Proceedings of the China-India-US Workshop on Science, Technology and Innovation Policy

Section VIII - **Rapporteurs' Reports**

Contents

Session I – Inaugural
July 7, 2008, 6:00 – 8:00 pm:

Chair, ***Dr. K. Kasturirangan,*** Director***,*** *National Institute of Advanced Studies*

Rapporteurs: ***Dr. Bethany Lyles Goldblum,*** *University of California, Berkeley;* ***Dr. Sonkia Gupta****, Indian Institute of Technology,* Madras

Key issues: energy generation, climate change, global warming, global economy, multinational research collaboration

The China-India-US Science, Technology & Innovation Policy Workshop, the first trilateral meeting organized by the Indo-US Science & Technology Forum, began with a plenary inaugural session chaired by **Dr. K. Kasturirangan**, Director of the *National Institute of Advanced Studies* (NIAS). NIAS, an institution founded on a trilateral partnership by industry, government and academia, is dedicated to finding scientific solutions for India as well as the world. NIAS has been in existence for 20 years and provides a nonpartisan platform for discussion, operating under the ideology that "There is no problem for which science cannot make a contribution." It is the vision of Dr. Kasturirangan that the workshop will contribute toward strengthening the public-private partnership in research, given that future progress in science & technology (S&T) demands collaborative research.

Dr. Norman Neureiter, Director of the Center for Science, Technology & Security Policy at the *American Association for the Advancement of Science*, emphasized the importance of developing cooperative collaborative scientific relationships between China, India and the US, stressing that the development of S&T in these countries will define the shape of the world to come. The US-China collaboration in S&T, which dates back to the early 1970s, provides a precedent for successful multinational research collaboration. Initially, forty concrete collaborative proposals were outlined which have resulted in sustained and successful scientific cooperation between these two countries for many years. Given the rising energy demand in India and China, it is the imperative that China, India and the US engage in multinational collaborative research and innovation in this key sector, among others, and it is the purpose of this workshop is to catalyze that cooperation.

Professor Mu Rongping, Director-General at the Institute of Policy & Management of the Chinese Academy of Sciences, recognized the importance of a global view of S&T, as well as innovation capacity with regards to such crucial issues as energy security, climate change and global transformation. Rongping called for a linkage between the natural and social sciences to address these vital concerns via an integrated approach, incorporating S&T as well as government policy. He further encouraged utilizing the Workshop as a platform for China-India-US collaboration.

Luce Professor of Science, Technology and International Affairs at *Georgetown University* in Washington, DC, **Prof. Carl Dahlman**, provided a comparative overview of the role of S&T in the national innovation systems of China, India and the US. In exploring global trends, Dahlman noted that the term, "national innovation system," is somewhat of a misnomer given that much research is being done across national barriers with multinational collaborations playing a crucial role in cooperative research. From a broad perspective, analysis suggests a global increase in investments in knowledge, not just machinery and equipment, a harbinger of positive change. According to **Dahlman**, the US continues to lead in S&T research, while China is making rapid progress in establishing the infrastructure and human resources necessary for S&T research and innovation. In contrast with India, China is well integrated into global research networks in terms of knowledge acquisition. China is currently unveiling an unbundling of production while India reveals an unbundling of services. Projecting at 2000-2006 growth rates, China and India are "set to be the largest and second largest economies in the world by 2018."

In a summary of the key policy issues in S&T for the three countries, **Dahlman** noted that China should improve research quality and production efficiency, India should push ahead towards the inception of improved infrastructure and human resources, and the United States should increase the stock of students in the fields of science and engineering, end complacency, and strengthen the attractiveness of research and development under the aegis of multinational collaborations. The challenges in S&T faced by these countries include environmental constraints, such as food shortages and energy crises, as well as overcoming poverty and addressing terrorism and pandemic diseases. Among key international issues are rising energy demands, which in China and India are largely being met through coal-fired power plants. Current coal power technologies represent a serious challenge for global warming, requiring clean coal scientific innovations, a situation that must be addressed through collaborative strategies.

Professor C.N.R. Rao, National Research Professor at the *Jawaharlal Nehru Centre for Advanced Scientific Research* and Science Advisor to the Government of India, provided an animated keynote address on the role of S&T in India, encouraging the recognition of "science as the foundation for S&T." He emphasized that the manufacturing of consumer goods in India and China should not be confused with innovation – still largely dominated by the US – and claimed that increased goods production is less desirable than increased knowledge. Despite some murmuring and lamenting by US colleagues, **Rao** felt strongly that, at present, the United States is leagues ahead of India and China in S&T research with the latter countries requiring sustained quality enhancement in order to compete. He cited that over 60% of global scientific research publications are from the United States and that within the United States, prolonged innovation at all levels of education has allowed for small universities and research laboratories to evolve into global centers for excellence in S&T. Rao noted that a 2007 report by the US National Academy of Sciences, entitled *Above the Gathering Storm,* provides recommendations for the future of S&T in the United States, including:

- improved K-12 science education,
- cultivation of a long-term outlook, and

- and establishment of the US as the most attractive site for higher education.

He suggesting that the implementation of these recommendations would benefit India and China, as well.

Rao also noted extraordinary recent progress by China, including an explosion in the number of scientific publications; China now dominates in the quantity of research publications in the field of material science. Chinese nationalism contributes positively to achieving higher standards for research in China, whereas this patriotism is lacking in India. India is further plagued by the poor quality of its science and education sector. However, India has committed more money in science and engineering in the last four years than in the entire history of India combined and matriculated 600,000 engineering undergraduate students last year alone. It is hoped that the creation of new infrastructure and human resources will facilitate the formation of the required critical mass for success in the fields of S&T in India. In conclusion, **Rao** suggested a view of the future in which the rise of the large middle class in China and India will drive consumption in the global economy.

The Honorable Union Minister for Science, Technology and Earth Sciences of the Government of India, **Shri Kapil Sibal** provided the inaugural address for the Workshop. Minister Sibal began by noting a host of new global concerns for the 21st century, including soaring oil prices, global warming, climate change, food shortages, rising poverty and energy shortages, which require global strategies to resolve local issues. He claimed that the stock phrase "Think globally. Act globally." is insufficient to address these issues. He went on to state that it is not even enough to "Think globally, but act locally," because many solutions for the West are not affordable as far as India is concerned. The affordability of proposed solutions is a critical factor, highlighted by Minister Sibal as he put forth the question, "What is the cost to help a village in India?" To be effective, solutions must fulfill the necessary parameters of accessibility, affordability and excellence. An example of successful technology that meets these criteria is the fuel-efficient Tata Nano, the world's cheapest car. **Minister Sibal** encouraged workshop participants to "Think locally. Act locally." Many areas don't have the finances, resources or technology necessary for self-provision. Thus, global success in S&T will be limited to those who can meet the requirement of affordability.

India needs education for their people and the world needs manpower. By collaboration, the world can move to address the problems we are now facing. **Minister Sibal** claims that if India is given the resources, the world will see a mushrooming of talent. Despite a nearly 300 percent increase in funding for research and education in science over the past four years, India has not yet been able to fully realize international opportunities for investments in education. Currently, state institutions, without a national mission (yet requiring national permission), have been a hindrance to progress in India. **Sibal** claims that for institutions with appropriate merit to emerge, a structure must be put in place to free these institutions from unnecessary constraints and regulations, giving them the freedom to collaborate as well as to float their own degrees. Essentially, more decision-making powers must be devolved to the states to facilitate the creation of world-class

research institutions. **Minister Sibal** stated that India has had robust growth in technological areas, such as information technology, which does not require sophisticated hardware, but has been a victim of technology denial regimes that impede advancement in other sectors. Technology constraints have limited progress in India and the Indo-US nuclear deal represents a means to do away with these denial regimes. The deal opens doors of international cooperation, not only in the nuclear energy sector, but also in many technological areas for India.

Given India and China's demographic strength and economic growth, it is clear that these two countries will play a significant role in shaping the coming world. Further, the global nature of problems such as climate change, epidemic diseases and energy shortage concerns require strategies to address these issues that are global in nature. **Minister Sibal** closed by stating that the global community has a financial as well as fundamental interest in the growth and prosperity of China and India and the only way progress can happen is via collaborative science, technology and innovation.

