Economics / Association Canadienne d'Économique de l'Énergie

WITH SUPPORT FROM:

USAEE – United States Association for Energy Economics

IAEE – International Association for Energy Economics – www.iaee.org

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TOPICS TO BE ADDRESSED INCLUDE:

Conventional Oil and Gas Issues
- Reserves and access to reserves
- Production and drilling activity
- Fiscal issues: incentive taxation and royalty regimes
- Enhanced recovery with CO_2 injection
- Estimating and forecasting project costs

Unconventional Oil and Gas Issues
- Reserves, resources and possible recovery
- Oil sands production costs
- Heavy oil prospects
- Coalbed methane and shale gas production
- Environmental footprint

Infrastructure Investments
- New pipelines
- LNG terminals, import/export
- Refining and moving 21st century liquid fuels
- Financing after the credit crisis

Carbon Capture and Sequestration
- Experiences to date
- Links with enhanced oil & gas recovery
- Potential to limit GHG
- Cost and the role of subsidies in CCS

Electricity Generation
- Supply adequacy
- New nuclear developments
- State/provincial regulation and economic distortions
- Ownership and cost of hydropower

Electricity Networks
- Market integration and reforms
- Transmission upgrades and pricing
- Distributed generation
- Smart grids and smart metering innovations

Energy Efficiency
- Measurement and verification
- Link to energy pricing
- Information and other market failures

Climate Change
- GHG emission reduction targets and costs
- Impacts of a cap-and-trade system or a carbon tax
- Developments in carbon-mitigation technologies
- International agreements post-Kyoto
- Cost effectiveness: reduction, sequestration or adaptation

Biofuels
- Regulatory incentives
- Life-cycle energy and economic assessments
- Linkages and competition with the food chain

Renewables in Electricity
- Renewable Portfolio Standards and regulatory approaches
- Wind development: growth and challenges
- Hydropower contribution
- Solar and geothermal technology updates

Energy and Transportation
- Transportation policy and efficiency
- Impact of the automobile crisis on energy demand
- Fuel efficiency standards

Geopolitics
- North American energy inter-dependence
- The future of OPEC
- Natural gas politics
- Persian Gulf security
- Renewable energy and energy security

Energy Poverty
- Access to modern energy services
- Energy prospects for developing countries

Visit our conference website at: http://www.usaee.org/usaee2010/

CALL FOR PAPERS

We are pleased to announce the Call for Papers for the 29th USAEE/IAEE North American Conference to be held October 14-16, 2010 at the Hyatt Regency Calgary hotel, in Calgary, Alberta, Canada. The Deadline for receipt of abstracts is May 21, 2010.

Paper abstracts, giving a concise overview of the topic to be covered and the method of analysis, should be ***one to two pages***. Abstracts should include the following brief sections: (1) overview, (2) methods, (3) results, (4) conclusions, and (5) references.

Please visit http://www.usaee.org/usaee2010/ to download a sample abstract template. NOTE: All abstracts must conform to the format structure outlined in sample abstract template. At least one author of an accepted paper must pay the registration fees and attend the conference to present the paper. The corresponding author submitting the abstract must provide complete contact details – mailing address, phone, fax, e-mail, etc. Authors will be notified by July 9, 2010 of their paper status.

Authors whose abstracts are accepted will have until September 3, 2010, to submit their full 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 **must be submitted online** to http://usaee.org/USAEE2010/submissions.aspx Abstracts submitted by email will not be processed. Please use the online abstract submission form.

STUDENTS

Students may submit an abstract for the concurrent sessions. The deadline for abstracts is May 21, 2010. Also, you may submit a paper for consideration in the USAEE Student Paper Award Competition (cash prizes plus waiver of conference registration fees). The paper submission has different requirements and a different deadline.

The deadline for submitting a paper for the Student Paper Awards is July 8, 2010. Visit http://www.usaee.org/USAEE2010/paperawards.html for full details. Students may also inquire about our scholarships for conference attendance. Visit http://www.usaee.org/USAEE2010/students.html for full details.

TRAVEL DOCUMENTS

All international delegates to the 29th USAEE/IAEE North American Conference are urged to contact their respective consulate, embassy or travel agent regarding the necessity of obtaining a visa for entry into Canada. If you need a letter of invitation to attend the conference, contact USAEE with an email request to usaee@usaee.org.

The Conference strongly suggests that you allow plenty of time for processing these documents.

Note: U.S. citizens attending the 29th USAEE/IAEE North American Conference will need to present a passport upon entry to Canada.

Visit our conference website at: http://www.usaee.org/usaee2010/

Working Paper Series

— CALL FOR ENERGY RESEARCH PAPERS —

The USAEE and IAEE have combined efforts to create a working paper series that gives you (and all USAEE/IAEE members) a chance to increase the circulation, visibility, and impact of your research. If you have an unpublished research paper that addresses any aspect of energy economics or energy policy, we would like to feature your paper in this new series. There is no cost to you, only benefits:

- Place your work where it can be seen and used on a daily basis.
- Gain timely feedback from other researchers working on related topics.
- Create a permanent and searchable archive of your research output within the largest available Electronic Paper Collection serving the social sciences.
- Provide unlimited, hassle-free, public downloads of your work on demand.
- Raise your research profile, and that of the USAEE/IAEE, by joining with fellow members to establish a new energy research *trademark* that is unparalleled in terms of its breadth and depth of focus.

The *USAEE/IAEE Working Paper Series* is a new component of the Social Science Research Network (SSRN) *Research Paper Series*. SSRN is the leading online source of full-text research papers in the social sciences, and is accessible at the following link: http://www.ssrn.com/. SSRN is indexed by Google and all other major online search engines, ensuring that anyone who does a keyword search in your area of research will be directed to your paper, including free downloads, and provided with your contact information. SSRN tabulates the number of abstract and full-text downloads of each paper in the series and publishes various "top-ten" lists to indicate which papers are most highly demanded within individual subject areas.

To view current working papers in our series please click here

Contributor Guidelines

The *USAEE/IAEE Working Paper Series* includes only papers that present original, scholarly research related to energy economics and policy. Editorials, marketing tracts, and promotional material will not be accepted. Other than this initial screening, the working papers will be unrefereed and authors are solely responsible for their content. Authors will retain all rights to their work, including the right to submit their working papers (or subsequent versions thereof) for publication elsewhere. Neither USAEE/IAEE nor SSRN will assume or usurp any copyright privileges with respect to papers included in the series.

Each working paper included in the *USAEE/IAEE Working Paper Series* must be authored or co-authored by a member in good standing of the USAEE/IAEE, and be submitted by that member. All papers will be assigned a USAEE/IAEE Working Paper number and fitted with a distinctive cover page that identifies it as part of the USAEE/IAEE series.

To include your research paper (or papers) in the *USAEE/IAEE Working Paper Series*, please email a copy of the work (in MS Word format), including a brief abstract, to the addresses given below.

Kevin Forbes
USAEE Working Paper Series Coordinator
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David Williams
USAEE/IAEE Executive Director
usaee@usaee.org

Lower Emission Levels and Australian Energy Impacts

By Alan Moran*

Australian and International Proposed Measures

The Stern Report sought reductions in global emissions of carbon dioxide by 80 per cent of current levels by 2050. Stern argued that the economic cost will be one per cent of world GDP, "which poses little threat to standards of living given that the economic output in the OECD countries is likely to rise by over 200 per cent and in developing countries by more than 400 per cent" during this period (P.239).

The Waxman-Markey Bill requires a 20 per cent reduction in U.S. emissions by 2020 and an 83 per cent reduction by 2050. Such a level of reduction would bring U.S. emissions to the present world average and is consistent with stabilizing global CO_2 equivalent emissions somewhere between the present 450 and the projected 550 parts per million.

Unsurprisingly given the volume of international meetings and consultations involved, Australia's trajectory CO_2-e plans are similar to those of other countries.

Country	2020 targets	2020 per capita reduction	2050 targets
Australia	5-15% below 2000 levels (4-14% below 1990 levels)	27-34 % below 2000 levels (34-41% below 1990 levels	60% below 2000 levels (60% below 1990 levels)
EU	20-30% below 1990 levels	24-34% below 1990 levels	60-80% below 1990 levels
UK	26-32% below 1990 levels	33-39 % below 1990 levels	80% below 1990 levels
U.S.	Return to 1990 levels	25% below 1990 levels	80% below 1990 levels

Comparisons in $CO_{2\text{-}e}$ Levels

All developed countries have incurred considerable costs in subsidising and regulating in favour of high cost energy sources with low CO_2 emissions. In spite of this, and the fact that the early gains are likely to be the easiest because they tap into the fabled "low hanging fruit", few major signatories will meet their Kyoto obligations.

Individual European Union countries will achieve their targets - Germany because of unification, and the United Kingdom because of the shift from coal powered electricity generation to gas.

The Australian Government involves itself in some aggressive chest thumping in arguing that its per capita reductions in 2020 are greater than those of its fellow carbon cutters. Australia claims to be meeting its (generous) Kyoto 2008-12 target of 108 per cent of 1990 levels but would be 30 per cent above 1990 levels were it not to measure its emissions on the basis of the creative 'Australia clause' in Article 3.7. That clause permits countries to count changes to land-use and forestry as part of their measures of net emissions.

The nearby table is drawn from the latest United Nations Framework Convention report and indicates levels of achievement compared to the 2008-12 targets expressed as the emissions in excess of, or below the 1990 base level. The latest data for 2005 levels is expressed on two bases: with and without counting land use changes as a result of policy towards clearing land for cultivation. Only the EU taken as a whole is close to the targets in the form they were originally agreed.

	2008-12	2005 actual	
	Target	Inc. clearing	Exc. clearing
Australia	8%	4.5%	25.6%
Canada	-6%	54.2%	25.3%
EU	-8%	-4.0%	-1.5%
Japan	-6%	7.1%	6.9%
NZ	0%	22.7%	24.7%
Norway	1%	-23.1%	8.8%
U.S.	-7%	16.3%	16.3%

Kyoto Commitments and Achievements over 1990 Baselines

Source: UNFCC. http://unfccc.int/resource/docs/2007/sbi/eng/30.pdf

The Global Task

In 2004, global greenhouse gas emissions (in CO_2 equivalents) were 28,790 million tonnes. Just over 10 per cent of these were from the former Soviet bloc with the rest split fairly evenly between the OECD countries and the developing world.

By 2008, developing countries' emissions exceeded those of the OECD countries. The faster growth in emissions within developing countries will increasingly dilute any actions taken by the developed OECD nations, the only group seriously considering abatement measures at the present. The dilution is further amplified if abatement in the OECD is achieved by smelting and other energy intensive activities being re-located to developing countries.

The IPCC report tended to downplay this leakage issue arguing: "Estimates of carbon leakage rates for action under Kyoto range from 5 to 20% as a result of a loss of price competitiveness, but they remain very uncertain."[1] Given the

* Alan Moran is Director Deregulation Unit, Institute of Public Affairs in Australia. He may be reached at amoran@ipa.org.au This article is based on an address to the IPA Conference, the *Economic Consequences of Climate Change,* given November 10, 2010, in Melbourne.
See footnote at end of text.

globalised nature of production and the incentives and necessities of businesses to relocate to venues where even modest cost savings are available, the IPCC's carbon leakage estimates may be too modest. To combat leakage, the EU is discussing countervailing duties on non-cooperating trade partners, a measure that would surely unravel the world trade regime.

It would require the adoption of as yet unknown fundamental technological developments to achieve any form of stabilisation at 2004 levels of 28,790 million tonnes. If the trajectory were global, stabilisation by 2030 with OECD countries reducing their emission levels by 20 per cent and the former Soviet bloc holding their emissions constant, then this would require developing countries to limit their increases in emissions to 15 GT (by 22 per cent). The contrast of this and business-as-usual (BAU) is illustrated below.

	2004	2030	2030 bau
OECD	13319	10655	18350
Former Soviet bloc	3168	3168	3168
Developing Countries	12303	14967	36671
Total	28790	28790	58188

Emission Stabilisation Scenario (million tonnes of CO_2 equivalent)

Source: Derived from Human Development Report 2007/2008, UNDP

While superficially generous to the developing countries, the 22 per cent increase is a massive reduction compared with business-as-usual growth levels. Compared with the 15 billion tonnes of carbon dioxide equivalent projected under this scenario, business-as-usual levels - based on previous growth rates - would see developing countries emitting over 37 billion tonnes in 2030.

Moreover, because of their population growth, limiting developing countries' emission levels to 15 billion tonnes of carbon dioxide equivalent would result in their emissions per head actually *falling*. Developing countries in 2030 are estimated to have a population at 7.2 billion, and under this scenario their per capita emissions would fall from 2.4 tonnes to 2.3 tonnes. This is one fifth of the OECD 2004 per capita average of 11.5 tonnes and only a quarter of the OECD average in 2030 (7.9 tonnes) once a 20 per cent reduction and population growth is incorporated.

The surrealistic nature of this feature of the debate was illustrated by the main agreement negotiated at L'Aquila last July, about which Mr. Rudd was effusive in his recent address to the Lowy Institute. The L'Aquila agreement required the developed countries to reduce their emissions in 2050 by 80 per cent and the developing countries by 50 per cent. Present per capita emission levels of carbon dioxide are 11.5 and 2.4 tonnes for the developed world and the developing world, respectively.

Using simple arithmetic, by 2050 the 80 per cent cut would leave the developed world with 2.9 tonnes of carbon dioxide per capita and the developing world with less than half of this at 1.2 tonnes per capita. And this is based on the unlikely event of population growth in the developing countries slowing to the level of that in the developed world.

On top of their ethereal time frame, the targets are, therefore, internally inconsistent. Politicians are plucking goals out of the air for which they know they will never be held accountable. China and India rejected the L'Aquila agreement before the ink had dried.

Australian Energy Resources

Especially since it has been privatised or otherwise commercialised, Australia's electricity supply industry is among the lowest cost the world. Generation comprises

- 56% black coal,
- 24% brown coal,
- 13% gas
- 5% hydro
- with a little wind, which is highly subsidised

We have hundreds of year's supply of black coal that is of inferior export quality and ideal for local use and over a thousand years supply of brown coal that is not transportable at all. Supply continuity is not a problem.

This availability of coal gives Australia particularly low cost electricity compared with other countries; (major customers attract large discounts on these prices).

The sustainability of Australian prices at these levels changes with a cap on carbon emissions and the associated tax. Australia's particular vulnerability to these measures is illustrated by comparing our generation source profile with that of other countries. Only about 5 per cent of Australian energy is derived from other than fossil fuels. Sweden, Switzerland and France with nuclear and hydro have over 40 per cent and most other countries are 10-20 per cent.

A Carbon Tax and its Effects

In terms of electricity generation costs, a carbon tax of $40 per tonne doubles the price of Australian coal based electricity. However, the objective is not to increase the price of electricity but to prevent CO_2 emissions and this would require far greater price effects.

Carbon Capture and Storage (CCS) development requires one third of the coal for CO_2 capture even before there are any transport and storage costs. The price of coal based generation incorporating CCS is likely to go beyond the $125 a tonne modelled below, which even though wind and some other solar is shown to be competitive, this can never fuel a modern power system.

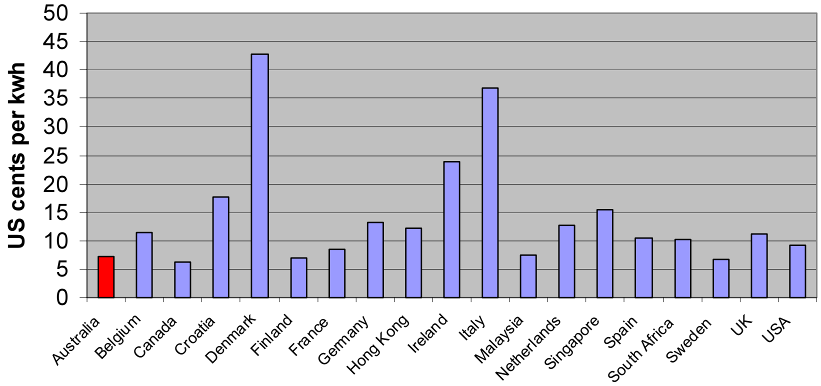
Natural gas is a replacement source of energy for coal and only incurs half the carbon tax. It also involves a lower capital outlay and less risk in the event of it not proving the best bet to combat regulatory measures.

But irrespective of the costs, it's not possible to meet the targets, without CCS if coal is used.

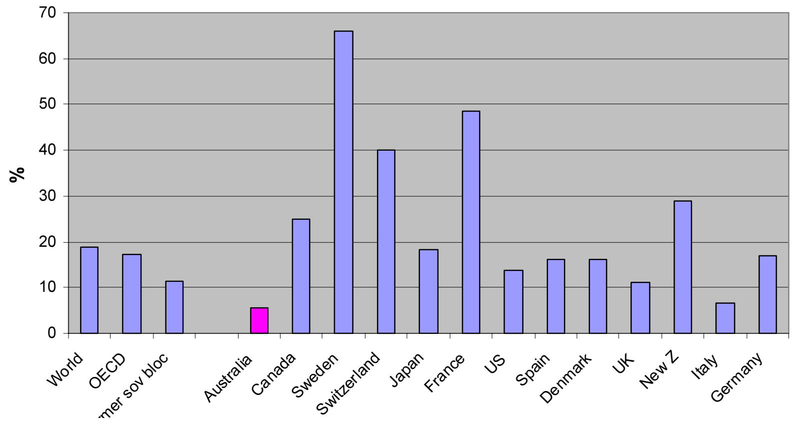
Australia has considerable reserves of gas, especially coal seam gas in Queensland. This is, however, more expensive to develop than conventional sources of natural gas and even they are 20-30 per cent more expensive than coal for base load supplies and may see that premium rise as a result of international demands.

The real issue regarding the substitution of gas for coal in electricity generation, aside from finding the capital, is that it is a forcible self-denial of the cheapest form of electricity, the consequences of which reverberate through the entire network of costs.

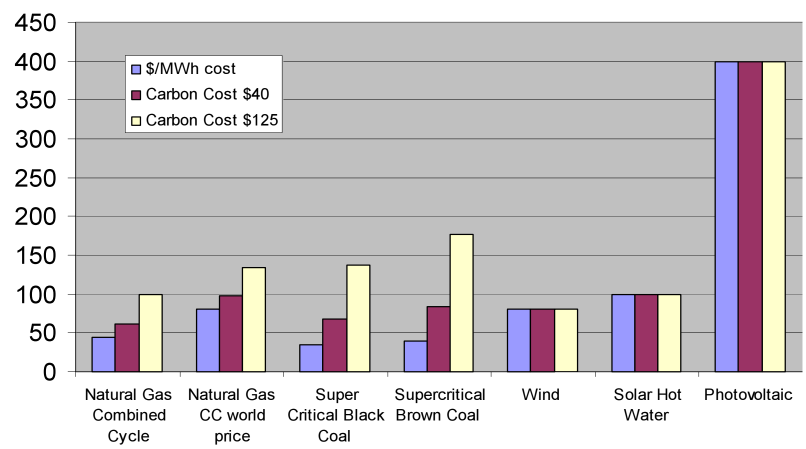
The carbon cost impost smashes Australian industry competitiveness.



Consumer Electricity Prices



Non-fossil Fuel Share



Economics of Differing Fuel Sources

Even if all countries were to apply a similar tax, as is envisaged in the Copenhagen treaty, Australia would still lose its competitive edge since this is based on supplies of well-located coal which would become dearer than nuclear energy.

Once in place, the carbon tax means that nobody will again build an aluminium smelter, a steelworks or any other facility that makes use of Australian low-cost energy. These major energy intensive Australian facilities owe much to the oil crises of three decades ago when smelters based on fuel-oil generated electricity could no longer be economic. Australia's coal created a gravitational pull that was a vital part of the development and prosperity that we have since enjoyed. We are now trying to reverse this.

Application of a Carbon Tax in Australia

On any basis a carbon tax will raise colossal revenues. Those to be raised in Australia are envisaged to be somewhat differently expended from those in the U.S. and EU. In Australia the Government is offering compensation to the brown coal generators of only about 35 per cent what they think they should have.

It is also making that compensation contingent on the generators remaining open. This is an ostensibly ridiculous requirement, since those generators must close if meaningful reductions in emissions are to be brought about. However, it recognises that if they close there will be an immediate electoral downside because Australia would lose 85 per cent of its generation capacity, with Victoria losing 95 per cent.

Treasury's October mid-year statement indicated ETS revenues of $16 billion a year by 2020 and growing. These numbers incorporate uncertain prices but if Australia reduces emissions by 5 per cent below 2000 levels by 2020, in line with the minimum Government's intentions, this would entail $16 billion costs at a price of $40 per tonne of CO_2. If this is the assumed price it means the government is not budgeting for purchases of overseas emission rights. Although the Treasury discusses these purchases, it does not quantify them in its latest document. Treasury modelling estimates overseas purchases at $26 billion a year by 2050.

Fiscal Balance ($)	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	5 yrs to 2012-13	12 yrs to 2019-20
Revenue from sale of permits	0	0	4450	11480	12070	12650	13360	13990	14640	15290	15990	15930	113920
Assistance measures													
Assistance for low & middle income households	0	0	-1496	-5063	-6430	-6560	-6700	-6880	-6970	-7100	-7190	-6559	-54389
Fuel tax offsets	0	0	-1010	-2220	-2550	-2290	-2350	-2410	-2460	-2500	-2530	-3230	-20320
Assistance to Emission Intensive Trade Exposed Industries	0	0	-1200	-3220	-3510	-3830	-4210	-4330	-4640	-5070	-5530	-4420	-35540
Electricity Sector Adjustment Scheme	0	0	-260	-680	-730	-790	-850	0	0	0	0	-940	-3310
Climate Change Action Fund (a)	-200	0	-700	-600	-450	-348	-150	0	0	0	0	-1803	-2750
Transitional assistance for Greenhouse Gas Reduction Scheme	0	-300	0	0	0	0	0	0	0	0	0	-130	-130
Total Assistance Measures	-200	-130	-4666	-11783	-13670	-13818	-14260	-13620	-14070	-14670	-15250	-17082	-116439
Net Impact	-200	-430	-216	-303	-1600	-1168	-900	370	570	620	740	-1152	-2519
Cumulative Impact (a)	-203	-633	-848	-1152	-2752	-3919	-4819	-4449	-3879	-3259	-2519	-1152	-2519

Like with the energy intensive industries, one outcome of the tax is that no firm can ever again build a coal based power station unless it receives a tax indemnification from the government. It is untrue that all we need is to clarify the regulatory arrangements so industry has certainty. The only certainty is that the carbon tax rules out, as it is intended to, any investment in a coal fired power station, without an indemnification guarantee from government and makes gas fired generation problematic.

Gradually, even if not suddenly, this brings increased costs and a reduction in reliability of the electricity system.

This means a slow strangulation of supplies and certainly means we exit key areas of the economy, especially smelting that uses about a quarter of existing electricity supplies. Tragically, even unwinding the death sentence on existing coal based power generation would not undo the damage that has been done. We have not had a major power station commissioned since 2002 and this leaves a gap in supplies, meaning higher prices and no more energy intensive industries.

Mollified by the analysis of Treasury, the Government is remarkably complacent about the effects on the economy. Treasury modelling shows a smooth progression to a carbon free energy environment as the century progresses.

Here's what your Prime Minister said:

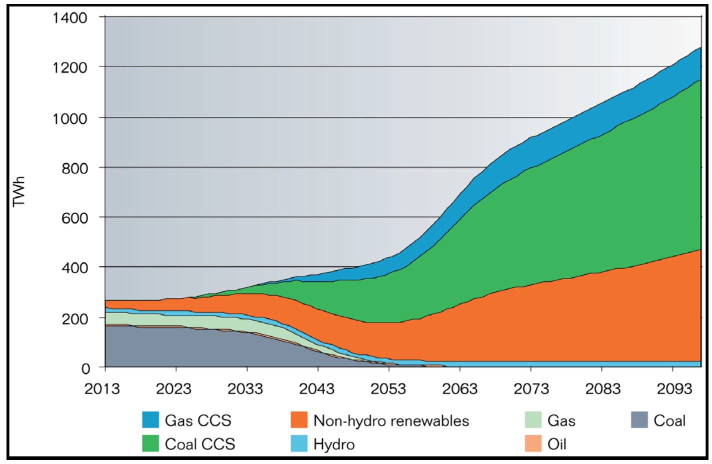
> *Treasury modelling done in 2008 demonstrates Australia can continue to achieve strong trend economic growth while making significant cuts in emissions through the CPRS. Treasury modelling also demonstrates that all major employment sectors grow over the years to 2020 - substantially increasing employment from today's levels. Treasury modelling also projects that clean industries will create sustainable jobs of the future - in fact by 2050 the renewable electricity sector will be 30 times larger than it is today*

This reproduces one scenario which the Australian Treasury envisages from the taxation regime recommended. By around 2050, 80 per cent of electricity is modelled as coming from exotic renewables and from gas and coal incorporating CCS.

The numbers are, however, pure conjecture. Though the economic modelling driving them is based on empirical observation, the uncertainties of projections going decades into the future are seldom raised.

The models themselves rest on demand and supply responses estimated as a result of known relationships between different products. But information on the relationships that are central to modelling forecasts is based on quite narrow ranges of observations, and the relationships can also change markedly over time.

Many relationships within the operational parameters of these models are, however, likely to be stable. We can be pretty certain, for example, of the demand response for, say, coal and the implications throughout the economy where price rises by 10 per cent. We would see some shift to other energy sources which have costs below the 10 per cent price increase; we would see some reduction in the end products using coal as a result of higher costs. And we would see some expansion in demand for products that use less coal and less energy, since these will have become relatively cheaper. All these changes would offset somewhat the initial loss caused by the increased cost.



Australia's Electricity Generation Technology Shares, 550 ppm Scenario

We also have experience of considerable changes in energy supply and the associated price increases. During the 1970s the price of crude oil quadrupled over a short period of time. This caused major economic dislocation and the worst recession since World War II. However, adjustments were made relatively easily because ways were found to economise on oil. These included substitutions by coal and natural gas and, for those nations not spooked by green witchcraft, nuclear power. The higher prices also stimulated increased oil supplies.

In the present modelling situation, such secondary effects would be confined to an expansion of nuclear power, currently representing 16 per cent of world electricity supplies, since this is the only feasible replacement for carbon-based fuels.

At issue is whether the situation being modelled is comparable to what we would face in estimating the effects of a tax designed to eliminate a product within a class of goods or that designed to eliminate the entire class. This can be visualised best with respect to the food sector. We could, for example, be quite confident of assessing the effects of a tax that drove out the use of oranges. People would choose alternative goods; there would be some loss of welfare, perhaps measurable in terms of gross national income. But there would be little major change.

Substitute for that measure a tax designed to eliminate consumption of all known foods. Clearly there would be mass starvation, and considerable loss of income, though new foods might be developed to allow continued human existence.

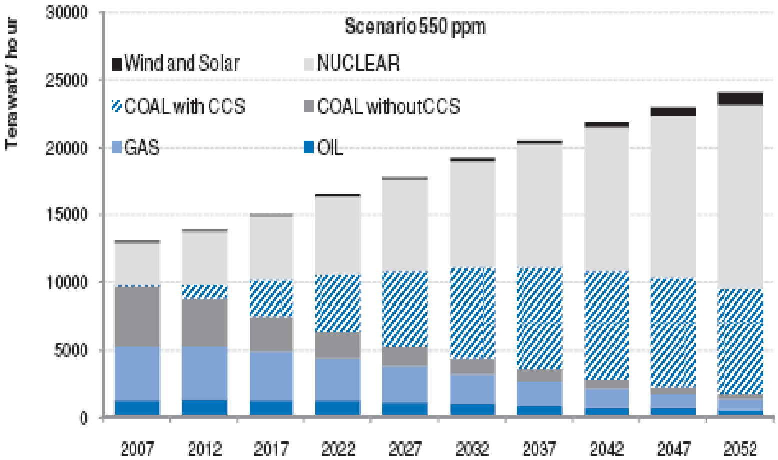
Some say such effects overstate the implications. After all, energy is only 5 per cent of GDP and rather less than this if its distribution costs are excluded. But much the same can be said of food, which in rich countries comprises only some 12 per cent of GDP and most of this is distribution and value-added features.

The question about a carbon tax designed to stabilise global CO_2 emissions that required countries such as Australia to reduce their emissions by 80 per cent is whether the better analogy is the tax on oranges or a tax on the whole class of foods.

Present-day energy consumption is highly reliant on carboniferous fuels. Energy itself is, second to food, the basic building block of all human activities. The only substitute we have for carbon-based energy is nuclear energy. With a carbon tax we have only the flimsiest of experience on which to model the effects. Unlike the case with oil in the 1970s, the substitutes do not exist, except for nuclear, and to enable that to replace carboniferous fuels requires great ingenuity—especially in finding ways to replace oil for motor vehicles, ships and aircraft.

In addition to such considerations, the modelling assumes a steady state movement from one pattern of the economy to another—it assumes that we simply move from coal to gas to some as-yet-undiscovered renewable, carbon capture, or nuclear. Such a movement is unlikely to occur without, at the very least, considerable transitory turmoil.

Importantly, modelling, in addressing a frictionless move to alternative energy sources, is driven by



OECD Estimates of World Electricity Generation

assumptions about new technologies yet to be devised like Carbon Capture and Storage (CCS).

In this sort of long-term economic modelling new technologies are assumed to develop without any evidence that this is possible. Without that, the costs of forcing emission reductions would be driven to astronomical levels and would bring a rapid reduction in living standards.

In a notable sign of sanity, the OECD climate change projections forecast only a miniscule role for renewable energy. The OECD projection's credibility is also enhanced by envisaging a sizeable increase in nuclear but it too has CCS playing a major role at some 30 per cent.

Al Gore opined on Australian television that CCS would never work. Many of us would agree. He went on to say however that Australia has a lot of sunshine and potential for renewable power. The absurdity of that statement is matched only by Prime Ministerial assertions using the results of the garbage-in-garbage-out assumption driven Treasury modelling to maintain that we will have more green jobs and full employment. Not only is this technology based forecasting pure conjecture but full employment is a basic assumption - not an outcome - of all such modelling.

Existing Measures

The foregoing examines the issues from the point of view of the ETS greenhouse tax. However, this is not being introduced within a policy vacuum. Already Australia, like other countries, has a considerable number of de facto taxes and subsidies ostensibly designed to combat CO_2 emissions. These include

- Subsidies to green energy that amount to at least $1 billion a year.
- The Mandatory Renewable Energy Target requires 9,500 GWh of renewable electricity by 2011 – about 4% of the total. The states have supplementary schemes. Victorian Premier Bracks in November 2005 argued that a, "lack of national leadership" by the Federal Government in not increasing the MRET scheme from the 9500 GWh target, "is costing Victoria – economically and environmentally – and cannot be allowed to continue." Victoria's scheme requires an additional 3,274 GWh a year of renewable electricity by 2016. It was expected to create "up to 2,000 new jobs, most of them in regional Victoria". None emerged. The state schemes are to be folded into the recently passed requirement for 20 per cent renewable energy 45,000 GWh. In a triumph of hope over logic and experience, this regulatory measure requires a doubling of renewable energy use by 2020. Based on the penalty costs involved, and excluding the (commercial) hydro portion, this entails annual aggregate costs of $1.8 billion.