Session II – Power Generation by Coal

July 8, 2008, 9:00am – 12:15pm

Chair, ***Dr. Arcot Ramachan****, The Energy and Resources Institute*
Presenters: ***Prof Wang Yi****, Institute of Policy and Management, Chinese Academy of Sciences*; ***Dr. James R. Katzner****, Exxon Mobil and Massachusetts Institute of Technology (retired)*; ***Dr. R.R. Sonde****, Thermax Corp., Ltd.*

Discussants: ***Prof. Duan Yibing****, Institute of Policy and Management, Chinese Academy of Sciences*; ***Dr. Susan Su****, U.S. Patent and Trademark Office*

Dr. Ramachandran opened the session by noting that design is the key to innovation. Design is often neglected because the focus tends to be much more on research and development (R&D). He went on to explain that innovation through design needs to be more strongly emphasized.

According to **Dr. Ramachandran**, "King Coal" is plentifully available indigenously [in India and elsewhere] and will easily last for the next 100 years or so. In recent years, coal has been coming back into the picture as a main source of energy to meet the needs of developing countries, and the effect on the environment through increased greenhouse gases is not sustainable. He called for a need to develop clean technologies to ensure that CLEAN coal will be available for power solutions for future generations.

At present, the world consumption of power is 15 terawatts of power, and this is set to increase to 30 terawatts by 2050. Based on these numbers, Dr. Ramachandran posed the question: how can India have a sustainable energy system? He went on to explain that neither coal, oil, nuclear energy, nor natural gas will ever fully replace one of the other energy sources completely. He suggested that rather, it is likely that each will have an impact on the other – that is, they will only supplement one another. This will continue at least through this century. Additionally, the concern over peak oil is more than justified in his view, estimating that oil might feasibly reach 200 USD per barrel by end of 2008.

Dr. Ramachandran pointed out that no new nuclear power station has been built in the US in the past 30 years. In Japan, Korea, and India to some extent, there have been advancements on promoting nuclear power. In parts of Europe, however, where public acceptance is arguably higher, and certainly necessary (France has ~70 percent power generated by nuclear but rest of EU needs to be on board) these seems to be a model from which to emulate.

Dr. Ramachandran noted that there are 80 billion tons of Coal in India and that even with increased demand and consumption, coal reserves in the country will last for next century. He raised the issue that R&D for clean coal technology has not happened at the rate at which it should. It has been receiving considerable more attention recently, however, it is still not enough. There is a need for more of a concerted effort in this area for R&D.

The key, explained is to encourage the utility industry to keep up with the trend of increased power efficiencies. Some questions to consider include: what are the technologies for the longer term? What are the next generation technologies likely to be: fuel cells? Integrated Gasification Combined Cycle (IGCC)? R&D efforts need to meet short, then medium, and eventually long term development goals because it is clear that coal will be remain an important power generation source in this century. In the longer term, research must be supported in the areas of carbon sequestration, capture and storage of carbon dioxide etc., for the reduction of emissions. Unfortunately, these technologies do not exist for power plants at the present time, but are only available for smaller scale facilities. Despite declining investment in clean technologies, next generation technologies have been funded most recently.

Dr. Ramachandran explained that governments, utilities providers, manufacturing facilities, and research institutions must work together to deal with high ash coals in a sustainable way. In India alone, "energy" is spread across five separate ministries, so a call for a more coordinated effort is needed at the national and international levels.

To this end, it is imperative to cooperate internationally to meet the challenges posed by global warming and industrial development. Dr. Ramachandran warned that "we cannot leave it to the market" to save our planet for future generations. He explained that we must move in the direction of international collaboration to work on sequestration and carbon capture and storage.

Dr. Ramachandran ended his address quoting economist Jeffrey Sachs: "all this will require a new global approach to problem solving... new budgetary incentives... particularly in developing countries. Rich countries should support these activities heavily... this will be an exciting time for scientists and engineers facing the challenges of global warming and sustainable development"

Dr. Ramachandran then called on **Prof. Wang Yi** to give his presentation, entitled, "Clean Coal-based Power Generation Technology Option in China"

Prof. Wang began by presenting data on the role of clean coal technologies in China . The country's energy consumption in 2007 was 2.65 billion tce and coal accounts for 69.5 percent of that. In terms of electricity generation, China's annual rate was 19 percent for 2007 with 3256 Tera Watt (TW) hours in that year alone. Professor Wang noted that of that, thermal energy accounted for 83 percent electricity generation. He noted that the installed capacity of power generation in China was 713.3 Giga Watts (GW) in 2007 and that coal based power was 78 percent. Professor Wang predicted that over the next 10 years, the growth trajectory will be the same.

According to the presentation, 95 percent of China's power plants are coal-fired, the total installed capacity of which has been increasing rapidly. He noted that not only is China one of the biggest coal consumers but it is also one of largest coal producers in the world as well, indicating that in 2006 China accounted for 38.5 percent of global coal consumption and production. Also of note is the fact, according to Professor Wang, that

China, the US, and India combine to account for approximately 65 percent of the world consumption.

With respect to the issues caused by coal consumption and production, Professor Wang noted that local air quality such as Sulfur Dioxide (S02) emissions, acid rain, ground subsidence, etc., can all be explained as negative consequences of coal. Ecological issues like ground subsidence and CO2 emission are attributable to coal production at a rate as high as 75 percent. Also, to a similar end, the transportation stress is also important to consider.

Chinas has 12 percent of the worlds known/proven coal reserves, 80 percent of which is in Shanxi, Shaanxi, inner Mongolia and Xinjiang provinces (all in northern China). Of importance to note, Professor Wang indicated that China's energy demands are expected to reach 6.5 billion tce by 2050 and that China will rely on coal as a main source of energy production for a long time to come (he estimated 30 – 50 years). At present, there is a low power: capital energy consumption in China (2 tce/year compared to the US which is 11 tce/year). Rapid economic growth and industrialization however, (8-10 percent/year) combined with the rapid pace of China's urbanization will likely change this percentage. He noted as well that rural commercial energy supply is also increasing.

With direct respect to government commitment in China, Professor Wang noted that in China, there should be a call for mandatory targets to be put into place for reaching energy efficiency targets by 20 percent, and that S02 emissions should decrease by 10 percent so as to be able to counteract the negative effects of coal power and the impact of coal use on climate change. Interestingly, Professor Wang illustrated that China's coal-based power generation technology development is occurring rapidly under the rubric of increased energy efficiency and environmental targets as follows:

- supercritical units – almost 100 percent locally made
- Ultra supercritical unit – 80-90 percent locally made
- Investment cost 3800-3900 RMB/kW, less than that of same unit in the world, competitiveness.
- 60 percent of newly added SC and USC unites are in China.

Professor Wang indicated that IGCC tends to have out perform both Super Critical (SC) and Ultra-Super Critical (USC). He explained that the advantages importantly include a higher efficiency by 43-50 percent. Currently, IGCC is on an industrial scaling demo stage and there is at present, a need for supporting policies to be put into place. The combination of IGCC with a polygeneration system development is needed in order to reduce the overall cost as well as provide what could ultimately be considered to be a more comprehensive approach to coal power generation. Polygeneration is a system that combines coal gasification, water/gas shifting, and then finally sulfur and carbon dioxide removal. It is a comprehensive system that can produce methanol, for example, and the benefits include high efficiency, easy pollution control, CO2 capture, and additionally, is a good source of H2 for fuel cells (as well as offering flexible feedstock: coal, petroleum, etc). There is a low overall cost as well for polygeneration and importantly, the technology components are mature as well (note: coal gasification is common in

ammonia production). Professor Wang noted that polygeneration as a concept in the chemical industry has always used in China, and notably asks: what is new and how can polygeneration development be promoted? What is needed, he explained is a policy framework that is conducive to polygeneration applications (such as easy access to grid connection, tax breaks, removing sectoral barriers, financial incentives, etc). A solid action plan/roadmap for reaching commercial scale applications is needed and might help to speed up the IGCC and polygeneration pilot projects for realizing leapfrog development from SC/USC. Professor Wang finished his talk by indicated that clean coal use based on gasification and polygeneration is a large and necessary component of such strategies for China's long-term development goals.

The next presentation was given by **James Katzer** formerly of Exxon Mobil and Massachusetts Institute of Technology. The title of Dr. Katzer's talk was "Improving Coal-Based Power Generation – a US View" and began with a quick overview of the technologies currently in use.

According to the presentation, coal-based electricity generating technologies are considered mature technologies, and are in practice on a large scale, however, further emissions reductions are desirable (and needed). Furthermore, cost effective CO2 capture and storage needed is badly needed as well as the creation of new pathways to innovation and commercialization to meet the challenges of energy demand in future generations.

Dr. Katzer gave the following metrics as a baseline: PC Thermal Efficiencies – sub-critical unit (33-37 percent HHV), supercritical unit (37-42 HHV), ultra-supercritical unit (42-45 HHV). He explained that the US has about 330 GW of coal power, which generates over 50 percent of the electricity in that country and that in the US, the average generator efficiency is 33 percent. Further, the US has no ultra supercritical, but Japan and the EU, where there tends to have more of a policy push to move in that direction. There are very low emissions at the ultra supercritical plants and thus, those tend to be very clean, but the remaining problem is that they do produce a large amount of CO2.

With direct respect to research & innovation, Dr. Katzer explained that new technology development is necessary. Further, the classical framework in the US, where research occurs at universities tends to yield results that stay on a small scale. While Dr. Katzer did point out that the Department of Energy (DOE) does support technology R&D in universities as well as in small companies (entrepreneurial research) and equipment makers, he noted that the US has only built a couple of coal plants a year in the past few years. Also important to note, Dr Katzer explained that DOE supports national laboratories, which are the main technology base in this area. Most of this research has been on emissions and making coal cleaner.

In the presentation, Dr. Katzer gave the example of the Electric Power Research Institute (EPRI). EPRI lost their funding and has essentially become a technology service organization. Consequently, the main support comes from DOE and thus, DOE is "in the lead" according to the presentation, meaning that they develop/articulate strategies, supports demonstration activities, national labs technology support base. In addition, equipment manufactures/builders: boiler makers, turbine makers, engineering companies,

etc and power companies are ultimately where the technologies are applied and thus, play an important role here. One thing that was stressed in this presentation was that innovation in this area is key. It is significant in terms of allowing for the improvement of most of the technologies used and needed in technological upgrading, and play a central role in the learning scale for scaling up.

Dr. Katzer mentioned specifically, flue-gas desulfurization, which, over time has experienced a general decline in cost and has come down by an estimated 40 percent since 1976. Efficiencies are now exceeding 99 percent (99.4 sulfur removal for high sulfur coal in the US). Also of importance, catalytic NOX reduction (SCR). To this end, the first commercial scale operation occurred around 1980 in Japan (1983 for German commercial installation and 1993 for the US). It is important to note that in this area in particular, a lot of innovation has occurred and this is significant because the end result is that, innovation led to a significant decrease in cost for the technology application. Currently, only 15 percent of coal capacity has SCR in use, and it is not accurate to consider SCR to be a major player at present. In terms of emissions performance, Dr. Katzer commented that PC emissions control technology is very effective today, and that achieving greater than 90 reduction for all emissions and greater than 99 percent reductions for particulates and Sox. Further, PC emissions control technology continues to improve and there still exists further emissions reductions potential (He indicated that this only costs 1.05 cents).

For Dr. Katzer, the next major challenge in the area of clean-coal production is carbon dioxide. In the US, the main player again is the DOE, specifically The Clean Coal Program, but he noted that there is a need for a commercial scale demonstration. Today, no clear forward vision exists and there are also multiple challenges that must be worked out. For PC, the most pressing issue is cost and it is unclear if the cost can be reduced enough for this to ever really be a viable application/solution. For Oxy-Fuel PC, there needs to be a commercial scale demonstration, and while this is coming along, and arguably should reduce cost of CO2 capture, it is clear through the presentation that IGCC should still be considered the best candidate at present. For IGCC, if it is possible to add additional technologies, it can be captured and stored in geologic formations and is a relatively straightforward process. He noted that there are plenty of sites in the US for this to happen, and that the capacity for this is enormous compared to the amount of CO2 that is projected to be used and stored. The big issue is capture for CO2 – the costs are about half for IGCC than for PC. If we get on learning curves, and start doing innovative research on the area, than it might be possible to decrease cost to 1.5 cents per hour.

With regard to the "way forward" Dr. Katzer explained that what is needed in the US (and the world) is to aggressively start integrated demonstration of generation with CCS in representative well characterized geologies with full monitoring capabilities. Simultaneously, it is necessary to establish required permitting legal, operational, and closure criteria associated with CCS as well as to establish uniform and enduring policies that encourage economic CCS applications. The successful completion of demonstration program which could serve to establish the technology and start moving it down the learning curve for innovation will lead to increased efficiency improvement, and cost reduction later on. If successful, according to Dr. Katzer, this will generate political and

public confidence in the safety and efficacy of geologic storage and will additionally provide a robust set of technology options ready to apply when society decides to manage CO2 emissions from power generation and other major stationary sources. In his own words, "doing this is essentially buying an insurance policy for the future... society is buying a insurance policy for future needs."

He concluded by suggested that there must be a way to move forward working together in an integrated way. Coal and geologic differences need to be kept in mind but at the basic level the needs and technology will be the same and have a lot in common.

The final presentation in this session was given by **Dr. R.R. Sonde** of Thermax, Corp, Ltd. Dr. Sonde's talk was titled "Power generation from coal in India: Research and Technology Platforms in Electricity Generation." He began by explained that when you juxtapose the workshop framework goals with power generation from coal – there is an immediate disconnect – which is historical in nature. The problem, according to Dr. Sonde, is that the technology has been developed for different platform altogether. Coal was "cheaper than mud" and as a result, the technology used to process it, was pedestrian as coal plants needed to be built and continue to run! The entire technology has remained in bringing down the cost – increasing power – decreasing cost. What we need now is to bridge the gap between the existing technology and trying to bring advances in the technology with meeting the overall global strategy for climate change together.

With direct respect to the Indian electricity markets, Dr. Sonde explained that the business environment is emerging due to the sectoral reforms. At present, cost regimes are generous when compared to normative performance levels, and generally speaking, in India, it can be explained as a sellers market. From there, he explained that over the past 4 to 5 year period a regulatory regime in which norms were tightened created what can be described as a controlled market. He noted that this is a process that every state has gone through globally as they develop, and that the final stage of making a deregulation regime – with no norms and a heavy impact of market forces will eventually give way to what can be best described as a buyers market. Under that condition, India is entering into a very interesting period where success of these particular reforms are not only vital in India but to the entire globe. He says that "only the biggest and cheapest can survive" and suggests further that the best and cheapest will never coalesce unless you have the best available technologies.

The unbundling of SEBs into generation, transmission, and distribution is necessary as well as the establishment of a regulatory body at the central and state level, privatization of distribution and captive coal mining and UMPP. The enactment of the Electricity Act in 2003 essentially made electricity a commodity and thus, a market driven system was introduced with wholesale trading, merchant power supply, power exchange, and competitive tariff based bidding.

According to this presentation, R&D is necessary for bridging the gap between the North and South, and that the technology gap must be closed worldwide. Worldwide, it is important to note that technology development and engineering are two separate activities. There is an inceptive challenge when dealing with new technology issues which

tended to fall onto engineering in absence of any technology platforms and thus, countries like India and China did reasonably well through this route but there were pitfalls in this approach. Most notably, "R&D did not percolate at a fundamental level." Further, there was a missed opportunity followed by systemic distortions in terms of the focus getting shifted to keeping things running – not innovating and improving. A focus on equipment multiplication, electricity perceived as an input, availability of easy imports, and a low focus on T.D. development, imported designs were implanted.

Dr. Sonde explained emphatically that "simply relying on 'cheap labor' in India and China is not really international collaboration." To this end, he reminded us that coal based capacity of utility plants will be 200-400 GW in 2030. EIA projections are much lower for growth of coal based capacity in India, at only 160 GW by 2030 with an annual growth rate of 3.3 percent compared to China's 4.3 percent GW by 2030. Of central importance here as well, is the issue of coal quality, which is extremely poor in India. Indian coal is a benign coal meaning that the sulfur content is low (< .4 percent) and that it is high ash.

According to Dr. Sonde, India's Vision with regard to coal is to expand power generation at a low cost while enhancing the country's energy securing and reducing impact on local and global environment. The immediate technological solutions required for enhancing efficiencies of existing plants is a first step. The long term goal is polygeneration. The "robotic edge" will help in terms of faster maintenance, faster inspections, remote monitoring, and high quality inspections. The Ash based problems need to be addressed in India. He called for a technology roadmap to develop India centric clean coal technologies with a view to produce cheap, reliable, and green power. Dr. Sonde noted that India needs global experience and that this hasn't been so effective for supercritical technologies. Ultra-supercritical will be even more different/difficult. India should not be allowed to reinvent the wheel – the technology is there globally – the leaders need to share what they have with India – to bring their knowledge to the table and India doesn't have to go through the learning curve all over again. Ultimately, he explained that UCG is a good clean coal technology solution that India needs to look at most closely/seriously.