The identified subsidies and estimated tax costs of the renewable requirement of $2.8 billion a year can be viewed as a tax on the 205 million tonnes of CO_2 emitted in the course of electricity generation. This is the regulatory equivalent of a carbon tax of over $13 per tonne of CO_2, a level that at one time was said to be all that was required to bring about the necessary abatement.

Export Effects

Rarely mentioned in the Australian context is energy exports. Coal accounts for 23 per cent of exports with gas and oil another 10 per cent.

The logic of a world in a carbon lockdown is that all of these exports would eventually be eliminated – the coal in the ground even with a value of only $10 per tonne is worth something like a year's national income. Although Australia also has massive uranium resources these would not plug the gap.

Concluding Comments

From the Australian Treasury modelling it is possible to infer the costs of doing nothing to 2020 and then catching up with the 2050 target thereafter should the need and achievability of such action prove necessary.

The Prime Minister says Treasury modelling shows that deferring action will increase the costs of achieving the results by 15 per cent compared to taking action now. Yet, the cost of deferring action to

2020, then catching up by 2050, according to the Treasury model is 0.3 per cent of GDP. Even if this is not overstated, 0.3 per cent of GDP seems a reasonable insurance policy price to pay to avoid imminently embarking on measures that would have dramatic consequences on a small economy that is highly dependent on carboniferous fuels. By 2020 we will be clearer on the need for emission reduction policies and we will, presumably, have access to all the technological advances that modellers claim will be forthcoming.

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Another way of analysing this is to determine the costs that would allegedly be incurred from taking no action at all. Again using the Treasury modelling, we can see the costs of doing nothing to defray emissions is 5 per cent of GDP by the end of this century. Significant though this may be it is dwarfed by the increase in GDP - sixfold - that is estimated to take place. Those costs are therefore readily affordable even if they exist.

There may be a risk from severe anthropogenic induced climate change. But there is also a risk of severe economic consequences in seeking to address such change. Deferring action until the costs and the implications of doing nothing are clearer is likely to be the best approach given the costs involved.

Footnote

[1] http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter11.pdf p622

Postscript:

The foregoing was written as the details were emerging of the leaked emails from the Climate Research Unit at the University of East Anglia and prior to the collapse of the December 2009 Copenhagen Climate Change Conference.

The diplomatic outcome of Copenhagen stemmed from the refusal of China and other key countries to accept major reductions in their emissions because this would seriously harm their economic prospects.

Developments in the science of greenhouse can only add to such reticence.

In its 2007 report, under pressure from statisticians, the IPCC was already downplaying its “hockey stick” depiction of a uniquely steeply rising temperature trend starting 30 years ago. The “Climategate” leaking of emails in late 2009 indicated a willingness of key IPCC scientists to use highly unethical measures to suppress dissent from their own views. Since then, the IPCC has recognised its 2007 report’s contention that Himalayan glaciers are likely to melt by 2035 was incorrect and has acknowledged that its claims of a rapid reduction of the Amazonian rainforests were based on material from an advocacy group’s rather than scientific research.

As of February 2010, the accuracy of the basic temperature data was being questioned. *The Guardian’s* Fred Pearce reported, “crucial data obtained by American scientists from Chinese collaborators cannot be verified because documents containing them no longer exist. And what data is available suggests that the findings are fundamentally flawed”.

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2/10Forum

Energy Challenges the Automobile Industry Faces in China

By Yimin Liu, Yong Yang and Erica Klampfl*

Introduction

In 2009, China's auto sales surged past the United States to reach a record level of 13.6 million units, compared with the United States' lowest annual sales in 27 years of 10.6 million units, including medium and heavy duty vehicles. This underscores China's importance to the global auto industry as it is the world's biggest market. However, as expected, this auto industry expansion in China has also resulted in a drastic increase in energy consumption.

This study will discuss the oil supply issue China is facing, corresponding energy and related auto industry policies China is implementing, the impacts of the aforementioned on the automobile industry, and the technological measures the Chinese automobile industry is taking to address these issues.

Fossil Energy Demand and Supply in China

China has limited reserves of oil and natural gas, and coal remains the leading source of energy in its industrial sectors. Domestic coal reserves surpass any other fuel source. At current rates of extraction, Chinese coal reserves will last 4 times longer than those for crude oil, which will be exhausted in about 11 years (Table 1). However, this does not factor in the potential future demand for coal in China from the production of coal-based synthetic liquids, which poses several concerns for the government, such as potential strains on water resources and shortages of coal supply. Around two thirds of China's electricity is generated from coal-fired power stations. In 2009, China's total annual electricity output was 3.65 trillion kWh: 81.7% (2.98 Trillion kwh) from thermal sources, 15% (554.5 Trillion kwh) from hydro power, and 1.9% (69.3 Trillion kwh) from nuclear sources.

	Crude Oil (Mt)	Natural Gas (Billion NM3)	Coal (Mt)
Identified Reserve (2007)	2117	1884	114500
Consumption (2008)	358	80.7	2740
Domestic Extraction (2008)	190	78.1	2793
Years to Depletion (at current rate of extraction)	11	24	41

Table 1
Domestic Crude Oil, Natural Gas, and Coal Reserves, Consumption and Years to Depletion

By itself, China is far from being able to meet the increase in energy demand because of its shortage of domestic crude oil and fast economic growth. In 1993, China became a net importer of oil, and it is now the world's third largest importer and second largest oil consumer. In 2008, oil imports accounted for more than 50% of China's total crude oil consumption. By 2020, imports are projected to reach beyond 75% of total crude oil consumption or as high as 800-900 million tons per year. China will likely have a refining capacity of 600 million tons by 2020; however, the government plans to control the capacity at around 450-480 million tons during that timeframe (Figure 1).

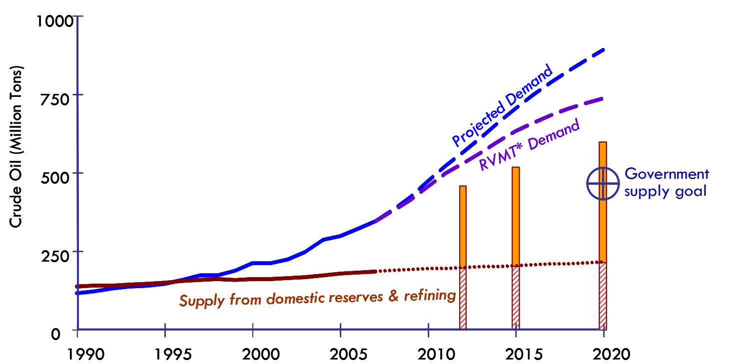

Figure 1
Demand and Supply of Crude Oil in China
RMVT= Reduced vehicle miles traveled, 75% of mile traveled in 2020.

Meanwhile, oil imports in China are limited by geopolitical risks: most of China's oil imports come through the Strait of Malacca, a passage vulnerable to war and political instability, and the majority of oil suppliers are located in unstable regions or battle zones (Figure 2). It is possible that energy demand will further exceed supply, and economic growth will be dragged down by energy shortages in China.

Energy Challenge the Automotive Industry Faces

Since 2002, vehicle sales have increased dramatically in China (about 1 million per year); however, according to the International Energy Agency, China's overall average vehicle ownership in 2008 is still just 38 vehicles per 1000 people, as compared with 815 vehicles per 1000 people in the U.S. Since per

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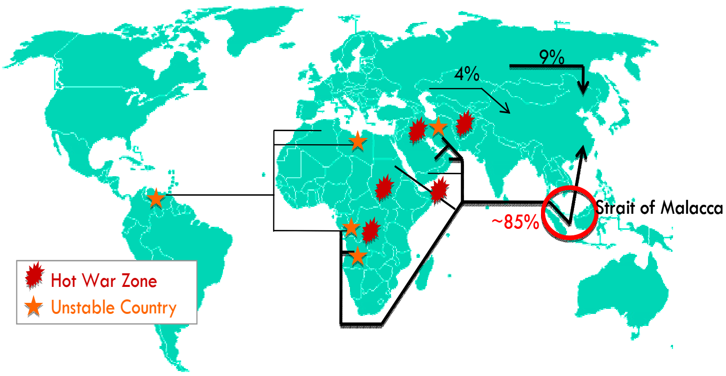

Figure 2
China's Imported Oil Suppliers and Transport Paths
Source: Presentation by Weijian Han at the University of Michigan

capita GDP grows in China at above 8% each year, it is expected that car ownership will increase quickly. The question is how much the vehicle fleet will grow before the energy constraint becomes too severe.

According to U.S. Department of Energy, China currently consumes about 7.8 million barrels of oil a day: 40% is used for transportation, including gasoline, jet, and diesel fuel, and 2% is used to fuel private cars. By 2020, it is projected that around half of China's oil will be used for transportation, and 10% of the total will be burned by private cars. Because of the country's growing demand for oil and increasing volume of vehicle sales, China's government has been aware of these problems for some time and has instituted a set of strong policies to achieve its energy goals. For example, the National Energy Administration (NEA) was established in July 2008 to approve new energy projects in China, set domestic wholesale energy prices, and implement the central government's energy policies. Since energy prices are controlled by the government, gasoline prices do not fluctuate with the international market. Even at the end of 2008 when gas prices in the world market dropped substantially, those in China decreased only moderately (Figure 3). Based on the trend of increasing gas prices in China over the past few years (from \$2.38/gallon to \$3.48/gallon in Beijing), we expect energy prices to persist upward over the next few years.

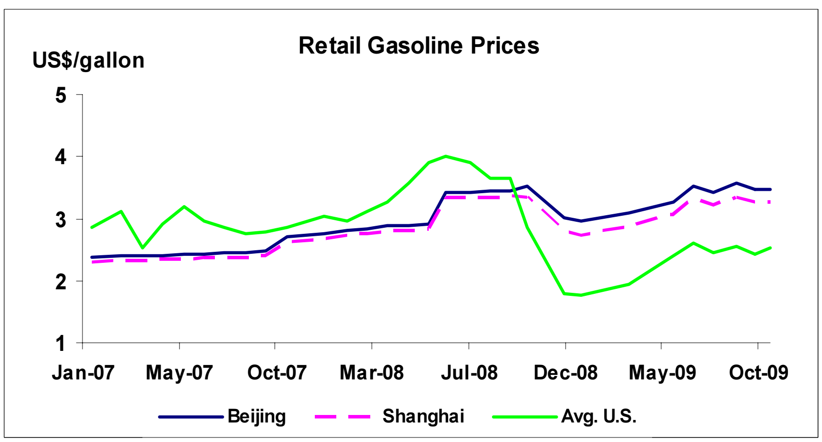

Figure 3
Retail Gas Prices in Representative Cities in China and Average for the U.S.

In addition to the increase of energy prices, current and future regulations have been enforced or proposed for the automobile industry in order to improve vehicle energy efficiency and reduce emissions in China. These regulations include fuel economy standards, emission standards, and vehicle consumption taxes,.

Currently, China does not impose fuel economy standards on each automotive manufacturer's fleet of vehicles, such as the Corporate Average Fuel Economy (CAFE) standard in the U.S. Instead, China has curb weight or gross vehicle weight (GVW) based fuel economy standards for each gasoline and diesel vehicle, requiring each passenger vehicle or commercial vehicle with curb weight or GVW in a certain range to meet a fuel consumption standard. Based on the implementation timeline, the standards are different: stage 1 focuses on new vehicles produced before January 2009; stage 2 regulates new vehicles produced before January 2011; and stage 3 has several implementation phases: in 2012, over 60% of each OEM's volume is required to meet the target; 70% in 2013; 80% in 2014 and 90% in 2015 and beyond. By 2020, China's fuel efficiency standard will match the EU's targeted CO_2 standards (Figure 4).

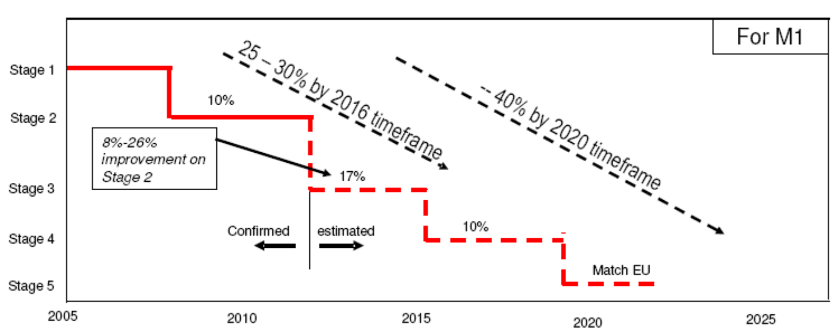

Figure 4
Fuel Economy Regulations by Year for Stages 1 to 5 in China

For example, in stage 1, each commercial vehicle with a gross weight of less than 3.5 ton has to meet a fuel consumption standard based on the range of GVW and the engine displacement. So, if its GVW ∈ (2000 KG, 2500 KG) and the engine size L ∈ $(1.5 < L \leq 2.0)$, then the fuel consumption of gasoline and diesel vehicles would have to be below 10 liter/100km and 8.4liter/100km, respectively. China's fuel economy standard is stricter for diesel vehicles than for the same type of gasoline vehicle, even if their weight and engine size are the same. A "no-comply no-sale policy" has been applied to domestic vehicles, but not yet implemented for imports in stage 1 and 2. This policy encourages powertrain technology improvements more than weight reduction: this is different from CAFE or CO_2 standards in the U.S.

In addition to fuel economy standards, there are also standards in different cities on other emissions, such as sulfur, NOx, and particulate matter, but not on CO_2. Beijing has implemented Euro IV equivalent emission standards; however, Shanghai and other cities still use Euro III equivalent emission standards. If these standards cannot be met, the vehicles can not be sold in China.

Beyond industry regulations, China has implemented taxation and provided subsidies for vehicle buyers to encourage them to purchase "green" vehicles. For example, purchasers of cars with engines above 4-liter capacity have to pay a consumption tax of 40% of the vehicle price. Additionally, taxes have risen from 15% to 25% on vehicles with 3 to 4 liter engines since September 2008; in contrast, taxes have dropped on automobiles with engines less than 1-liter capacity from 3% to 1% from 2006 to 2008 (Table 2). On the other hand, taxi fleets and local government agencies in 13 Chinese cities have been offered subsidies of up to $8,800 for each hybrid or all-electric vehicle they purchase: this is regardless of the fact that China gets three-fourths of its electricity from coal, which may produce more greenhouse gases than other fuels. This subsidy for the acquisition of electrical vehicles by state agencies is called "13 Cities, 1,000 Vehicles," with the aim of placing 1,000 electric vehicles in each of the 13 cities.

<table>
<tr><th rowspan="2">Engine Displacement (Liter)</th><th colspan="3">Before April 1, 2006</th><th colspan="2">April 1, 2006 -- August 31, 2008</th><th colspan="2">Sept. 1, 2008</th></tr>
<tr><th>Passenger Car</th><th>SUV</th><th>Mini Bus <22 seat</th><th>Passenger Vehicle</th><th>Light/Mid Comm Vehicle 10<Seat>23</th><th>Passenger Vehicle</th><th>Commercial Vehicle</th></tr>
<tr><td>≤1.0L</td><td>3%</td><td rowspan="5">3%</td><td rowspan="3">3%</td><td rowspan="2">3%</td><td rowspan="9">5%</td><td>1%</td><td rowspan="9">5%</td></tr>
<tr><td>1.0 < L ≤ 1.5</td><td rowspan="3">5%</td><td>3%</td></tr>
<tr><td>1.5 < L ≤ 2.0</td><td>5%</td><td>5%</td></tr>
<tr><td>2.0 < L ≤ 2.2</td><td rowspan="6">5%</td><td rowspan="3">9%</td><td rowspan="3">9%</td></tr>
<tr><td>2.2 < L ≤ 2.4</td><td rowspan="5">8%</td></tr>
<tr><td>2.4 < L ≤ 2.5</td><td rowspan="4">5%</td></tr>
<tr><td>2.5 < L ≤ 3.0</td><td>12%</td><td>12%</td></tr>
<tr><td>3.0 < L ≤ 4.0</td><td>15%</td><td>25%</td></tr>
<tr><td>> 4.0L</td><td>20%</td><td>40%</td></tr>
</table>

Table 2
Vehicle Consumption Taxes in China

To support 13 Cities, 1,000 Vehicles, the state electricity grid has been ordered to set up electric car charging stations in Beijing, Shanghai, and Tianjin. Furthermore, the government provides research subsidies for electric car designs, and the National R&D fund encourages new local technology growth by allocating $150 million to automotive manufacturers for new energy vehicle research. China wants to raise its annual production capacity to 500,000 hybrids or all-electric cars and buses by the end of 2011, according to an article in the April, 2009 issue of the *New York Times*.