Additionally, there are very strong sentiments on CCS technology in emerging economies such as India. The principle reason is that there is too much talk on CCS with precious little action on the ground in developed countries. Apart from Slipner, all other projects are CCS-EOR which is truly not a CCS option and may not be an option where oil reserves are limited. Till date no coal based CCS demonstration plant exists. More than technology, at present, the central barrier is the costs which deters deployment of CCS even in the developed world.

Dr. Sonde posed the following challenge for India and the developed world, highlighting the Indian perspective that technologies whether retrofits to existing facilities or new power generating stations required to be developed with quite a bit of customization to Indian situation. He explained that normal technology transfer processes in all these areas are hugely expensive and adds substantially to cost. Thus, development through an indigenously created route can only be possible where there is a large S&T base that takes

a long time to mature. On the global perspective he posed the question: why should the developed world should develop or even customize technologies to suite Indian conditions?

To conclude, Dr. Sonde quoted Paolo Coelho: "when you really want something to happen, the whole universe conspires to help you to achieve your dreams" – The Alchemist.

DISCUSSION:

Duan Yibing from the Institute of Policy Management was the first discussant to address the panel with regard to what he labeled the "adoption of clean coal technologies in power generation – balancing economical and environmental effects." In his comments, he raised the issue of energy and the environment at SED in both China and the US. He stated that electricity production ranks as the number one goal and further, that the five initial goals that have been established are clean and efficient and secure electricity production and transmission. The target areas are: (1) clean water, (2) clean air, and (3) clean efficient transportation.

Professor Duan noted that potential global CCT Market is in western nations where there is more advanced technology while there is less in terms of domestic application markets. He called for an agreement on emissions regulations in order to push forward CCT adoption on a global scale. He went on to concluded his remarks by suggesting that global challenges need global commitment – global actions, and emissions regulations.

Susan Su from the US Patent and Trademark Office opened her remarks with a brief point on polygeneration, noting that it seems to be the most advantageous and posed the question as to whether or not it would be shared (by the Chinese) with US and India and beyond? It seems that the US and India are still focusing more on IGCC and next generation technologies according to Dr. Su.

Her second point had to do with innovation, or rather, the lack of innovation in India and China, which she noted had been one of the central foci of the day's discussions. She noted that a repeat theme from the talks preceding her raised the issue of China and India playing catch up to the West. Dr. Su made the assertion that coal power is not a very "sexy" topic for the younger generation and went on to suggest that while the world is so concerned about environmental impact, and at the same time, graduate students might want to limit their environmental focus on biomass, solar or wind power. Thus, she posed the question: how can we generate interest from students so that the research can be continued rather than building on existing innovation? To be able to garner this interest will help to generate funding and focus on the research which seems to have been lacking.

Finally, regarding this approach of thinking locally and acting locally - we certainly recognize the differences in coal reserves, political and societal and economic differences will have an impact on how technologies will be developed. Dr. Su asked whether a top-down government driven approach might be easier to implement – or whether the

solution might come from the bottom-up, based on initiatives by scientists or concerned citizens. Ultimately, she posed the question: is it possible to generate enough interest to sway the opinions and set the agendas of government or, should/ must there be a different approach for each country?

In response to the questions and points posed by the two discussants, **Dr. Wang** was first to respond. He explained that there is no one technology, but that there will always need to be a system in place that relies on several technologies at the same time. In the north of China as compared to the south of China, he noted that there are different resources which ultimately means that there will need to be different paths to technology development. He noted that there was a need to develop a strategy and specific priorities, and that it was imperative to decide how best to integrate these technologies together for polygeneration. Hopefully China can share that knowledge with India, the US and the world.

Secondly, Dr. Wang stressed the fact that power generation in China must be diversified. The focus shouldn't be just on one technology. Nuclear is only 1.2 percent of power generation there. He suggested further that by the year 2020, China will be better able to take advantage of the full capability of new technologies available globally and that in China, they are really only working with coal-generated power at the moment.

With respect to the top-down/bottom-up debate, Dr. Wang noted that China has both bottom up and top down approaches in place and that there are mandatory targets set by central government for example. There are many companies working in this area and power companies that are run by the central government have a particular drive to promote clean coal technologies. Chinese companies are strong competitors in supercritical and ultra supercritical. He importantly emphasized the fact that nearly all foreign companies have started to pull out here because China is so strong.

The second person to respond to the issues and questions raised by the discussants was **Dr. Katzer** who pointed out that certainly it is true that coal and coal power is not generally perceived to be sexy by young researchers, but it is possible to stimulate interest. He seemed to be of the belief that when there is a long term objective/goal that can typically be sufficient for attracting talented individuals.

He then explained that there needs to be one centralized funding effort and a substantial increases as well. Dr. Katzer commented that on the US side, "the era of cheap oil" allowed for coal research to wither significantly and that while DOE has continued a support program to a select few universities, an expansion in this area will help considerably. Dr. Katzer did acknowledge that young technologists are very interested in green technology development and said that with a clear vision of where we are going, the US will be in a better position to garner interest by top talent. At present, he noted, coal research is still very much considered to be a government supported necessity at this point in addition to the general understanding that this research is done for the betterment of society. He explained that the government needs to be supporting these efforts until it is ready for large scale development. He strongly advocated for bottom-up action, pushing for policy interest to be generated. Ultimately, he concluded that policy makers will not

make the hard decisions they need to make without this kind of grassroots mobilization and that everything else will fall into place once that happens.

Importantly also, Dr. Katzer said that in the future there will be a need for all types of power generation and that as a result, not all young technologists need to make a move to coal research but without support for coal research they will go where there is most opportunity for funding and success.

Finally, **Dr. Sonde** briefly addressed the issues and questions raised by the two discussants. He reiterated from his initial remarks that coal technology is not considered different technology and that is why there is a problem. What is required is not to set up a center, but the integration of various individual components. In his opinion, centers of excellence should be set up to do this. He explained that what is truly needed is for there to be a catalyst, and gave the example of nano catalysis, which he explained can be used to excite the younger generation. He suggested that "they should be excited by the prospects of helping future generations" in terms of achieving sustainable development goals.

Dr. Blanpied asked a question of the panelists with reference to the Infosys model of education and outreach. He asked whether their program, which is intended to change the curricula, is inspiring or not, and whether there is a lesson that can be learned from Infosys regarding how to generate similar programs. Dr. Blanpied asked for coal technology – what is the feasibility of companies around to the world to motivate young people through motivating their professors? It seems that this is an area where emphasis on social responsibility might make a considerable difference.

The next question raised was from **Dr. Mu**, who asked: in the long run, what kind of substitute technologies will compete with present clean technologies? Dr. Mu said "I prefer clean technologies that mainly focus on and utilize clean coal for chemical industry for example" but then went on to say that we cannot rely on a single resource – we need to diversify. CCT should be combined with renewables – fuel cells, for examples. He also raised the problem of using food for energy is also problematic and important.

Following Dr. Mu, **Dr. Suttmeier** asked a very interesting question regarding the impact of water in CCT. H asked specifically: is water a significant factor in clean coal technologies – especially considering the water constraints in India and China – and even in the US. Secondly, with regard to the issue of IPR – what is the extent to which you see conflict over IP as a major hurdle to international collaboration? Are there new innovative schemes for managing IPR? Can governments band together to assume costs of licensing?

In response to this question, the panelists concurred that water is certainly a very important issue and perhaps will always be an issue. It is a large issue with coal plants today, and water must be recycled. Water and energy are two most crucial challenges of the coming decade. Water is very important in China and India. IGCC can save water significantly but for power generation it is still an obstacle. Lack of water is a problem. Water productivity should be a target goal to be set as well.

IPR – always complex. IP costs are not so large, however, in the overall scheme of things. They don't cause significant changes. If the advantage is not there, IP cost isn't going to be viable either. In the future, developing countries need to commit to CO2 reductions – but this must be compared to developed countries. Technology transfer is also crucial here.

Lisa Saum Manning asked whether increasing technological capacity extend the lifespan of remaining coal reserves, and the response was that if the overall efficiency of use can be driven up – but outside of that, probably not. The US has approximately 280 billion tons of coals and the panelists again seemed to concur that this certainly will ultimately not have much of an impact in terms of career decisions.