In conjunction with the national policies, some major cities have implemented additional restrictions. Beijing bans light duty diesel vehicles in the city, and Shanghai restricts vehicles with a non-Shanghai registered license plate driving on lifted-high ways during rush hours. One major policy issue is the mismatch between intended high emission standards and the existence of low fuel quality. In addition, multiple government agencies like the National Development and Reform Commission, the Ministry of Industry and Information, the Ministry of Environmental protection, and even local governments, sometimes enact uncoordinated or conflicting policies.

Response from the Automobile Industry

China estimates that vehicles may consume 300 million tons of fuel by 2020 and plans to cut vehicle fuel consumption 30% by that timeframe. This includes 60 million tons of savings by deploying new energy vehicles, such as EVs, and 30-40 million tons of savings by deploying alternative fuel vehicles, such as natural gas vehicles.

Up until 2009, most vehicles sold in China were still small sized, fuel-efficient vehicles. 36.8% of consumers purchased their vehicles in the C segment in 2008, increasing to 41.2% in 2009. Between 2008 and 2009, the market shares in the B, sub-B, and small SUV segments also grew (Figure 5). In the future, with the disposable income growth of Chinese consumers, the market shares of fuel-inefficient vehicles may increase, adding more pressure to the demand for fuel.

Because of China's diesel fuel shortage, China does not encourage diesel vehicle development.

Trucks, farm tractors, and military vehicles consume 20-25% of China's diesel fuel. Polk forecasted that China may plan to have 20% of car sales be diesel by 2020. China also plans to develop compressed natural gas (CNG) vehicles in certain regions where the natural gas supply is rich, including the southwest, northwest and northeast. China has E10 vehicles available in nine provinces, but it does not appear to favor developing corn-based E85 vehicles because of potential competition with the production of corn for food. China currently also produces micro and mild hybrid vehicles, which are 5-10% and 10-20% more fuel efficient, respectively, than conventional vehicles. China plans to leapfrog full hybrid vehicles and directly develop plug-in and battery electric vehicles in the 2015—2020 timeframe. By some estimates, converting public fleets to CNG and hybrid electric vehicles could reduce China's energy use by up to 1.6 quadrillion British Thermal Units (BTUs) by 2025, which equals to almost 2% of China's current annual energy use.

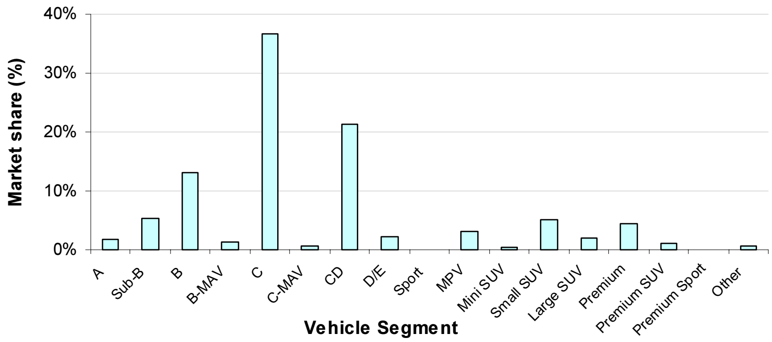

Figure 5
2008 Passenger Vehicle Segment Shares in China

State Grid Corporation of China (SGCC), the largest electric power transmission and distribution company in the world, is speeding up construction of electric car charging stations in Shanghai, Beijing, Tianjin, and other large cities in the country: these will serve electric buses and passenger vehicles in a trial run. Nationwide coverage of the charging station network will be launched immediately if the pilot project (the "13 cities, 1,000 NEVs" national pilot program) operates well and gets approved by the nation's top economic regulator. A recent circulation posted by Ministry of Finance and Ministry of Science and Technology also requested local governments to support facility construction and maintenance, but no details have been revealed yet.

	HEV, PHEV, & BEV Brand		
Local Maker	2008	2009	2010
SAIC		Roewe 750	
FAW	Besturn B70	Bus	
Changan	Jiexun	Zhixiang	
Chery	A5	S18	
Geely		EK-1	EK-2
BYD	F3 DM	F6 DM	E6
Greet Wall		Kulla	Peri
Brilliance	Zunchi		
Hafei Motor		Saibao	Coda

Table 3
Some Electric Vehicle Models Produced by Local Automakers

The Chinese government wants to raise its annual production capacity of hybrid or all-electric cars and buses from 2,100 in 2008 to 500,000 by the end of 2011. So far, most large and growing Chinese OEMs, such as SAIC, FAW, Changan, and BYD, have announced HEV, BEV or PHEV production plans because of financial advantages (government subsidies) and practical advantages (infrequent intercity driving, short commute distance, and frequent low speeds). Some such vehicle models have already been sold in the Chinese market, such as Jiexun by Changan, and Besturn B70 by FAW.

Because of energy shortages and government support, OEMs in China are starting to offer a broad range of EVs (HEV, PHEV, and BEV) and further develop EV technology, even though EVs may not significantly reduce the production of greenhouse gases from light-duty vehicles in China, since most of the electricity is generated from coal. These extensive development activities could make China a major driving force for EV adoption in the world, since the economies of scale will reduce battery technology costs substantially. Automotive players in the U.S. and Europe need to act quickly in the field of EVs in order to seize future potential opportunities for increasing market shares of EVs and developing related technology for improving energy efficiency and satisfying consumers' needs.

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Biofuels in China: Development Dynamics, Policy Imperatives, and Future Growth

By Caleb O'Kray and Kang Wu*

Introduction

Despite controversies over food security and land availability, biofuels are established concepts in the field of energy[1]. Environmental consciousness[2], high oil prices, and other problems associated with fossil energy have brought biofuels to life from the backburner. Developed (e.g. the United States, Canada, and European Union) and developing nations (e.g. Brazil, India, and China) alike have turned to biofuels with high hopes for a partial solution to their growing demands for transportation fuels. Only time can dictate whether biofuels will live up to their hyped expectations. Individual countries have created incentives to research, develop, and manage biofuels differently.

China is currently the second largest energy consuming country in the world after the U.S. Its energy consumption is heavily dominated by coal and other fossil energy, which are non-renewable in nature and more polluting than renewable energy. China is in need of expanding its renewable energy use and finding alternative fuels to power the rapid growth of the economy in general and the transportation sector in particular. Under these circumstances, biofuels present some unique opportunities for China to manage—along with the use of other renewable energy—its over dependence on fossil energy.

This article examines China's biofuels development at present and in the future, policies, and obstacles. China's approach to biofuel development may be an important lesson for others attempting to develop biofuels in their own countries. China has already solidified itself as a major world player in biofuels, trailing only behind Brazil and the US in net biofuel production and consumption and is ahead of other countries.

Biofuels Development in China: A Snapshot

China has dabbled in biofuel production for the past two decades. Their efforts in research and development are paving the way for wide-scale biofuel expansion throughout the country. Recent food security concerns, however, have somewhat stymied biofuels production in China. China's biofuel situation reflects its domestic energy, security, economic and agricultural policies.

Ethanol

While China had the same objectives for pursuing biofuel development, ethanol and biodiesel have taken distinct paths. Research, policy, and implementation have come at different phases. The agriculture, technology, and end-product uses are vastly different for ethanol and biodiesel. As such, it is best to deal with them separately, although they do share beginnings.

The initial phase focused on the research and development of relevant technologies for biofuel production (1986-2001). Research focused on ethanol, fermented methane gas and biodiesel. The National High Technology Research and Development Initiative (which became known later as Plan 863) provided the funds and incentives to undertake this research. Plan 863 was enacted in March of 1986. The general plan studied six varied and yet interrelated sectors: telecommunications, automation, biotechnology, energy, new materials and ocean development. Scientists at the Chinese Academy of Social Sciences led the research team; China's Ministry of Science and Technology provided guidance for the research focusing on ethanol and biodiesel development.

Ethanol development in China occurred in three subsequent phases: (1) a demonstration period (1986-2001); (2) legislative infrastructure, including financial incentives (2001-2004); and (3) enforcement, accompanied by pilot programs that gradually expand, if successful (2004-present).

1. In the demonstration period, the Tianguan Group, based in Nanyang, Henan Province, launched a 200 thousand metric tons (tonnes) ethanol production testing. The central government chose Nanyang for the demonstration because its large wheat surplus presented a prime feedstock for ethanol. From this demonstration project sprung a pilot program for blending ethanol with transportation gasoline in three Henan cities: Zhengzhou, Luoyang and Nanyang. The National Development and Reform Commission (NDRC), the state's central planning commission, and

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See footnotes at end of text.

the China Petrochemical Corporation (Sinopec) supervised this demonstration process.

2. The legislative phase introduced ethanol standards and a legal system that stipulates production, transportation and sales. On April 2, 2001, China released regulations Denatured Fuel Ethanol and Bioethanol Gasoline for Automobiles, establishing E10 production standards. A year later on March 22, 2002, the government began to enforce the Law Concerning Testing for the Use of Bioethanol Gasoline for Automobiles, launching a model to introduce E10 into strategic areas of China. The Bioethanol Utilization Plan was included in the 10th Five-Year Program (2001-2005), establishing a legal system for biofuels and for the relevant raw materials required.[3] The system regulates ethanol production, transportation and sales.
3. Following the pilot programs, on February 10, 2004, China announced its Law Concerning Testing for the Extensive Use of Ethanol Blended Gasoline for Automobiles and the Regulations Concerning the Conduct of Testing for the Extensive Use of Ethanol Blended Gasoline for Automobiles. This marked the beginning of phase three. All relevant conditions for extension of the pilot program made this incremental step forward possible. Logistics, sales, and production were all satisfactory at the small scale.

At the start of 2009, China's four initial and four additional ethanol projects had a total capacity of 2.2 million metric tons (tonnes) or some 47 thousand barrels per day (kb/d) in the four provinces, one autonomous region, and one municipality: Heilongjiang, Jilin, Henan, Anhui, Guangxi, and Chongqing (Table 1). The actual ethanol production in 2008 is estimated at 35 kb/d, indicating a relatively high utilization rate.

The use of E-10 gasoline in China is currently promoted in some regions, including five provinces—Heilongjiang, Jilin, Liaoning, Henan, and Anhui—as well as selected cities in Hubei, Hebei, Shandong, Jiangsu, and Guangxi provinces. By the end of 2010, ethanol gasoline is expected to be used in all provinces except for Tibet, Qinghai, Gansu, Ningxia, and Shanxi provinces/autonomous regions. For ethanol blending, 10% is the norm at present.

Biodiesel

There is a rising demand for biodiesel since the Chinese diesel market is twice that of the gasoline market. Commercial viability is the largest constraint on biodiesel production. China is a net importer in all the major edible vegetable oils, the largest importer in the world. Locally produced feedstock is expensive to come by and the lack of it inhibits large scale commercial production.

Coupled with the lack of fatty organic matter, the lack of land upon which new crops could grow exacerbates the difficulty of biodiesel production. As a result, China produces more ethanol than biodiesel. In May of 2006 China took some preliminary steps toward biodiesel promotion by setting up a special development fund to encourage research, development, and production. Biodiesel's future in China relies on three key factors:

1. Government support and NDRC defining a clear plan for biodiesel production and relevant feedstock harvesting
2. Research and development to solidify technologies for production.
3. Defining and obtaining key organic sources for production. Potential inputs include rapeseed, Jatropha nuts, switchgrass, sunflower seeds, Chinese pistachio, peanuts, sesame seeds, Barbados nuts, Fufang vines, Yousha bean, and Chinese dogwood nuts.

China has a large and growing biodiesel producing capacity. At the start of 2009, China had a total of some 2.1 million tonnes, or 41 kb/d, of biodiesel producing capacity (Table 2). Compared to ethanol, the biodiesel projects are smaller in size and more scattered with much lower utilization rates. In fact, the 2008 biodiesel production is estimated at 6 kb/d only, with a utilization rate well below 20%.

Government Policies

Central government financial incentives have made biofuel production viable. The incentives can be summarized as follows:

- Four initial ethanol projects were supported by the government with subsidies. Up to now, most ethanol was produced from grain in China. The government subsidy on grain-based ethanol production has been reducing annually, from 1,883 yuan per metric ton (tonne) in 2005 (US$29.0 per barrel (bbl)), to 1,628 yuan/tonne (US$25.7/bbl) in 2006 and 1,373 yuan/tonne (US$22.7/bbl) in 2007. In 2008, the subsidy stopped completely.
- The government has started support for selected new biodiesel projects and new ethanol projects

using non-grain as feedstock.
- Same prices as comparable gasoline are enforced by government to make sure that consumers do not pay extra for gasohol.
- The consumption tax that applies to conventional gasoline is waived for ethanol gasoline.
- Ethanol projects using non-grain feedstock are encouraged.

For the last part of the incentives listed above, the NDRC has banned any expansion of projects or new projects using grains as feedstock, while cassava, sweet potato, and sweet sorghum will be used for ethanol, and various oily seeds will be used for biodiesel. By 2010, pilot ethanol projects using sweet sorghum will be established in Northeast China, Shandong Province, and other places, while cassava and sweet potato based pilot ethanol projects are to be set up in Guangxi, Chongqing, Sichuan, and other provinces. Among these feedstock materials, some research indicates that cassava has the potential to become an efficient and attractive crop for fuel ethanol production in China.[4] For biodiesel, projects using oily seeds will be established in Sichuan, Guizhou, Yunnan, Hebei, and other provinces.

In the foreseeable future, the government will dominate ethanol development. Thus, while there are countless local and small private natural ethanol production plants in China producing food grade alcohol, the four original fuel ethanol production plants are all run by state-owned enterprises. By fiat, these producers can only sell their products to Sinopec and CNPC, the two state-run petroleum companies. Sinopec and CNPC then blend the ethanol with gasoline and distribute E10 to gas stations. Over half of the gas stations in China are in the hands the two state oil companies. The state dominates ethanol production. It is reasonable to expect public awareness and consumer demand to have lesser roles in both the short and medium term.

Future Growth of China Biofuels Development

On March 20, 2008, China announced its latest 11th Five-Year Program on Renewable Energy Development[5] with a target of increasing the production of non-grain based ethanol to 44 kb/d by 2010. Earlier, on August 31, 2007, the NDRC released the Mid- to Long-Term Development Program for Renewable Energy for the next 15 years.[6] The 2020 targets are to increase the use of fuel ethanol to 218 kb/d and biodiesel to 40 kb/d by 2020.

Currently, China has various ethanol projects with a combined capacity of 9.2 kb/d under construction and more projects with at least 111 kb/d of total capacity are planned. For biodiesel, nearly 130 kb/d of additional capacity may be added, which are either under construction or planned.

While there are many budding industries and sources of biomass energy in China, in the long-term, economic feasibility will be the determining factor. Prices and profitability will determine the optimum feedstock for production locations throughout the country.

In China, fuel ethanol is profitable when oil prices approach 6 yuan/liter (US$3.32/ gallon).[7] Content requirements and the influence of state owned purchasers of biofuel will continue to define national demand. The policy direction articulated by an NDRC report in May of 2006 was to expand supply by requiring ethanol use in three national municipalities (Beijing, Shanghai, and Tianjin) and expand demand through government sponsored constructing of new ethanol production plants, including one in Guangxi Province (cassava-based) and one in Hubei Province (rice-based).