Dr. Ahuja asked a question of the panel with regard to the overall cost of emissions controls and when the price comes down, will efficiencies of extraction improve? The general response was that the capture costs are "over the peak" but again, you will not know this fully until you do it at scale according to Dr. Katzer. Dr. Katzer suggested that initial estimates tend to be low but that on a commercial scale, they will go down. Dr. Katzer also suggested that in his view, this is manageable at least in developed countries.

Dr. Dahlman made a comment that there is no incentive for firms in US because of pricing structures and he suggested that what is needed are prototype plants to set an example. In China, according to Dr. Dahlman, the private sector is finding tremendous opportunity and government is lacking. In India there seems to be tremendous complexity because of high ash content. If India is to make any of this possible, technology transfer assistance is necessary. Thus, the question of who pays for this IS a global problem. How do you find a mechanism to finance the kind of program needed to get the ball rolling – especially when there are established countries like the US and Western Europe combined with new/late industrializes? To make progress it is important to understand how to finance this and get the ball rolling.

Essentially, the response from the panelists suggested that until there is a policy in place, and numbers (cost) is known and agreed upon; it is too difficult to make future economic decisions. Economic decisions must be made on what is known. There is no cost associated with CO2 today or in the future. There may well be, but we just don't know what it is at the moment. If you are putting 2-3 billion dollars into a plant you need to know the cost profile for CO2 is going to be there – and will be enduring. Then you can do forward planning and proceed with doing things – scenario planning must be done, but, there absolutely needs to be concrete knowledge and numbers.

Funding must come from all levels/all areas. This will require funding on global scale from the World Bank and other regional banks, which are looking at this problem. The question is ultimately not one of funding but rather, it is one of appropriate technology. Global assistance for developing technologies will leverage funding in the future – money isn't the problem – the technology needs to be understood more fully before funding. IPR must also be addressed.

Dr. Bhanadwaj posed the following: if CO2 was not a concern, in the Indian context it is unclear when India will be able to move to large scale IGCC. If IGCC is so expensive, is it ultimately worth it in the long run? The answer is yes! This is because the costs will come down, and further, there will be increased efficiency levels. Third, IGCC can bring SOx levels down to zero. There are efforts to lower costs of carbon capture. We cannot make decisions for the long run that are only focused on today's levels.

Dr. Kneller asked what percent of coal plants use SC/USC? The answer to this question was less than 10 percent, and that the emphasis should really be on efficiency – it is crucial that we bring the levels down.

In conclusion, questions that were raised to sum up the session related to how and with what technologies, and economies of scale, from the viewpoint of increasing efficiencies and reducing pollution?

The reality is that five years is probably too short a period of time. Emissions control technologies have improved a lot in both efficiency and cost – in past decade. Dr. Katzer said "I don't think it's a technology failure, I do think it's a policy failure." IGCC has a number of developments that are essentially demonstratable, but a new unit has not been built. An area that really stands out is mercury reduction from power plants. There has been careful quantification in this area to get above the 90 percent mercury removal.

Dr. Sonde mentioned that in terms of the efficiency increase seen over the past 5 years might not actually be the returns people want to see and that technological advancement will not ultimately bring down consumption because as it gets more affordable people will use more of it (Sondee).

The question was raised as to how much money would be needed to do pilot projects in this area. How much scientific cooperation would be necessary to achieve meaningful goals? If we were to make a proposal at the end of the conference – what is the magnitude that we are talking about? The answer to this, according to Dr. Katzer is that there would need to be an increase of about 1 billion USD per year to do these types of demonstrations and that these would likely need to happen over the next 8-10 years to go through this.

The final remarks of the session were made by Dr. Sonde, who noted that funding is necessary here and now. He noted as well that collaboration here and now is essential for India to make the next step to supercritical. India cannot wait for other countries to give sell them technologies after they have moved to the next generation... technologies and know how must be shared today – there are currently plants that are going under construction. Shotgun collaboration must happen through IPR transfer so that that new plant can be successful.

Session III – Information Technology

July 8, 2008, 2:30-5:40pm

Chair, ***Ms. Bhavya Lal,*** *Science and Technology Policy Institute,* Washington, DC
Presenters: ***Mr. S. Sadagopan,*** *International Institute of Information* Science, Bangalore; ***Prof. Mu Rongping****, Institute of Policy and Management, Chinese Academy of Science)*; ***Mr. Peter Harsha****, Computing Research Association. .*

Discussants: ***Prof. Duan Yibing****, Institute of Policy and Management, Chinese Academy of Sciences*; ***Prof. Amitav Mallik,*** *Former member, National Security Advisory Board (India),*

Rapporteurs: ***Prof. P. Balaji****, International Institute for Information Technology*, Bangalore; **Ms. Tricia Wang***, University of California, San Diego*

The Chair set the stage for the three presentations by highlighting the following characteristics of contemporary information technology (IT):

1. growth of information technology (IT) capabilities in countries that were classified as "developing,"
2. growth of manufacturing and service industries in developing countries, even if innovative capabilities are still lagging;
3. increased demand for cutting edge technologies outside the United States, and
4. growth in vertical domains and specialization in different parts of the world, with some R&D shifting to "developing" countries.

Indian presenter: ***Professor S. Sadagopan***, International Institute of Information Technology, Bangalore.

The United States is the world leader in products, services and technologies, while China and India as 'rising stars' in manufacturing and services respectively. But China is making bold efforts in local content provision and establishing local standards, while India is witnessing the emergence of small technologically capable firms.

3 key features of the Indian IT industry:
1. The 6 largest service companies (Satyam, Wipro, Infosys, TCS, Cognizant and HCL - SWITCH) account for a mere 2.4 percent of the global software services market.
2. There is also a move toward 'broadbanding' of services with growth in IT infrastructure services, applications development etc.
3. The country has approximately 1.6 million jobs in software services and the business process outsourcing (BPO) sectors.

Supportive public policy initiatives:
1. set up higher education institutes to supply the necessary manpower to the industry;
2. established the Software Technology Parks (STPs) to provide data connectivity to facilitate exports;

3. exemption of export revenues from corporate taxes;
4. ERNET - initiative of the 1980s to provide internet access for academia
5. establishment of IT ministries at the federal and state government levels

Other key features:

1. lack of a well-developed research eco-system;
2. research is confused and shackled by bureaucratic norms
3. money is often spread thin on research projects - there is little effort to deliver competitive advantage by focusing on technological development as part of a national strategy. The early, successful experiences with Atomic Energy and Space efforts not replicated;
4. tentative efforts in e-governance and telemedicine represent new technological efforts and research strategies
5. inability of government to use universities to conduct and deliver research; universities produce too few PhDs and sometimes of questionable quality
6. more MNCs submit patents in India than Indian firms, although there is some evidence of rub-off effects
7. problem with poor quality data to support policy and research

Concluding thoughts:

Government has an important enabling role by to support IT production and use. One means of doing this is to create a critical mass of researchers and centers of research in key IT areas.

Chinese presenter: ***Professor Mu Rongping***, *Institute of Policy and Management, Chinese Academy of Sciences*

The focus of the presentation was on the development of ICT and manufacturing of communication equipment in China. Some indicators:
1. ranks 5th in terms of number of science and technology publications;
2. ranks 10th in terms of science and technology patents;
3. China is the largest producer (by volume) in the world; since 2002, government emphasis on industrialization and informatization;
4. manufacturing strength especially evident in all areas of communication sector (switching, transmission and terminal equipment)
5. widespread use of 3G in Chinese cities and government plans to introduce 4G with pre-competitive research support for universities and firms
6. despite rapid growth in production, and even scale of R&D activity (as measured by the Innovation Capacity Index), R&D effectiveness is limited (as measured by Innovative Development Index) by international standards
7. need to move away from a reliance on low wages and to improve innovation
8. according to the Medium and Long Term Policy for Science and Technology of 2006, 2.5 percent of the GDP will be spent on R&D
9. to achieve that goal, government is extending support to build a technological platform by funding universities and research laboratories, and by establishing innovation

funds; limiting growth of sectors where high profits discourage innovation; increasing international cooperation with a focus on long-term interests (the 30-year tie with the Max Planck Institutes in Germany was given as an example and the increasing two-way flow of ideas was offered as evidence of growing innovation capabilities in China)

US Presenter: ***Mr. Peter Harsha***, Director, Government Affairs, *Computing Research Association*, Washington DC

The CRA:
1. it is an advocacy agency that communicates the importance of computer research to policy makers the importance of computer research,
2. having witnessed a decline in federal funding for such research, the CRA is is working to combat the decline