The demand for denatured ethanol is determined by central government policies, including required production of E10 by the two national oil companies and monthly demand quotas for each of the fuel ethanol producers set by the oil companies.

China has launched sorghum-based ethanol production on a trial basis in Heilongjiang, Inner Mongolia, Shandong, Xinjiang and Tianjin. Presently the trial project in Heilongjiang is capable of producing 5 thousand tonnes of ethanol a year. Sorghum-based ethanol will remain in the testing stages until technology and efficiency bring the product up to par with competing raw materials. There is some question, however, whether the domestic supply of sorghum, cassava, and sugarcane can meet the demand to produce the targeted 218 kb/d of fuel ethanol by 2020.[8]

Obstacles for Biofuels Development

The greatest obstacles restraining biofuel development in China are uncertainty of oil prices, feedstock supply, and government policies. The biofuels industry is presently married to government support. Government policies have delivered contradicting messages, leaving many investors and developers at odds.

Commercial feasibility, contingent upon conventional petroleum prices and technological advances, continues to pose a problem for widespread biofuel production.

Land limitations and food security loom large for China. With their unique history, the Chinese desire to secure food supplies for their population. Despite the many variables involved in the biofuel production equation, arable land availability is one of the few constants. Regional water scarcity issues have pressured officials into thinking twice before unilaterally expanding feedstock and biofuel production.

In addition to the above, oil price volatility creates another huge uncertainty. Although in the long run overall oil prices are moving higher, history suggested that they may still drop at times, which can render some biofuel investment projects uneconomical, and thus slow down the progress of biofuel development.

6. Conclusions

The importance of biofuels has been growing in China's energy strategy and development. In the next five years and beyond one can expect the central government to further tighten its grip on biofuel development. Private production and trade is not entirely out of the question in the long-run. Ethanol production in China will increase, but it has already hit a growth snag with the exhaustion of surplus grain stockpiles and the challenges are high to develop non-grain crops. Commercial biodiesel production will continue to lag behind commercial ethanol production until it achieves greater state backing (both political and financial) and until biofuel science discovers an optimum feedstock for profit and energy efficiency.

Overall, the increasing emphasis on renewable energy as an alternative source to conventional energy, for both policy support and investment helps to create a favorable environment for biofuels development in China. However, land and water limitations, and oil price volatility, coupled with political will, in the face of potential economic losses, pose some of the largest constraints for biofuel development in China, as well as in other countries wanting to develop biofuels. Biofuel development may alleviate some rural poverty and increase national energy independence, but market and scientific uncertainty enshrouds China's biofuels future.

Footnotes

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[2] See, for example, Schnoor JL, 2006, "Biofuels and the Environment", Environmental Science & Technology 40 (13): 4042-4042.

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[3] See Jansson, C. et al, 2009, "Cassava, a Potential Biofuel Crop for (the) People's Republic of China, Applied Energy, 60 (2009): S95-S99.

[5] See http://www.sdpc.gov.cn/nyjt/nyzywx/W020080318390887398136.pdf, accessed on September 20, 2009.

[6] See http://www.china.com.cn/policy/txt/2007-09/04/content_8800358.htm, accessed on September 15, 2009.

[7] On October 1, 2009, #93 gasoline in Beijing was sold for 6.28 yuan/liter (US3.48/gallon).

[8] Based on the un-used land potential, Tian et al's preliminary estimates show that China could potentially produce 22 million tonnes (479 kb/d) of ethanol. Similarly, the biodiesel production potential is 0.5 million tonnes (98 kb/d) by using winter idle land and cottonseeds. It is, however, unclear how the un-use land potential can be transformed to actual producing capability. For further information, see Tian, Y., et al, 2009, "Estimation of the Un-Used Land Potential for Biofuels Development for (the) People's Republic of China, Applied Energy, 60 (2009): S77-S85.

A Proposal for Wind-energy Conversion for Low Wind–speed Areas of India

By José A. Orosa*

Introduction

In its origins, the Indian renewable-energy program was a response to the rural energy crisis prevalent in the 1970s. In this sense, the renewable energy program has resulted in unrealistic targets and allocation of budgets, which have led to failure [1]. Implementation of energy-conservation initiatives in India has suffered from loopholes, such as numerous independent Ministries, namely, the Ministry of Power, Ministry of Petroleum and Gas, Ministry of Coal, Ministry of Nonconventional Energy Sources (MNES), and Department of Atomic Energy, which deal with energy resources in India; this multiple control has, consequently, resulted in weak coordination links [2].

Currently, fossil fuels account for about 64% of the total primary energy supply in India, whereas traditional biomass accounts for about 33% of the total [3]. As expected, the energy consumption of India will continue to grow at a significant rate in the future [4] and hence highlights the need to reduce India's dependence on both coal and oil. To achieve this objective, India has independent ministries for New and Renewable Energy and for Renewable Energy technologies (RETs), which are now well established in India and handle energy aspects that include solar photovoltaic, solar thermal, wind, biogas, and biomass for both power and heat generation, in addition to cogeneration and small hydro projects. India is one of the very few countries in the world to have such portfolios. Promoting renewable energy in India has assumed great importance in recent years, and the technology that has achieved the most dramatic growth rate and success is wind energy [4]. For example, in 2002, India had a wind-power capacity of 1267 MW, generating about 6.5 billion units of electricity; it currently occupies the fifth position in wind-power installation in the world, placed after Germany, United States, Denmark, and Spain [1]. Although large turbines are also manufactured in India, relatively small turbines have a significant share in the total installed capacity [4]. Furthermore, in spite of the relatively low wind regimes at 50-m hub height, comparing by international standards, India has made significant progress in wind-based power generation, and the installed capacity of wind increased from 41 MW in 1992 to 6053 MW in September 2006 [3].

Finally, although the emphasis on renewable energy in India has been growing, aggressive policies, targets, and work programs for promoting RETs are still lacking. The rural areas provide a significant opportunity to apply photovoltaic, microhydro, and biopower technologies in future years [4]. Furthermore, there is a need for targeted technology development and research and development (R&D) for cost reduction–low wind–speed machines, inverters, and controllers of a few kW—for reduction of the manufacturing cost of photovoltaic modules [3].

In the present article, the actual conversion of wind energy in India will be reviewed, and future corrections are proposed, with special emphasis on rural areas and low wind–speed energy converters.

Decentralized Energy Technologies in Rural Areas

In recent research works [5], it was shown that decentralized energy technologies based on the availability of local resources can be a viable alternative to rural electrification in India through the extension of the main grid. Most of the decentralized plants are based on wind power, hydroelectricity, and biomass gasification. At the village level, the decentralized planning approach has been attempted on a small scale for isolated projects that meet limited energy needs.

Another recent research [6] investigated how rural electrification could be achieved in India using different sources of energy and the effects that it would have on the steps toward climate change mitigation. With this aim, the electrification options for rural nonelectrified households in India were modelled, and the impacts of the four different types of electrification were assessed: central grid–based, using electric appliances; decentralized diesel-based, using electric appliances; decentralized renewable energy–based, using electric appliances; and decentralized renewable energy–based, using mainly renewable energy–based appliances. The results of the above study showed that rural electrification with renewable energy could reduce up to 90% of the total CO_2 emissions originating from the residential sector, compared to electrification with grid and diesel systems, and therefore have very high climate change–mitigation potentials. It is also expected that renewable energy–based electrification could also reduce use of primary energy, compared to electrification with grid and diesel systems,

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and thereby save energy resources.

Similarly, research on adaptation of wind turbines for remote and stand-alone applications is receiving increasingly greater attention. For example, hybrid power systems using 1–50 kW wind turbines are being developed for generating electricity in the grid and, in many parts of India, for grid connections. In the latter case, distributed energy resources, such as small wind systems ranging from 50 to 300 kW, provide energy for village electrification, water pumping, battery charging, use by small industries, and so on. In India, however, the use of wind as an energy source for decentralized energy generation is at a preliminary stage [5].

One of the principal decentralized applications is the pumping of water from groundwater for irrigation. There were reportedly more than 15 million electricity-driven pumps and 6 million diesel pumps in operation in the agriculture sector in the year 2003. Under this situation, diesel is expected to become increasingly expensive and scarce and, in consequence, a substantial potential for using renewable sources of energy for pumping of irrigation water is expected. In India, the options of renewable energy for water pumping include solar photovoltaic pumps, windmill pumps, and dual partial substitute for diesel [7]. When the photovoltaic pump system was analyzed, it was concluded that the power obtained from this system in the field is generally less than the rated power. It is due to reasons such as decreases in the efficiency of a solar cell when temperature increases, solar irradiance lower than 1 kW/m^2, and the high downtime required for repair and maintenance.

However, when the use of the windmill pump was analyzed [7], it was noted that the total number of windmill pumps installed was far below their estimated potential of 0.4 million. One of the main barriers against the large-scale adoption of windmills is the financial viability, because the annual useful energy delivered by a water-pumping windmill depends on the wind-power availability feasibility in a region and the corresponding problems related to wind-energy conversion, which are discussed below.

Facts Related to Wind Power in India

Wind-power technology is experiencing a major growth, especially in the United States and Europe, and a significant growth has been observed in developing countries such as China and India. As a result of scientific assessments of wind resources throughout India, wind power has emerged as a viable and cost-effective option for power generation [8]. Thus, the wind-power potential in India has been assessed at 45,000 MW, with 1% land required for wind-power generation in potential areas. Assuming a capacity utilization factor of 25%, the identified potential can generate electricity equivalent to approximately 100 TWh per annum [5]. On the basis of the growth trends, the predictions about the future of wind energy in India showed that 99% of India's technical wind-energy potential may be achieved by the year 2030 [8]. Furthermore, it has been assumed that with better resource assessment and further increase in conversion efficiencies, the identified potential can generate approximately 117 TWh by 2051–2052 [5].

To accomplish these improvements, the MNES, Indian Renewable Energy Development Agency, and the wind industry are working together through various R&D programs. For example, Herbert et al. [9] reviewed the models used for wind-resource assessment, site selection, and aerodynamics, including an analysis of the wake effect. They concluded that with reference to the site selection, the coastal and dry arid zones have good wind potential, and the winds blowing during the period from November to March are relatively weak in India. Of the five potential Indian states, Maharashtra and Karnataka show a relatively steep increase compared with other states [10].

When the aerodynamic models were analyzed, it was observed that both the horizontal-axis wind turbine (HAWT) and vertical-axis wind turbine (VAWT) design are very efficient; however, both are being rigorously tested and improved until date [9]. In spite of these developments, wind speeds less than 5 m/s are not of much relevance to wind-energy applications. Chikkodi, Horti, Kahanderayanahalli, Kamkarhatti, Raichur, and Bidar have wind velocities greater than 5 m/s for most of the months of the year; the wind-energy potential is high in these locations and, therefore, construction of wind farms is recommended at these locations [10].

Problems of Wind-energy Conversion

As shown before, the electricity generated by wind is still more expensive than power obtained from conventional power plants, unless the environmental benefits of wind power are taken into account. If the cost of wind energy could be reduced by an additional 30–50%, then it would be globally competitive. The goal of achieving this reduction has inspired designers to seek cost reduction by increasing the size, tailoring of turbines for specific sites, exploring new structural dynamic concepts, developing custom generators, and power electronics, in addition to implementing modern control-system strategies

[11]. It was concluded that to improve wind energy conversion, the principal design factors that must be analyzed are the power in the wind, the load factor, wind turbine–axis orientation, the area required, and the grid connection.

The power in the wind depends on the wind statistics, the seasonal and diurnal variations of wind power, and variation with time. In particular, when the wind blows strongly (speeds more than 12 m/s, there is no shortage of power, and often, the generated power has to be dumped. Difficulties appear if there are extended periods of low- or zero-speed winds.

The load factor is not a major concern when the wind electric generator acts as a fuel-saver on the electric network; nevertheless, if the generator is pumping irrigation water, for example, in an asynchronous mode, the load is very important.

To select between different orientations of the axis, according to the orientation of turbines, HAWTs and VAWTs can be considered. The principal advantages of VAWTs over conventional HAWTs are that VAWTs are omnidirectional and, in consequence, they accept the wind from any direction. This simplifies their design and eliminates the problem imposed by gyroscopic forces on the rotor of conventional machines as the turbines yaw into the wind. The vertical axis of rotation also permits mounting the generator and gear at the ground level. On the negative side, VAWT requires guy wires attached to the top for support, which may limit its applications, particularly for offshore sites.

The area of land required depends on the size of the wind farm, and the optimum spacing in a row is 8–12 times the rotor diameter in the wind direction and 1.5–3 times the rotor diameter in crosswind directions.

The last parameter is related to the grid connections. For the economic exploitation of wind energy, a reliable grid is as important as the availability of strong winds. The loss of generation for want of a stable grid can be 10–20%, and this deficiency may perhaps be the main reason for the low actual energy output of wind mills compared to the predicted value [11]. Consequently, this is one of the most important factors that must be corrected in future wind energy–converter designs.

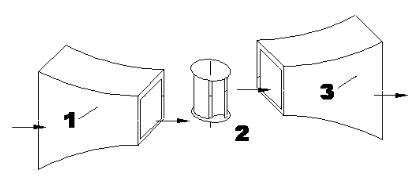
Future Proposals for Wind-energy Conversion in India

The principal parameters analyzed above are related to the cost of wind energy and, hence, with the financial viability; these factors are now considered for a proposal for the future. As shown before, India portrays the need for a renewable energy conversion in decentralized areas, where the principal problem is the instability in wind velocity, which in turn increases the cost of wind energy.

In previous research works, Shikha proposed a wind concentrator for this same problematic situation [12, 13]. This same concept was further analyzed [14, 15], and its energy conversion was improved based on the phase change of moist air. This recent implementation is based on the Foehn effect and consists of a nozzle, a rotor, and a diffuser designed to get the maximum mechanical energy from the free stream of airflow [16]. Finally, a Savonius rotor was proposed [17] for low wind–speed areas, as shown in Figure 1.

Experimental results showed that VAWTs offer a great number of advantages, such as accepting wind from all directions, being easier to build, being able to respond more quickly to changes in the wind direction or velocity, and presenting a higher net efficiency of converting winds to electricity. Furthermore, results have shown a clear increment of three fold energy conversion.

Finally, in recent research works, the combined effect of two wind farms was simulated; one with and another without wind concentrators [18]. Results showed major energy-conversion stability under different ranges of wind speed. Furthermore, other applications of this system, such as controlling the velocity of wind turbines with the relative humidity of moist air, are suggested.



1. Nozzle 2. Rotor 3. Diffuser

Figure 1. Wind Concentrator Proposal

Conclusions

Currently, in India, extensive powers have been handed to the Bureau of Energy Efficiency (BEE) under the Energy Conservation Act, 2001. However, for more efficient administration of the Act, it is felt that there could be an independent body, called the Association of Indian Energy Managers, to which some of the tasks and activities of BEE could be delegated.

The currently used centralized energy planning model ignores the energy needs of rural and poor areas and has also led to environmental degradation, whereas the decentralized energy planning model is in the interest of efficient utilization of resources. It is found that small-scale power-generation systems based on renewable energy sources are more efficient and cost effective. Thus, the focus should be on small-scale RETs that can be implemented locally by communities and small-scale producers, but which can make a significant overall contribution toward the national energy supply. Although India has made considerable progress in implementing technologies based on renewable sources of energy, the decentralized energy–technology applications are still few [5]. It was found that rural electrification with renewable energy could reduce up to 90% of total CO2 emissions; therefore, these options have very high climate change–mitigation potentials and could also reduce primary energy use, compared to electrification with grid and diesel systems, and thereby save energy resources [6].

Once a possible solution for this problematic situation was obtained, the reason why it has not yet been corrected has been reviewed. It is concluded that, at present, many renewable sources are in the classic chicken-and-egg situation: the financiers and manufacturers are reluctant to invest the capital needed to reduce cost when the demand is low and uncertain, whereas the demand remains low because the potential economies of scale cannot be released at low levels of production. Renewable energy needs to gain the confidence of developers, customers, planners, and financiers. This can be established by renewable energy establishing a strong track record, performing to expectations, and improving its competitive position relative to conventional fuels. In this sense, the barrier in renewable energy development and penetration is, with reference to wind power, the tapping of wind potential, which is difficult due to the wide dispersal of wind resources.

Finally, although the emphasis on renewable energy in India has been growing, aggressive policies, targets, and work programs are still lacking. There is a need for targeted technology development and R&D for cost reduction. For example, for implementation of actual wind-energy conversion, a wind concentrator based on the phase change of moist air and a Savonius rotor are proposed, from which obvious increments of three-fold fold energy conversion are expected to be obtained.

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Carbon Capture and Storage in China: Options for the Shenhua Direct Coal Liquefaction Plant

By Hui Su and Jerald J. Fletcher*

Introduction

In this carbon constrained world, climate change driven by carbon intensive energy sources is receiving wide attention. Carbon capture and storage (CCS) is defined as the collection of CO_2 from industrial or utility plants including power plants, oil refineries and chemical works, and subsequently storing it in secure underground reservoirs. Cited as a "potentially important climate change mitigation measures in the coming decades" (Philibert et al., IEA, 2007; OECD/IEA, 2006), CCS is under consideration as an important carbon management option. CCS is expected to be the second most important emission reduction technology (OECD/IEA, 2006) by 2050, second only to energy efficiency improvements. It is considered the only option that can provide long-term greenhouse gas (GHG) mitigation while allowing for continued large-scale use of the existing fossil infrastructure and abundant fossil energy resources (Herzog, 1998). As a critical element within a mitigation portfolio, CCS is also becoming increasingly important for China. Any efforts from China would inevitably play an important role in global carbon management efforts since China is the leading consumer of coal-derived energy and carbon dioxide emitter.

Motivation for China's CCS Options

Climate change considerations are motivating factors for China's development of CCS mitigation options. With rapidly increasing GHG emissions, China is facing increasing international pressure to reduce emissions and commit to long-term reductions under the post-Kyoto framework. During the 11^{th} five-year planning period (2006-2010), the Chinese government set goals for reducing energy consumption per unit of GDP by 20% and CO_2 emissions by 1.32 billion tons by 2010 (NDRC, April 2007; NDRC, June 2007). President Hu's speech at the UN climate change conference on September 22, 2009 emphasized that China would "endeavour to cut carbon dioxide emissions per unit of GDP by a notable margin by 2020 from the 2005 level."

However, coal, the most carbon-intensive type of fossil fuel, will remain the dominant component of China's energy mix in the foreseeable future. Given that most energy-related CO_2 emissions come from the use of fossil fuels, China's attempts to increase energy security through the use of domestic resources, primarily coal, make GHG emission abatement difficult. Successful large scale application of CCS technologies in China would reduce CO_2 emissions while enabling the continued use of coal.

CCS is a key component of China's development of integrated gasification combined cycle (IGCC) clean coal technologies. IGCC is a process in which coal is gasified to synthesize chemicals and fuels and hydrogen produced to drive turbines to generate electricity. In contrast with the halt of the U.S. Department of Energy (DOE) advanced IGCC demonstration project (FutureGen), China is actively developing its clean coal technologies and establishing its own set of IGCC projects (GreenGen) – the first in 2009 in Tianjing (Technology Review, 2008). IGCC plants produce far less pollution than conventional coal plants while providing a CO_2 stream pure enough to store. Rapid development of such clean coal technologies in China provides an ideal opportunity for commercial CCS development.

Developing CCS technologies provides an opportunity for Chinese enterprises to take a leadership role in the application of carbon mitigation alternatives. The Chinese government is expected to allocate funds equivalent to a quarter of the US$ 586 billion stimulus package to environmental related projects, renewable energy development and improvement of energy efficiency as measures to simulate China's economy[1]. These funds provide governmental incentives for Chinese power companies. Accordingly, the development of CCS would increase economic activity through the creation of new business opportunities and associated jobs to sustain economic growth while responding to the current global economic crisis.

It is worth noting that any climate change mitigation including CCS could improve China's standing in the world. China hopes to be seen as a responsible and constructive force for dealing with the most critical global issues of the 21^{st} century (Lieberthal and Sandalow, 2009). Any positive action in climate change mitigation can be expected to enhance its international prestige.

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See footnotes at end of text.

Development of CCS in China

In 1998, China began its first CO_2 storage project CO_2-EOR in the Liaohe oil field in the Bohai Basin in North-East China (IPCC, 2005). In 2003 China joined the Carbon Sequestration Leadership Forum (CSLF), a ministerial-level organization initiated by DOE. The initiative promotes collaborative research, deployment and demonstration of CCS projects among the CSLF signatory member countries[2]. Among the seven recognized and completed CSLF projects, two are located in China. The first one is the China United Coal Bed Methane Corporation and the Alberta Research Council of Canada joint venture for extracting coal-bed methane via CO_2 injection (CO_2-ECBM) in the Qinshui Basin of eastern China in 2005[3]. A second project is the Regional Opportunities for CCS in China, lead by Battelle, U.S. Pacific Northwest National Laboratory (PNNL) and the Chinese Academy of Sciences. This project estimated market opportunities for CCS in China by compiling characteristics of large anthropogenic CO_2 sources and candidate geologic storage formations across China[4] (Dahowski, 2005). Meng (2007) estimated the potential of Chinese coal-fed ammonia plants for CO_2 storage in saline aquifers. The estimated cost for compressing, transporting and storing CO_2 in saline aquifers ranged from \$15 to \$21/t of CO_2. In 2007 China's Ministry of Science and Technology (MST) and the British Geological Survey launched a pilot CCS project looking into the possibility of storing carbon in depleted oil and gas fields and unmined coal seams[5]. China's HuaNeng Group and Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO) collaborated on a post-combustion capture (PCC) pilot plant for thermal power stations in Beijing in 2008[6]. More recently, the UK Department of Energy and Climate Change invested more than £3 million in developing CCS in China[7].

Introduction to the Shenhua DCL Project

The Shenhua Group (Shenhua) is one of the largest energy companies in China and the world's largest coal producer. The Chinese National Council provided about \$1.3 billion US from the "Coal Replace Oil" fund to Shenhua to initiate coal-to-liqiud (CTL) development in Janary 1998. Since then Shenhua has developed a business strategy and began CTL development in northwestern China's major coal production areas. Increases in crude oil prices further stimulated Shenhua's CTL development. With support from China's National Development and Reform Commission (NDRC), Shenhua has allocated about \$10 billion USD to the development of its coal coversion projects.

The Chinese government's initial encouragement to pursue CTL development was driven by energy security considerations. China's efforts to increase clean coal utilization to mitigate the environmental impacts of traditional coal combustion also factor into Shenhua's CTL developememt decisions. Shenhua has primary responsibility for the coal related goals of the Chinese National Energy Security and Alternative Fuel Program (WVU, 2009). The China Shenhua Coal Liquefaction and Chemical Company Ltd. (CSCLCCL) is developing the world's first modern commercial direct coal liquefaction (DCL) facility to produce transportation fuels. The DCL plant completed a trial run in January 2009 that provided information for further development. The second trial run is now underway as of September, 2009. When fully operational, the DCL plant is expected to produce nearly 1 megatonnes (Mt) of oil products per year, equivalent to approximately 25,000 barrels of oil per day. The estimated total cost of the first phase of the DCL plants is \$1.5 billion US.

Geologic CCS Potential in Ordos Basin

In conjunction with transportation fuels, the plant will also produce nearly 3.4 megatonnes (Mt) of CO_2 per year. In 2008, the Chinese government curtailed the coal liquefaction program due to concerns about pollution and excessive water consumption. Shenhua's DCL plant is one of two major facilities approved to proceed while others were suspended (Reuters, 2009). In addition, in recent years the Shenhua DCL plant has drawn worldwide attention as the world's first modern, commercial DCL demonstration project.

Shenhua is considering alternative methods to permanently store or sequester CO_2 in geological formations in the Ordos Basin. Geologic CCS is particularly well suited for large point sources such as the DCL project since CO_2 can be efficiently captured (Bode and Jung, 2006). Over 80% of CO_2 emissions in the DCL process, equivalent to approximately 3 Mt of CO_2 per year, can be stored directly without additional capture costs. The CTL project with CCS technology enjoys a comparative advantage over CCS projects for traditional coal-fired sources.

Conclusions

CTL production with CCS potentially offers a route towards widespread reduction of CO_2 emissions.

The development of a CCS project related to the Shenhua DCL plant will contribute to China's CO_2 emission control program as well as to the feasibility of continued growth of the coal gasification and liquefaction industry. If the proposed CCS plan comes to fruition, its economic viability and environmental sustainability may well determine the future of the CTL industry in China.

More importantly, the success of the Shenhua CCS plan may well determine the potential for CCS as one of a portfolio of mitigation options in China and represent a significant step towards China's carbon management efforts.

Footnotes

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Environmental Impacts of Rising Energy Use in China: Solutions for a Sustainable Development

By Stéphane Rouhier*

Today, China is the world's second largest energy consumer and by 2015 is expected to overtake the U.S. as number one. Nevertheless, on a per capita basis, its consumption level is low compared with industrialised countries. According to Brown (2005), if the Chinese were to use oil with the same intensity as Americans, by 2031 they would need 99 million barrels per day. 2030 production is projected at 116.3 mbd (IEA, 2007). Sinton (2008) says that if China were to equal U.S. per capita coal use, it would use twice as much as it now does. Sinton also says if China were to equal US per capita total primary energy consumption, the result would be consumption amounting to 87 percent of 2006 world consumption. Thus, Chinese development may put pressure on the global security of supply. However, this article will focus on the environmental issue that is related to energy.

The Chinese Energy Mix[1]

Before studying the state of the Chinese environment, one first needs to analyse its energy consumption as it is one of the drivers of its degradation. China currently consumes 1,900 million tons of oil equivalent (Mtoe, hereafter) and mainly relies on coal that represents 64 percent of its energy consumption. Oil (19 percent) and biomass (11 percent) are the two other main sources of energy. On a global scale, the world's consumption is more balanced even though it is still dominated by fossil fuels. Oil and coal represent respectively 34 and 26 percent of global consumption while natural gas accounts for 21 percent.

Comparing these two mixes shows China's heavy reliance on coal. This can be explained by the fact that China consumes very little natural gas and is endowed with huge reserves of coal. The use of coal has been increasing in recent years due to the surge in electricity needs which is coal-based at 80 percent. Regarding oil consumption, it has been rising recently but is still less intensively used as the Chinese government has for long lauded self-sufficiency. The use of hydropower and nuclear power is lower in China than worldwide even though it has many projects involving the expansion of these two types of energy as well as other renewables. Lastly, biomass remains an important source of energy although its use has been considerably reduced in the last two decades. It is noteworthy that in China, unlike in most other developed countries, biomass refers to non-commercial traditional biomass.

In terms of forecasts, the increase in Chinese energy demand over the period 2006-2030 will dwarf that of other countries. This increase is projected to represent nearly 2,000 Mtoe which corresponds to four-times the rise in energy demand of both Latin America and Africa or three-times that of the OECD over the same period. Coal will remain the dominant fuel in 2030, with a share of 63 percent while nuclear power, as well as natural gas, hydro and other renewables will increase their shares at the expense of biomass.

Environmental Consequences

All energy sources have drawbacks from an environmental point of view. Exploiting an energy source can create unwanted and damaging by-products or drive other products' supply down. More simply, hazards exist and accidents may happen. However, the two worst forms of energy sources are the traditional (also known as non-commercial) biomass and coal. Burning coal[2], as well as wood or waste for the biomass, releases sulphur oxides, carbon oxides, nitrous oxides, and other impurities into the air. For instance, 70 percent of smoke dust emission, 90 percent of sulphur dioxide emission, 67 percent of nitrogen oxide and 70 percent of carbon dioxide in China are due to coal combustion (Zhang, 2007). Burning coal also releases mercury. Mercury enters the environment as industrial air pollution from factories, notably when coal is burned. It is then deposited into oceans and waters and contaminates the food chain (NRDC, 2007). Since it is a global pollutant, it disperses around the globe and affects the five continents. For example, the U.S. EPA reported that a third of the U.S.'s lakes and a quarter of its rivers are polluted with mercury. Therefore, it has recommended not to eat fish caught there (Pottinger et al., 2004). According to Pottinger et al. (2004), 30 percent or more of mercury in the American waters or soils come from other countries, in particular China, which is reported to be the world's largest (non-natural) emitter of mercury. All theses emissions affect the environment on three levels. The global environment is affected through global warming by emissions of carbon

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See footnotes at end of text.

dioxide. The environment is regionally altered by emissions of nitrous and sulphur dioxides that cause acid rain. On a local level, particulate emissions, among others, can pose a direct threat to human health. These three types of pollution will be successively analysed.

Global Consequences

Global environmental degradation is due to the significant increase of greenhouse gases and more particularly CO_2, which makes the largest contribution to global warming. CO_2 is mostly released into the environment when a fossil fuel is combusted for energy use. Among all the types of fossil fuel, coal is the one that discharges the most CO_2 when burned. As China uses a lot of coal in its energy mix, it is today the leading global CO_2 emitter. The effects of such an increase are numerous and well-known and will impact health, agriculture, forest, water resources, coastal areas, species and natural areas. In 2030, Chinese emissions are forecast to be 66 percent higher than those of the U.S., which is ranked second (IEA, 2007).

Regional Consequences

Regional pollution is embodied by acid rain which occurs when SO_2 and NO_X are mixed together in the air and create acidic compounds that are absorbed by clouds (IEA, 2007). Acid deposition has been recognised as a potential environmental problem in China in the late 70s, early 80s (Larssen et al., 1999). Nowadays, about 40 percent of China suffers from acid rain, mainly south of the Yangtze River and in coastal areas (He et al., 2002). Acid rain has repercussions on vegetation, soils, crop yields, buildings, and public health. In terms of costs, a study undertaken by Zhang, Wen (2000, cited in Day, 2005) showed that Chinese agricultural production has already been lowered by 5 to 10 percent due to acid deposition.

Local Consequences

The reasons for the local pollution are also a heavy reliance on coal and non-conventional biomass that both emit a lot of noxious gases (carbon oxides, sulphur oxides, nitrous oxides, particulate matter…). For instance, nitrogen dioxide is a lung irritant which increases the lung sensitivity to other pollutants. Sulphur dioxide is an acidic gas that can lead to short-term lung irritation or long-term lung tissue changes and has negative impact on agricultural crops. According to WHO[3], 17 percent of all deaths in the Asia-Pacific Region (in which the bulk of the population is represented by China) are related to environmental problems. This pollution can either be referred to as indoor air pollution (through the use of biomass in most of the cases) or outdoor air pollution[4]. Indoor air pollution occurs mainly in poor areas where traditional biomass is highly used. In developing countries, people tend to rely on wood, dung or crop residues for domestic energy. For example, in China, it has been shown that two-thirds of women with lung cancer were non-smokers (Bruce et al., 2000). According to Zhang, Smith (2007), indoor air pollution is responsible for more than 400,000 premature deaths annually in China. As for outdoor air pollution, in the last ranking of the world's most polluted cities, China accounted for 20 of them[5] and according to a World Health Organization report (2004), only 31 percent of Chinese cities met the WHO standards in terms of air quality. Recently Wen, Chen (2008) assessed the economic losses of air pollution at 4.1 percent of GDP in 2002. And in its last report on this topic, the World Bank (2007a) assessed the economic cost of Chinese pollution (both water and air) at 3 or 6 percent of the GDP in 2003, depending on the methodology used (Adjusted human capital approach or Value of statistical life).