The US innovation model:
1. supported by the well-understood importance of role of IT in defense, health care, as an enabler of the sciences and as a driver of the economy
2. IT innovation in the United States was successful because of the "interplay of federally funded university research, federally and privately funded industrial research, and entrepreneurial companies founded and staffed by people who moved back and forth between universities and industry," according to a 1995 report by the National Academies of Computer Science and Telecommunications Board.
3. at least 19 sectors identified by 2002 where federal funding had played a role
4. Federal role in IT R&D coordinated by NTIRD which oversees 13 agencies, with computing research primarily with the National Science Foundation (NSF) and the Defense Advanced Research Projects Agency (DARPA)
5. NSF focused mostly on individual researchers and their projects, whereas DARPA focused on placing big bets on long-term projects by bringing together large collaborative research groups;
6. diversity of approaches led to dynamic technologies and ideas that circulated among universities and the private sector. It also led to serendipitous outcomes from basic research

However, this extraordinary model is no longer in place, due to the funding shifts that have taken place, especially since 1999 at DARPA. It has led to:
1. funding to universities has fallen sharply (by more than 50 percent)
2. new managerial approaches at DARPA shifted its funding priorities to shorter research life cycle to produce immediately deployable technologies as opposed to funding basic research

Outcomes of policy shifts:
1. immediate outcome is that research that does not fall under DARPA's new approach rests with the NSF. However, since the NSF is a not a long-term research agency, funding for potentially fruitful long-term research is affected.
2. US graduate students are no longer pursuing long-term IT-based research.

3. a shortage of minds working on long-term defense problems, which is a national security concern that will not manifest itself until a few years from now
4. the United States is beginning to show signs that it may not play as central a role in IT innovation as it did in earlier years. In a global context, India and China are two countries that have emulated some of the best practices of R&D in the United States as well as experimenting and producing unique home-grown strategies that have catapulted them into the global innovation club.

Discussant 1: ***Professor Amitava Mallik***, Pune

1. the term 'eco-system' came into use with the advent of IT to describe how the synergies brought about by factors such as human resource availability, funding support, and government-academia linkages
2. the United States manage to create such eco-systems more effectively before others; China appears to be imitating this, while India seems to finding it hard
3. although innovation is widely emphasized, the priorities are not always shared; for example, in some contexts the focus is on adding features, whereas in others it is on lowering costs
4. Indian achievements too modestly described especially since the country has reached the export target of $50 billion that it set for itself.
5. India too focused on software services and short-term gains while bootstrapping itself, without creating an institutional ecosystem for innovation or intellectual property
6. As the various innovation indices suggest, China seems to be more methodical in the pursuit and measurement of innovation
7. India and China and lagging in IT innovation but they are growing rapidly

Concluding thoughts
Since ICTs encompass many technologies and techniques, and IT thrives in an open global ecosystem, is co-innovation conceivable between the three countries so that we achieve IT for all?

Discussant 2: ***Professor Duan Yibing***, *Institute of Policy and Management, Chinese Academy of Sciences*

1. What is the leading IT challenge for India?
2. What is the exact nature of the research challenges for IT in the United States and how can it be made a Federal priority?

Responses to Discussants and themes from the Open Discussions:

I. IT for All and co-innovation

a. Responding to Discussant 1, Professor Sadagopan made the following points:
1. one area of cooperation is to identify imaginative ways of cutting back on health care costs. Bio-informatics can cut down on drug development cost. GE's design and manufacture of ultra sound scanners in India for the world market.
2. within India some initiatives have been made in the areas of health and education. Presently, though, it touches only about 2 percent of the population. In a country with 300 million people below the poverty line, there is a need to a identify strategies to scale such efforts.

b. **Dr. William Blanpied**, *George Mason University*, asked about the role of inclusive innovative. To this, **Dr A K Chakrabarti**, *Department of Information Technology*, Government of India pointed to two initiatives:
1. 10 million community service centers being established in the country. Each center will serve 6 villages and offer a range of IT enabled services.
2. mobile payment forum supported by the Reserve Bank of India. This takes advantage of the proliferation of mobile phones in the country to provide enhanced livelihood opportunities with things such as access to updated prices.

2. Role of Federal policy on innovation in the United States

a. **Mr. Peter Harsha** replied to the question from Discussant 2:
IT well positioned as a research field in the US Federal budget due to its cross-cutting nature unless it is pro-actively taken away. But it remains a struggle to lobby Congress about the importance of funding on-going work and that IT is not a 'solved' problem. CRA has a visioning effort to educate the community, the public, and policy makers about the grand challenges remaining in IT.

b. This was followed by a question from **Blanpied**: What impact does the perception that students of IT upon graduation have on the number of students enrolling in computer and math based majors in the United States and what is the perception of foreign born students?

Harsha said that over 50 percent of the students are foreign born. This means that the United States should ask why US-born students are not going into IT research. He identified the following reason:
1. cyclicality in enrollment corresponding to the boom and bust of the US IT industry
2. perception among students that involves long hours of programming in isolation
3. long-term viability of a profession where jobs are likely to be shipped to low-cost locations such as India or China

Ms. Bhavya Lal then referred a recent paper by **Prof. Christopher Hill** from George Mason University which claimed that in a 'post-scientific' society such as the United

States, training scientists was less important than training 'integrators' i.e. those who are trained in the arts and business.

3. National policies for India and China

a. **Prof. Carl Dahlman** posed a question about how decisions about standards and protocols fit within overall national IT policies

Prof. Sadagopan pointed out that, unlike China, India has refrained from creating its own national standards. Instead, it has begun to participate in global fora where standards are set so that Indian firms have an early advantage in building product not only for the domestic market but also to capture segments of the global market. Initially efforts were limited to being an observer; more recently, the idea has been to influence standard setting.

Harsha said that governments must ask how preferences for IT policies support specific architectures, and that national IT policy must not constrict innovation.

b. **Ms. Tricia Wang** wanted to know the role of national IT policy in either accommodating or reshaping the international internet regime?

Sadagopan said that given international diversity in culture, language, content, ideology, notions of privacy and so on, a one-size fits all global internet regime is unrealistic. Instead, he argued for a framework that is malleable enough to accommodate national variations.

c. **Wang** asked how Indian IT policy enable IT adoption and innovation without promoting indifference among the local political elite? Specifically, the government of India had a head start over China in creating an internet network, but because the Indian network was created with UN funds, once the UN pulled out, the government nor the local political elites understood the value of such a network. Meanwhile, China's leaders took a top-down approach and was able to convince the local leaders that the internet was indeed an important national network. Therefore, how can India's new IT policy ensure that a national policy would be accepted by local politicians?

Sadagopan said that he wanted to reemphasize the importance of an enabling role. He pointed out that there is much misconception that a market economy means the abdication of state responsibilities. Instead, he said, the state continues to have a crucial role in the provision of public goods, especially in the creation of a an infrastructure for higher education and research.

4. Role of Foreign Investment

Dahlman asked about the outcomes for international collaboration with a decease in national funding in the United States?

Harsha said that indeed international collaborations can make up for the lack of national funding sources. However, this raises questions for national security. He

points out that global research environment, attention should be given to who finances IT research, and the composition of research students in terms of their nationality. For example, many countries in the Middle East that are now investing in American research institutions. In the long-term, the United States should ask to what extent IT research that is funded by a foreign government benefits or hurts the country.

Another question from the floor raised the issue of whether a tighter investment policy in China, to encourage local firms and standards, would make it harder for Chinese firms to compete internationally?

Concluding Thoughts

Policy changes in each country indicates that policy making decisions are ultimately rooted in the political environment. A nurturing environment acknowledges the importance of a diversity of approaches to funding in terms of:

- balanced institutional allocation of research funds
- promotion of cross-institutional collaboration and flow of ideas
- easy movement of ideas and people between private and public institutions
- support for timely and strategic research areas.

Paying attention to IT policy as a means to IT innovation will be central to each country's pathways. If anything, the underlying emphasis is that successful IT policy leads to economic growth and social stability. Integrated IT innovative policies are reflective of successfully globally integrated societies.

Since the implementation of IT policies within each country inevitably presents new questions and challenges because of the unique socio-cultural context of each sovereign nation, approaches will also inevitably vary among each countries. We believe that the key is to appreciate the unique socio-political history and milieu of each country, and with this understanding then we build a common foundation is which to analyze the varying IT policies of each nation.