To conclude, China is severely hit by pollution which puts a heavy burden on populations. Pollution causes many diseases and deaths and hampers agricultural productivity and buildings' longevity. Therefore, it represents a public issue that needs to be urgently tackled.

Solutions to Implement an Environmentally Sustainable Development

In economic theory and in absence of externalities, efficient pricing exists when the incremental cost of producing, transporting and distributing a commodity equals its market price (The World Bank, 2007b). It is the reason why many scholars have advocated for a subsidy removal in China. As subsidies affect either the prices paid by producers or consumers, or the prices received by producers, they create market distortions. Assuming that polluting fuels are most of the time subsidised, this leads to an over-optimal level of pollution. Reducing (or removing) subsidies enables a reduction in the incentive to consume or to over-consume polluting sources of energy. The IEA (1999) showed that a subsidy removal in China would reduce CO2 emissions by 13.44 percent while increasing GDP by approximately 0.37 percent. Larsen, Shah (1992) advocated that economic policies should first and foremost remove fossil fuel subsidies in order to protect both local and global environment. The same rationale can be applied to externalities. Internalising them (and thus, putting a price on noxious emissions) is one of the common ways to tackle pollution. This idea dates back to the works of Pigou and has been used with emissions trading in the Kyoto Protocol, in the U.S. with the EPA's Emissions Trading Program, and in Finland or Sweden with carbon taxes (Blackman, Harrington, 1999).

The notion of energy prices and a possible increase of these prices in China has already been considered. Hang, Tu (2007) calculated coal, oil and electricity price elasticity in China to underline the positive impacts of higher energy prices on energy efficiency and security of supply. Shi, Polenske (2005) also confirmed that China's energy intensity was negatively correlated with energy prices. The abovementioned study from the IEA (1999) also emphasised the positive effects of a subsidy removal on CO2 emissions in China. Rouhier (2009) recently showed that a price instrument could work in China thanks to a negative price elasticity of both SO2 and CO2 emissions. First of all, through a subsidy removal, the government would enable energy prices to give correct signals to consumers that would thus reduce the quantity of fossil fuels consumed and to producers that would go for better technologies or less polluting fuels. Then, by making the producers pay for the externalities they create through, for example, carbon emissions fees or a sulphur tax, the government would also reduce pollution. Such a price increase would affect energy efficiency as well as diversification. Indeed, pricing has a big role to play, either by making energy more expensive and thus, more valuable (energy efficiency), or by increasing polluting fuels' prices (fuel switching), or by making new and less polluting technologies financially interesting (emissions control). Overall, more expensive energy prices would increase energy intensity, help reduce the consumption of polluting fuels and thus carbon (as well as sulphur) emissions, and also improve public finance.

Even though this solution will be hard to implement and might face social dissent, we do believe in its legitimacy. Yushi *et al*. (2008) assessed the direct external cost of coal at RMB 1,745 billion. They performed a cost-benefit analysis of the full internalisation of coal external costs and found that the total added social wealth of such a solution was about RMB 942.3 billion. Besides, most of these changes could occur at reasonable costs thanks to international co-operation through the global climate policy and the Clean Development Mechanisms. On this point, one must point out that international negotiations, notably in Copenhagen, will have an impact on what can be financed through those mechanisms. Developed countries might be reluctant to finance the internalisation of Chinese externalities. However, with the money that would be saved by the government (subsidy removal) plus the money that will be collected through a price on pollution, government would be able to finance new infrastructure as well as implement policies to improve the fate of the poor.

Footnotes

[1] Figures based upon IEA (2008).

[2] It is noteworthy that the extraction of coal also emits coal-bed gas that is most of the time methane. Methane belongs to the category of greenhouse gases and is 21 times more damaging than carbon dioxide. Hence not only burning coal is environmentally damaging, but also extracting it and transporting it.

[3] http://www.wpro.who.int/china/sites/ehe/overview.htm

[4] It should also be noted that there is a growing gap between water resources, water quality and the ever-increasing needs of people or industries.

[5] World Bank – China quick facts available at http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/CHINAEXTN/0,,contentMDK:20680895~pagePK:1497618~piPK:217854~theSitePK:318950,00.html

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Carbon Capture and Storage: Science and Technology Focus for Mitigation of Climate Change

By Malti Goel*

Introduction

Global warming is attributed to increasing greenhouse gas emissions and mounting concentrations of carbon dioxide and other gases in the atmosphere. Since the middle of the 19th century, increasing worldwide anthropogenic activity is said to have given rise to a steady increase of carbon dioxide in the atmosphere. This is corroborated by direct measurement of CO_2 concentrations at Mauna Loa Laboratory in Hawaii (USA). The CO_2, present in the atmosphere as a trace gas, has an average atmospheric concentration of 280 ppmv. In 1958 the observed concentration was 315 ppmv, which suggested an increase of about 0.5 ppmv per year in the initial half of the 20th century. In 2005 the measured concentration of CO_2 was 374 ppmv, suggesting an increase of about 1 ppmv per year in the latter part of the 20th century.

The rising concentration of CO_2 is ascribed mainly to the use of fossil fuels—coal, oil and gas—for energy production and consumption. According to the International Energy Outlook 2007, world energy consumption is expected to grow from 442 quadrillion Btu (~ 750 billion boe) in 2004 to 702 quadrillion Btu (~ 1200 bboe) in 2030. In view of coal meeting 40% of world wide electricity needs and its high contribution to greenhouse gas emissions, it is imperative that options for reducing emissions from coal use be explored.

Carbon Capture and Storage

In this context CO_2 sequestration—carbon capture and storage (CCS)—is widely acknowledged as an emerging technology to address the problem of increasing carbon dioxide (CO_2) in the atmosphere. CCS is an effective means for reducing atmospheric CO_2 concentration, either through reduction of emissions using advanced clean technology or capture of excess CO_2 from the atmosphere. Although CCS is in the development stage, the International Energy Agency has estimated the potential contribution of CCS in removing CO_2 to be as high as 25 % of the global emissions in 2050.

To create awareness of the various technology options for carbon capture and storage as well as to keep pace with the future technology in coal based generation, a conference on Awareness and Capacity Building Programme on Carbon Capture and Storage (ACBCCS 2009) [1] was organized at the Indian National Science Academy in New Delhi from July 27 to 31, 2009. In this five day programme representatives from major stakeholder industries and academia participated with scientists from across the country and addressed the research frontiers associated with CCS. The conference was supported by the Ministry of Earth Sciences, Government of India and the National Environment Science Academy and highlighted current aspects of Indian research in CCS, as briefly discussed below.

Carbon Capture and Storage involves three basic steps.

- Capturing CO_2 from its point sources
- Liquefying and transporting the captured CO_2 to appropriate locations
- Permanently storing CO_2 away from the atmosphere in terrestrial or geological or oceanic formations.

CO_2 capture in coal based generation is approached in three ways, viz., pre-combustion, combustion and post combustion CO_2 capture (Figure 1).

Pre-combustion CO_2 Capture

The pre-combustion capture technology aims to remove or minimize CO_2 from the fuel before it is combusted. From natural gas CO_2 separation is routinely done by scrubbing before it is combusted. Coal needs to be, gasified before CO_2 separation. Integrated Gasification Combined Cycle (IGCC) technology is an appropriate choice. The CO_2 from coal gas should be removed at the higher temperature of gasification so as to reduce overall energy consumption. The CO_2 sequestration studies to find the materials—rare earths, composites and absorbents—which can perform at these high temperatures has been a research challenge. The development of the right materials that can withstand the required temperature for capturing CO_2 emanating from the coal Syn gas is the foremost requirement. Other requirements are regenerability of the material and the cost-effectiveness of the separa-

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See footnotes at end of text.

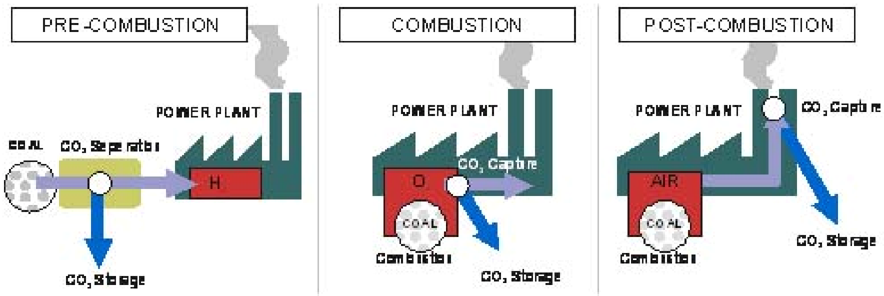


Figure 1
Pre-combusinton, Combustion and Post Combustion CO_2 Capture[2]

tion method. After removing CO_2 hydrogen remains as pollution free fuel.

CO_2 Capture During Coal Combustion

In coal combustion, improvement in the efficiency of generation can go a long way to reduce emissions. Pulverized fuel combustion is the most practical technology and has been adopted by 97% of the thermal power plants, world over. Pulverized fuel power plants under super-critical conditions offer improved efficiency. Research is also being conducted in advanced coal based technologies like molten carbonate fuel cell, chemical looping combustion, etc. for low emissions. Burning of coal in 100% oxygen is another option to reduce air pollution and increase the efficiency of power generation. The flue gas becomes rich in CO_2, about 90%, which is easier to capture. The oxy coal combustion is beneficial, but technically highly challenging. An oxy coal combustion pilot plant facility of 30MW has been demonstrated in Germany (Vattenfall and Alstom) in 2008. To discuss research issues relevant to development of oxy-fuel combustion technologies on a commercial scale, the International Energy Agency Greenhouse Gas R&D Programme (IEA GHG) organized the first Oxy-fuel Combustion Conference in Cottbus this year. A few other demonstrations are in the pipeline in USA, Canada and Australia.

Post Combustion CO_2 Capturing

The post-combustion CO_2 capture technology is concerned with CO_2 separation from the flue gas of a conventional power plant. The flue gas is dirty since it contains many other pollutants besides CO_2. The share of CO_2 is of the order of 8-14%. The CO_2 can be captured by using techniques of chemical absorption, physical adsorption, cryogenic separation and membrane separation. The amine based solvent separation is well known technology, but the challenge lies in regeneration of the solvent and development of cost-effective adsorbents. New techniques like pressure and volume swing absorption cycles and use of polymeric membranes are being investigated. Vast possibilities exist for materials development in CO_2 sequestration research.

The estimated cost of post combustion CO_2 capture and storage has also been worked out. In electricity generation, the application of CCS may double the cost of generation, depending on the technology used. CO_2 capture is estimated to cost about 70% of the total (the remaining is for transportation and storage) and the energy penalty is also significantly high. A comparison of recovery and capture cost according to the technology used is given in Table. 1.

S.No.	Technology/ Parameter	CO_2 recovery %	CO_2 purity Achieved%	Energy Penalty %	Capture Cost US$/ton CO_2
1.	Chemical absorption	90	> 98	36	47
2.	Physical adsorption	90	44	47	61
3	Membrane separation	90	43	52	78

Table 1: Comparison of Post Combustion CO_2 Capture Options
Source- Post combustion CO_2 capture, Anshu Nanoti and Amar N.Goswami in ACBCCS-2009

Post Combustion CO_2 Capture and Storage

Besides these physical and chemical methods, biological routes are also being tested for post combustion CO_2 capture and storage.

Biological Route: The biological route to capture CO_2 from flue gas requires an algae pond in the vicinity of a thermal power plant. Development of strains with high productivity appears to be the most cost-effective solution. But the greatest challenge is to isolate algae and genetically improve algal strain for both higher oil content and overall productivity. Marine algae could also form a possible solution for thermal power plants situated along the sea coast. Micro-mediated CO_2 sequestration using carbonic anhydrase offers another option. A proper understanding of enzymes and hetero-trophic microbial systems would help in stabilizing atmospheric carbon through photo-autotrophic and non-photosynthetic CO_2 fixation processes.

Ocean Sequestration: Oceans are vastly unexplored option for CO_2 storage. Oceans have higher CO_2 flux than the atmosphere. The options for storing CO_2 can be on the surface, below the surface and on the deep sea floor. However, its effect on the marine ecosystem and living resources is yet to be assessed. The lowest estimate of CO_2 that can be stored in the Sea floor of ocean basins in a super cooled liquid state permanently is approximately 5000 giga tones (Gt). In addition to these, iron fertilization studies for increasing phytoplankton productivity by CO_2 injection in Northern and Southern Oceans have been carried out. The most recent one is LOHAFEX (LOHA – Iron, FEX - fertilization experiment) conducted in 2009.

Terrestrial Sequestration: Some other methods for CO_2 sequestration and storage are also under investigation. Terrestrial sequestration aims at biological amplification of carbon fixation in soil and biota. Increasing forest cover is considered the most appropriate and cost-effective proposition as a means of mitigation of climate change. However, it requires enormous data on carbon stocks, rate of sequestration and soil emission over different land covers. Recent advances in modern biology, including advancement in genomic sciences, provide new methods for enhancement of the photosynthetic reaction rate in plants for CO_2 sequestration. Such genetic approaches are expected to increase crop productivity in the long-run.

Underground Storage: Many new concepts and also being developed for CO_2 sequestration and storage. For example, the use of deep underground formations like saline aquifers and basalt rocks for storage of bulk of CO_2. While saline waters at a depth of 800m or more could safely dissolve CO_2 without contamination of ground water, basalts are expected to provide solid cap rocks and thus a higher level of integrity for CO_2 storage on geological time scales. Basalt rocks react with CO_2 and can convert it into mineral carbonates. Such inter-trappean zones between basalt flows are considered to be most stable. The Columbia River basin in USA has shown encouraging results in CO_2 storage in basalts.

Enhanced Oil Recovery: CO_2 injection as a secondary method of enhanced oil recovery is another promising technology. The CO_2 injected in depleting oil or natural gas reservoirs is expected to increase the viscosity of leftover crude and result in oil recovery. Enhanced oil recovery from oil fields and coal bed methane recovery in coal seams are additional options for CO_2 storage. Business models on these lines are also being developed. However, very little knowledge base exists in these areas and results are still in their infancy. It requires a greater thrust to make CO_2 sequestration commercially viable.

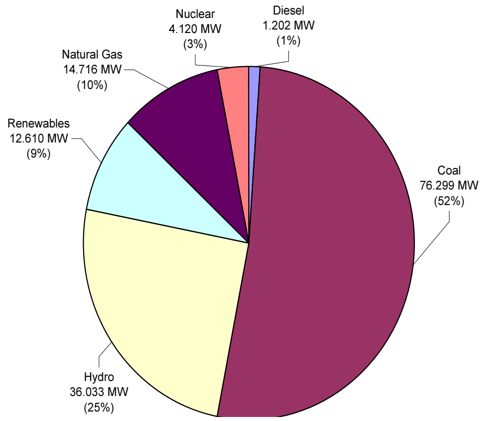
New Breakthrough Concepts: Advanced concepts of CO_2 sequestration are also being examined to achieve cost-effective solutions.

- Application of plasma for decomposition of coal before combustion may lead to an efficient route of carbon free power generation.
- Advances in nano-sciences to find more efficient nano-material compositions for selective capture of CO_2 can offer cost-effective solutions for large-scale separation process in the long run.
- Nano catalysis to enhance the reaction rate of CO_2 with other chemicals and thus help the removal of CO_2 from the atmosphere.
- The above mentioned research on carbon sequestration has focused on capture from large point sources, however, attempts are also being made to capture CO_2 directly from the air. The advantage is that CO_2 emissions from anywhere can be captured, including emissions from mobile sources such as automobiles, airplanes and other diffused sources like agriculture. In addition the capture unit can be located at a favorable sequestration site away from the point source, avoiding the need for extensive CO_2 transportation infrastructure. Global Research Technologies have demonstrated such air extraction device to capture the carbon dioxide molecules from free-flowing air.

The Indian Situation

The energy situation in India is unique. India's share of global CO_2 emissions is 3%, but on per capita basis it is much lower than the world average. Coal is used in 69% of electricity generation (52% of the installed capacity) and 70% of the energy needs of manufacturing and process industries like steel, cement, fertilizers and others are met through coal. The share of different fuels in the total installed capacity in 2008 is shown in Figure 2. India has made tremendous strides in renewable energies. In wind energy utilization the share has increased from almost nil to 9% in the last two decades. India has retained its position as the fifth largest country in the world in wind installed capacity for more than a decade.

The Indian economy is currently growing at a rate of 7 to 8% per annum. India's policy for sustainable development includes: increasing the use of renewable energy, promoting energy efficiency and changing the fuel mix to cleaner sources, controlling energy pricing, pollution abatement and increasing forestation. This is expectsed to result in a relatively low carbon development path. In the energy mix, the share of fossil fuels is expected to be 50- 60%, depending mostly on coal as natural gas supplies are inadequate. In the projected growth in 2031-32 (the installed capacity approaching 800 GW - Integrated Energy Policy of India 2006) the coal requirements for three different scenarios, namely; (i) coal dominant, (ii) reference scenario and (ii) renewable dominant with energy efficiency measures has been



Total Installed: 144,980 MW

Figure 2. Contribution of Various Sources of Energy in the Installed Capacity in 2008.

Source- All India Electricity Statistics, General Review 2008, CEA, Min. of Power, Government. of India.

worked out[3]. The coal demand is expected to grow to 2.0 Bt in 2031-32 for the reference scenario, 2.6 Bt for coal dominant scenario and 1.6 Bt for renewable dominant case.

In India, plans are underway to introduce new capacity additions using super-critical boilers for increased generation efficiency. An advanced coal based Integrated Gasification Combined Cycle (IGCC) demonstration was made way back in 1989 at Bharat Heavy Electrical Ltd.(BHEL) in a pilot plant of 6.2 MW capacity. Coal with up to 40% ash was tested at temperatures of 960 ^{o}C and 1050 ^{o}C at 0.8 MPa in a fluidized bed gasifier. The Indian power industry also has plans to introduce test facilities for oxy fuel combustion using indigenous coal. The National Action Plan on Climate Change has been announced to address global climate change concerns through mitigation and adaptation measures.

CO_2 sequestration research in India started in 2004 through industry and government support. The National Programme on CO_2 Sequestration (NPCS) research has been initiated from the inter-sectoral perspectives of pure and applied research with the participation of academic institutions and R&D laboratories across the country. Since carbon capture technology involves huge costs and high risk, its commercial viability cannot be ensured in the near future. As far as advancement in clean coal technology is concerned, whether IGCC or supercritical power generation cycle or oxy fuel combustion cycle will prove more effective for CCS, is yet to be determined.

Conclusions

The rise in global average temperature is the most contentious issue of our times. Innovations in technology for mitigation of CO_2 need to be made an inclusive process of the growth and development of every country. India has a unique distribution of installed electricity capacity; Coal – 52%, Oil & gas – 11%, Hydro –25%, Renewables – 9%, and Nuclear – 3%. India's policy for economic growth and sustainable development is expected to result in a relatively low carbon energy path. The National Action Plan for Climate Change has been formulated. It has identified eight action areas. The ACBCCS-2009 provided scientific awareness on CCS technology developments.

Since climate change is a global phenomenon and is posing a danger to the existence of the entire world, it requires policy and technology actions by all the nations. The Copenhagen meeting is a unique opportunity in a more than one way. Instead of fixing a uniform cap, the developed nations must come forward to check CO_2 emissions at a scale and speed greater than the developing nations. Individually each country needs to develop an approach for reducing emissions from fossil fuel use through advancements in energy technology and carbon capture research, besides the use of efficient lighting, green buildings and clean technologies such as solar and wind.

Footnotes

[1] The author was the organizing secretary

[2] ACBCCS-2009 News Flier

[3] Integrated Energy Policy, Report of the Expert Committee 2006, Government of India.

World Natural Gas Markets and Trade: A Multi-Modeling Perspective

Edited by Hillard Huntington

This special issue is an important outgrowth of the Stanford University Energy Modeling Forum (EMF) 23 working group. The volume explores nascent modeling efforts to represent international natural gas markets and trade for improving the understanding of key policy and investment decisions. Although formal modeling is not required to describe the growth of liquefied natural gas or the role of spot markets, decision makers can gain powerful insights from these frameworks.

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Special IAEE Support Fund for Students from Developing Countries

IAEE is pleased to announce the continuation of a special program which offers support to students from developing countries to participate in three of the Association's conferences in 2010. The support will consist of a cash stipend of up to $1500.00 plus waiver of conference registration fees for a limited number of eligible students, who are citizens of developing countries (who can be registered as full-time students in programs of study anywhere in the world), to attend either the 33rd IAEE International Conference in Rio de Janeiro, Brazil, June 6-9, 2010, the 11th IAEE European Conference in Vilnius, Lithuania, or the 29th USAEE/IAEE North American Conference in Calgary, Alberta, Canada, October 14-16, 2010.

Application deadlines for these conferences are as follows: Rio de Janeiro Conference – application cut-off date, March 22, 2010; Vilnius Conference – application cut-off date, June 16, 2010; Calgary Conference – application cut-off date, July 29, 2010.

Please submit the following information electronically to iaee@iaee.org to have your request for support considered. Make the subject line of your email read "Application to IAEE Support Fund (mention the conference you wish to attend)."

- Full name, mailing address, phone/fax/email, country of origin and educational degree pursuing.
- A letter stating you are a full-time graduate/college student, a brief description of your coursework and energy interests, and the professional benefit you anticipate from attending the conference. The letter should also provide the name and contact information of your main faculty supervisor or your department chair, and should include a copy of your student identification card.
- A letter from your academic faculty, preferably your faculty supervisor, recommending you for this support and highlighting some of your academic research and achievements, and your academic progress.
- A cost estimate of your travel/lodging expenses to participate in one of the above conferences.

Please note that students may apply for this support at only one of the above conferences. Multiple requests will not be considered. Further note that you must be a student member of IAEE to be considered for this support. Membership information can be found by visiting https://www.iaee.org/en/membership/application.aspx

Applicants will be notified whether their application has been approved approximately 14 days past the application cut-off date above. After the applicant has received IAEE approval, it will be their responsibility to make their own travel (air/ground, etc.) and hotel accommodations, etc. to participate in the conference. Reimbursement up to $1500.00 will be made upon receipt of itemized expenses.

For further information regarding the IAEE support fund for students from developing countries to participate in our conferences in 2010, please do not hesitate to contact David Williams at 216-464-5365 or via e-mail at: iaee@iaee.org

Calendar

3-6 May 2010, Hydrogen Conference and Expo at Long Beach, CA, USA. Contact: Bruce Cole, Conference Coordinator, McNabb Marketing, USA. Phone: 207-236-6196 Email: bcole@mcnabbmarketing.com URL: http://www.hydrogenconference.org/expo.asp

5-5 May 2010, Product Liability at Glasgow. Contact: Elizabeth Jarvis, Power Seminars Ltd, United Kingdom. Phone: 0141 427 0735. Fax: 0141 427 2020 Email: ej@powerseminars.co.uk URL: http://www.powerseminars.co.uk/prd_liab.html

6-7 May 2010, Ocean Energy at Brussels, Belgium. Contact: Conference Secretariat, Green Power Conferences, South Bank House, Black Prince Road, London, SE1 7SJ, United Kingdom. Phone: +44 (0)207 099 0600 Email: info@greenpowerconferences.com URL: www.greenpowerconferences.com

16-17 May 2010, Nano Cement, Steel and Construction Industries Conference at Cairo, Egypt. Contact: Ms. Neveen Samy, Administration Assistant, SabryCorp Ltd. for Science and Development, Egypt. Phone: +20 2 2414 6493. Fax: +20 2 2415 0992 Email: neveen.samy@sabrycorp.com URL: http://www.nanocon.sabrycorp.com/conf/nanocon/10/

May 31, 2010 - June 2, 2010, Master Class 'Developments in LNG' by Energy Delta Institute at Regardz Aiport Hotel Rotterdam, The Netherlands. Contact: Jasper Hofman, Energy Delta Institute, Netherlands. Phone: 0031 (0) 50 5248308 Email: hofman@energydelta.nl URL: www.energydelta.org/nl/mainmenu/edi-programmes/specific-programmes/master-class-developments-in-lng

1-2 June 2010, Caspian Oil & Gas Conference at Hyatt Regency Hotel. Contact: Vladislav Grabovsky, Senior Project Manager, ITE Group Plc., 105-109 Salusbury Road, London, NW6 6RG, United Kingdom. Phone: +44 207 596 5008. Fax: +44 207 596 5106 Email: oilgas@ite-exhibitions.com URL: www.oilgas-events.com

6-9 June 2010, 33rd IAEE International Conference: The Future of Energy: Global Challenges, Diverse Solutions at Rio de Janeiro, Brazil. Contact: IAEE Conference Secretariat, IAEE, 28790 Chagrin Blvd Ste 350, Cleveland, OH, 44122, USA. Phone: 216-464-5365. Fax: 216-464-2737 Email: iaee@iaee.org URL: www.iaee.org

22-24 June 2010, RPGC / 8 th Russian Petroleum & Gas Congress at Expocentre, Moscow. Contact: ITE Group Plc, 105-109 Salusbury Road, London, NW6 6RG, United Kingdom. Phone: +44 207 596 5000. Fax: +44 207 596 5106 Email: oilgas@ite-exhibitions.com URL: www.oilgas-events.com

23-25 June 2010, European Energy Markets Conference 2010 at Comillas University, Madrid, Spain. Contact: Julian Barquin, Prof., Comillas University, Alberto Aguilera 23, Madrid, 28015 Email: eem10madrid@gmail.com URL: www.eem10.com

24-25 June 2010, 3rd International Workshop on Empirical Methods in Energy Economics at University of Surrey, UK. Contact: Lester C Hunt & Jo Evans, Local Organizers, Surrey Energy Economics Centre (SEEC), University of Surrey, Department of Economics, Guildford, Surrey, GU2 7XH, United Kingdom. Phone: +44(0)1483 686956. Fax: +44(0)1483 689548 Email: emee2010@surrey.ac.uk URL: http://www.seec.surrey.ac.uk/Events/EMEE2010.htm

June 28, 2010 - July 2, 2010, The Fourth World Congress of Environmental and Resource Economists at Montreal, Canada. Contact: Conference Secretariat, Universite du Quebec a Montreal, Canada Email: info@wcere2010.org URL: www.wcere2010.org

June 29, 2010 - July 3, 2010, 85th Annual Conference of the Western Economic Association International at Portland, Oregon. Contact: Conference Coordinator, WEAI, Executive Office, 18837 Brookhurst St Ste 304, Fountain Valley, CA, 92708, USA. Phone: 714-965-8800. Fax: 714-965-8829 Email: info@weai.org URL: www.weai.org

8-9 July 2010, 4th Atlantic Workshop on Energy and Environmental Economics at A Toxa (Galicia, Spain). Contact: Xavier Labandeira, Professor, University of Vigo, Facultade CC EE, Campus As Lagoas, Vigo, 36310, Spain. Phone: 986813518. Fax: 986812401 Email: rede@uvigo.es URL: www.rede.uvigo.es/toxa

20-21 July 2010, Biomass '10: Renewable Power, Fuels, and Chemicals Workshop at Grand Forks, ND. Contact: Kari Gagner, Communications Associate, EERC, University of NorthDakota, 15 North 23rd St, Grand Forks, ND, 58202, USA. Phone: 701-777-5174 Email: kgagner@undeerc.org URL: www.undeerc.org

25-28 August 2010, 11th IAEE European Conference: Energy Economy, Policies and Supply Security: Surviving the Global Economic Crisis at Vilnius, Lithuania. Contact: David Williams, Executive Director, IAEE, 28790 Chagrin Blvd., Ste. 350, Cleveland, OH, 44122, USA. Phone: 216-464-5365. Fax: 216-464-2737 Email: iaee@iaee.org URL: www.iaee.org

August 29, 2010 - September 3, 2010, 9th International NCCR Climate Summer School: Adaptation and Mitigation: Responses to Climate Change at Grindelwald, Switzerland. Contact: University of Bern, NCCR Climate Management Centre, Hringerstrasse 25, Bern, CH-3012, Switzerland. Phone: +41 31 631 31 45. Fax: +41 31 631 43 38 Email: nccr-climate@oeschger.unibe.ch URL: http://www.nccr-climate.unibe.ch/summer_school/2010/

22-23 September 2010, BIEE 8th Academic Conference at St Johns College, Oxford, UK. Contact: BIEE Admin Office, British Institute of Energy Economics, United Kingdom. Phone: + 44 01296 747916 Email: admin@biee.org URL: www.biee.org

27-29 September 2010, Hydro 2010 - Meeting Demands for a Changing World at Lisbon, Portugal. Contact: Mrs. Margaret Bourke, Coordinator, Hydropower & Dams, PO Box 285, Wallington, Surrey, SM6 6AN, United Kingdom. Fax: 44-0-20-8773-7255 Email: mb@hydropower-dams.com

5-7 October 2010, 2010 Coal Market Strategies at Tucson, Arizona - JW Marriott Starpass. Contact: Teresa Coffer, American Coal Council, 1101 Pennsylvania Ave. N.W., Ste. 600, Washington, DC, 20004. Phone: 202-756-4540 Email: tcoffer@americancoalcouncil.org URL: www.americancoalcouncil.org

6-7 October 2010, KIOGE / 18 th Kazakhstan International Oil & Gas Conference at Intercontinental Hotel, Almaty. Contact: Vladislav Grabovsky, Senior Project Manager, ITE Groupl Plc., 105-109 Salusbury Road, London, NW6 6RG, United Kingdom. Phone: +44 207 596 5008. Fax: +44 207 596 5106 Email: oilgas@ite-exhibitions.com URL: www.oilgas-events.com

14-16 October 2010, 29th USAEE/IAEE North American Conference: Energy and the Environment: Conventional and Unconventional Solutions at Calgary, AB, Canada. Contact: USAEE, 28790 Chagrin Blvd Ste 350, Cleveland, OH, 44122, USA. Phone: 216-464-2785. Fax: 216-464-2768 Email: usaee@usaee.org URL: www.usaee.org

October 31, 2010 - November 3, 2010, 9th International Oil & Gas Conference and Exhibition. at New Delhi, India. Contact: U.N Bose, Petrotech-2010, Petrotech, C/O Office of GM (HR) – Head Coordination, ONGC, 8th Floor, Jeevan Bharati Building, 124 Indira Chowk, New Delhi, Delhi, 110001, India. Phone: +91-11-23301220 Email: technical@petrotech.in URL: http://www.petrotech.in

6-7 December 2010, 2010 Coal Trading Conference at New York, NY. Contact: Teresa Coffer, American Coal Council, 1101 Pennsylvania Ave. N.W., Ste. 600, Washington, DC, 20004, USA. Phone: 202-756-4540 Email: tcoffer@americancoalcouncil.org URL: www.americancoalcouncil.org

February 27, 2011 - March 2, 2011, Nanotech Insight at Cairo, Egypt. Contact: Ms. Neveen Samy, Administration Assistant, SabryCorp Ltd. for Science and Development, Egypt. Phone: +20 2 2414 6493. Fax: +20 2 2415 0992 URL: http://www.nanotechinsight.net/conf/nanoinsight/11/

Publications

Weather Risk Management: A Guide for Corporations, Hedge Funds and Investors, Kenny Tang (2010). Price: £125.00. Contact: Risk Books, Haymarket House, 28–29 Haymarket, London, SW1Y 4RX, UK. Phone:44 (0) 870 240 8859. Fax: 44 (0) 20 7484 9797. Email: books@incisivemedia.com URL: http://riskbooks.com

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