Session IV – Pharmaceuticals

July 9, 2008, 9:00am – 12:15pm:

Chair, ***Prof. Wen Ke**, Institute of Policy and Management, Chinese Academy of Sciences*
Presenters: ***Prof. Robert Kneller**, Research Center for Advanced Science and Technology, University of Tokyo*; ***Prof. Javed Iqbal**, Institute for Life Sciences, Hyderabad;* ***Prof. Xiao Guangling**, Tsinghua University.*

Discussants: ***Prof. Duan Yibing**, Institute of Policy and Management, Chinese Academy of Sciences*; ***Dr. Susan Su**, U.S. Patent and Trademark Office*

Rapporteurs: ***Dr. Lisa Saum-Manning**, Brookhaven National Laboratory*, ***Dr. Anne Poduska**, Indian Institute of Science*.

In her introduction to the panel, ***Prof. Wen Ke*** identified several key issues of interest to India, China, and the United States in regards to pharmaceuticals. One issue is how to provide medical needs as populations have increasing lifespans, especially in developing countries. She noted that there is always a need for developing new medicines, and preventative medicine is gaining more importance, especially in regards to aging populations. Another key issue is the need to develop policies to bridge both economics and medical developments. A third issue is how to reduce medical costs.

Wen proposed one way to solve these problems: by employing innovative science and technology. She also noted that more communication and collaboration in policy-making will help facilitate innovation. With these considerations, she outlined three goals for the following discussion: one, to highlight the development of medicine in India, China, and the USA; two, to outline responsibilities and policies related to pharmaceutical issues; three, to explore potential pharmaceutical research and development collaborations.

Prof. Robert Kneller was the first presenter, giving a talk entitled "The Contribution of Universities and New Companies to Drug Discovery." He discussed how large amounts of innovative drugs are discovered in universities or biotechs in the US, Canada, Australia–and not big pharmaceutical companies. But, however, almost all standard small molecules are discovered in large pharmaceutical companies.

He also explored some of the factors behind universities and biotech companies producing a large number of innovative drugs, such as the large amount of research and development funding and the objective mechanism of peer review and recruitment. He also postulated about why big pharmaceuticals aren't picking up these innovative drugs; he believes that this is due to a rational business decision, for these large companies seem to rely on entrepreneurial new companies to discover drugs, and then when those drugs are successful, the pharmaceutical companies then buy them out.

Kneller emphasized the importance of small start-up pharmaceutical companies for innovation in biotechnology, and noted that they need a supportive institutional environment, which includes: money for research; favorable immigration policies; an open innovation stance; clear patent rights; incentives for universities to act entrepreneurially; and flexibility in licensing new startups

Next, **Dr. Javed Iqbal** gave a presentation entitled "Innovation in the Indian Pharmaceutical Industries," which was an overview of pharmaceuticals in India, such as the role of research partnerships between Indian companies and multinational companies as well as the contributions of contract research organizations. He stressed the importance of a symbiotic, complementary relationship between Indian and international multinational companies for risk-sharing and exchange of expertise.

Iqbal first explained the co-development models present in the Indian pharmaceutical industry and the amount of risk-sharing present in collaborations with international companies. These models are based on the interest of multi-national companies (MNC's) to broaden their capacity for drug development while decreasing costs, so there is business movement to India because of cost and innovation. And, simultaneously, pharmaceutical companies in India are increasing the number of international partnerships to gain revenue and to develop their own expertise. **Iqbal** identified these partnerships to be symbiotic relationships.

Most advances in research and development in India have happened in the last five years, according to **Iqbal**. Cost is a concern, however: several Indian companies are developing their own drug products but lack the ability advance a drug through the entire clinical trial process and market them worldwide. Consequently, they make licensing agreements or make completed drug sales to large international pharmaceutical companies.

Another business opportunity is in research partnerships: a MNC gives a partner an early/midstage drug candidate and has them develop it further. Thus, this gives Indian companies access to novel compounds and potential help from the MNC. It can then expand its own drug development capabilities while it shares the cost and risk with the larger MNC.

Contract research organizations (CRO's) are another important part of the Indian pharmaceutical scene, said Iqbal. CRO's are contracted to perform specific stages of drug discovery, development or testing, and they are given a fixed fee upon reaching a milestone. In this case, Indian companies don't assume any of the risk associated with drug development.

Additionally, India has a vibrant generics and active pharmaceutical ingredient market (API). These companies carefully monitor the intellectual property (IP) protection of major drug products. When they come off patent, they try to find ways of making the drug in different ways.

Iqbal also drew larger comparisons among India, China, and the United States. Indian companies are making strides in the highest-value segments of global value chains. Chinese companies, on the other hand, seem to be more prevalent in lower-value segments, such as preclinical testing, animal experimentation, and manufacturing.

He also noted several examples of strong pharmaceutical companies in India, such as **Dr. Reddy's** Laboratories, Glenmark and Cipla. He noted that 20 percent of Dr. Reddy's discovery work is done on new-concept drugs. There are also many examples of value-sharing relationships (e.g. Ranbaxy–GaxoSmithKline, Merck).

The final presentation was "Medical Industry Status and Development Trend in China" by **Prof. Xiao Guangling**, which outlined the medical industry's development in China and highlighted its expansion.

First, **Xiao** illustrated the medical industry's development in China. From 1978-2005, the production value of the medical industry has increased by 16 percent yearly, and the output of China's medicinal chemicals is second in the world. Additionally, traditional Chinese medicine has been becoming more standardized and scientific. China also has 834 industrial medicinal enterprises, mainly located in the eastern area, with Sichuan as the main province for producing traditional Chinese medicine.

Xiao noted that foreign trade in 2007 had the highest record in history: around 39 billion dollars. However, industrial innovation capabilities in Chinese medicine is insufficient–but China's international medical patents has greatly increased, as the average annual patent growth is 36 percent. Next, Xiao discussed the developmental trends of the medical industry in China. He noted that China is one of the largest medical markets in the world, but has one of the smallest per capita expenditure on medicine (around $10 per capita). He state that the rapid development of biotech will have influence on pharma biotech

Finally, in identifying the main measures of development of the medical industry in China, **Xiao** said that such measures include: protecting intellectual property rights, strengthening international cooperation, setting up biological industrial bases and advancing integrated development of the medical industry, and building a good environment of market and policy.

After these presentations, the first discussant **Dr. Vijay Chandru** responded to each presenter's message. For **Kneller**'s talk, he noted that the innovation chain breaks when going between academia and pharma–the person who discovers the drug loses touch with the process once it goes to pharma. The stock market is an important issue: Indian companies list on stock market only when they are highly profitable. There isn't an investment community to support innovative research for the venture-capital, small producing companies. Instead, they go with revenue-producing models that are more service-oriented. He questioned how innovation can be pursued and whether one route would be by licensing out to international pharmaceutical companies. He noted that the biggest success in this respect is Glenmark, but **Dr. Reddy's** was a pioneer in the co-development model.

In response to **Iqbal**'s talk, he said that the mushrooming of CRO's and the drawing back of the diaspora has a big effect on the culture of innovation, and this happens when the value chain brings back talent from the US.

Chandru noted that, in **Xiao**'s presentation, there were incredible numbers showing the growth of the Chinese medical industry, such as the 16 percent annual growth over 27 years. He mentioned the large presence of traditional medicine and that, in the move towards standardization of traditional medicine, India should learn from China in this respect.

Before closing, **Chandru** brought up a theme close to his heart: the intersection of computation and theoretical research and development. He mentioned that there's a dryness in the new molecule pipeline: for example, in 2007, 36 billion dollars were spent on finding new molecules, but only 18 were approved by the Federal Drug Administration (FDA).

The second respondent, **Prof. Aaron Levine**, began by postulating about how firms in India, China, US, fit into the value chain and how they are starting to move up in the value chain. He outlined several related points before his discussion, for example, that the high-value segment includes new drug discovery and development. Moreover, for India, an alternative pathway through generics exists, which is also high-value and it put India on the scale it is today. And, after the drug discovery and development, said **Levine**, then comes the clinical trials (which begins with animals and moves onto humans in Phases 0-4, with Phase 3 as an especially expensive step in the process).

With this in mind, **Levine** noted that the US is a fairly mature pharmaceutical industry with players who fall into all parts of the chain. This field is led by giant MNC's such as Merck, but it is also influenced by small biotechs such as university spin-offs that play a crucial role in innovative new drugs. India and China are also important large players but not mature and they don't always cover complete value chain as thoroughly.

According to **Levine**, there is rapid growth in China's pharmaceutical and medical areas and have roles both in domestic and global markets. China's largest component is API and production of API, with some growth of CRO. It appears that China is lagging a little in production of innovative new drugs; however, MNC's are rapidly increasing the number of research and development centers in China and could help them move up the pharmaceutical chain into higher value areas.

India, on the other hand, is a little more established in global market than China, due to generics and the lack of respect for patent rights up until 2005 so there was a large presence of reverse engineering. There is a transition to highest value added section, such as the identification and development of new drug targets. Moreover, there's a hybrid business model, with less risky elements (such as CRO's) and also higher-risk drug development, which is a promising approach as they try to move up the value chain.

Levine brought up several points for further discussion, such as the ethical concerns about clinical trials on treatment-naïve populations that are meant for western wealthy populations, or using traditional medicine as a starting point to identify new compounds. He also thought that MNC collaborations could give access to a growing domestic market, but there are concerns such as: intellectual property, regulation for new/unproven treatments (including medical tourism for Westerners in India/China).

He closed by posing several questions. For **Kneller**, he asked which factor is most important in developing new, innovative drugs and what would help policy makers in India/China move up the value chain by pushing innovation. And, to all of the presenters, he wanted to know what sorts of collaborations would be most beneficial for India/China to move up the value chain and what policies would help with that.

Kneller was the first respondent to **Levine**'s questions. He said that, to make the environment for new companies better, they needed better access to capital (through taxation of investors and companies) and the freedom for new companies to make international alliances to license IP. Moreover, university researchers should be allowed to work with companies (but this interaction must be regulated). For example, **Kneller** proposed that faculty could consult, work for companies, and hold stock—but this interaction should not be unregulated and their primary responsibility should be for teaching and there should be a conflict of interest statement in place.

He noted that caution should be exercised in these university-company collaborations, as they could turn into an open door for big companies. For example, said **Kneller**, in Japan, most of the valuable IP goes directly to the big companies. It preempts the energy of faculty/students and of innovation. This happens 50-75 percent of all discoveries in Japan—but less than 10 percent in US. He expressed concern about big companies automatically control most of the discoveries from universities.

The other panelists responded to **Levine**'s question regarding collaboration and moving up the value chain. **Iqbal** said that partnerships with a more knowledgeable partner would be valuable, as accountability and culture are very important. Many pharmaceutical companies in India are still driven by the family model, and accountability is an issue. He noted several important issues when choosing a partner, such as money and profits, but the most important consideration is the complementarity and scientific skills. **Xiao** noted that cooperation in China is mainly with the USA and Europe, and foreign companies give China foreign medicines that are produced in China. **Prof. Mu Rongping** added that 40 innovation centers receive financial support from the government through deduction of taxes and loans; however there are no large-scale companies in China and the pharmaceutical industry in China is weak.

Prof. Carl Dahlman then posed the following questions. How important was this period of ignoring patents for building up India's pharmaceutical industry? And how did China do it without patent infringement? Also, cost is a big barrier for globalization of pharmaceuticals (especially in Phase 3 and 4). Are there any Indian/Chinese companies that are big enough to get to Phase 3 or 4? And, finally, why is there a dearth of small

molecules, despite the large amount of spending? And how does traditional medicine factor into this in terms of policy implications and MNC involvement?

Iqbal was the first to respond. He noted that in January 2005 marked the big IPO WTO deal and Indian pharma isn't very big. **Dr. Ranjeev Reddy**, in the early 1990's, thought that the future was in innovative discovery—that was the beginning of innovation with his lab startup in Hyderabad. **Iqbal** stated that only the innovative companies will survive and generics have a very narrow profit margin. Moreover, innovation won't be alone—innovation will occur with partnerships with other countries. Not many Indian companies will be willing to put money on discovery research, and no Indian company today has deep pockets to go all the way to Stage 4.

The pipelines are dry because of tactical mistake in 90's, said **Iqbal**. He said India "went gaga" over combinatorial chemistry and forgot that replacing the human mind with machines won't give you innovation. Although machines do have their own benefits, human ingenuity can't be replaced—the big innovations happen with small companies and passed onto big companies. Understanding of biology will help with drug discovery (especially in this post-genome era), concluded **Iqbal**.

In response to the first question, **Xiao** said that, in 1992 the patent law changed and as a consequence, in the past 10 years, the number of patents has increased. About 3 percent of industry is in the medical industry and he suggested that 7 percent of industry will be medical by 2020. He stated that China needs the government to put money in medical research: currently, 14 percent of government research and development money goes into medical research. He suggested that this amount should reach 25 percent in 2020. And, in response to the third question, he said that Chinese medicine incorporates both Western and Chinese medical ideas. There have been studies about how traditional medicine works but there is no conclusion.

Kneller was the last to respond, and he noted that the identification and validation of targets is an issue. It appears that a lot of targets exist where the function has not been validated, and the bottleneck for small molecules is mainly in academic work.

Next, **Mr. Rodney Nichols** made several points. First, he said that it is important to note the ethical considerations in trying to accelerate any kind of unproven treatment. In the USA, there has been backlash in genetic therapy and research in general could be slowed down if there are not well-informed trials. Moreover, the venture-capital companies do a deeper, profound analysis of patent being commercialized more than any big companies. These venture-capital companies bring together the best patent lawyers, commercialization, and science. They know the high risk involved, so they work very hard to make their stuff work and have strong financial interests.

Prof. Dilip Ahuja was the next to pose some questions for the panelists. First, he noted that informed consent is rarely informed in India, so how to we make sure that the poor aren't exploited? Second, for **Xiao**, he asked: what is the complementarity between traditional and Western medicine? Is it rural versus urban? Or according to diseases? For

example, in India, you go to ayurvedic methods when Western medicine gives up or has no treatment.

Iqbal responded to **Ahuja**'s question. He said that clinical trials are done in a very unethical manner, and India needs a well-established system to regulate, monitor, allow for clinical trials here—and it should have the power to send people to jail. He noted that there are issues because people do trials because they're paid. With his company, they went to the DGCI and they knew nothing about trials. He said there is an urgent need for the government to make an agency to streamline the process. He concluded that there's a lot of pressure on India to provide this service and he hopes this will happen.

Xiao also responded, saying that there are Chinese and western medicine hospitals. There is a philosophical difference between the two, though: Western medicine wants to kill something, whereas Chinese medicine is to improve something or to make it stronger. He noted that, if you need to recover quickly, you use Western medicine, but if you're ill for a long time, then you use traditional medicine. For example, with cancer, people use Western medicine for short-term treatment, but Chinese medicine for long-term recovery. He said that all of this depends on individual choice, but generally in hospital, they give both Chinese and Western medicine together. He joked that, when you recover, you don't know which medicine worked!

To conclude, **Kneller** noted that it is important to have ethical trials. In the United States, you have issues with informed consent, but there are limits as to how much you can tell them because they might not agree to participate.

Another participant, **Dr. Adam Goldblum**, posed several questions for the panelists. The first related to the cost of drug development. He said that preclinical tests usually cost $2-10 million, and Phase 2-3 can cost hundreds of millions of dollars. How do we lower the cost of drug development/clinical trials? How do we streamline that process? In setting up your systems in China/India, can you streamline things to make the cost of companies more cost-effective?

Goldblum next brought up the issue involving the structure of how drugs come to market. He noted that biotech is important in US/Canada, but Europe is more towards pharma. These drugs are successful in the US because of the infrastructure and companies can focus on being a machine that produces medicine and being pragmatic without concerns about commercialization. Big companies, on the other hand, don't have so much drive because they don't have to be successful right away—they have big drugs making them money all of the time. How can India and China take advantage of that kind of a system to help identify new and promising therapies?

His final question was in regards to the validation of targets. **Goldblum** said that validation is seen after Phase 2 of trials, which costs a lot of money. He asked how companies can more quickly identify new targets that are truly validated?

Xiao said that the government controls the cost of medicines when a lot of people use it, but he didn't know the exact process of innovation.

Iqbal responded by saying that innovation is done with the small biotech firms and they don't have to worry about clinical trials, Phase 4. But in terms of how do we make India more attractive in terms of the preclinical/discovery stage, he proposed a public/private partnership, with the Western companies absorbing the cost of the discovery.

He also said that Indian companies need to adopt the motto "Kill fast, kill cheap." **Iqbal** noted that people get attached to molecules and they need to get beyond it…Many companies don't want public/private partnerships, as they want things close to their chest. But they need to be more open and work with companies that have complementary skills. India has a good model, said **Iqbal**, as India has centers doing open-ended research within the Council of Scientific and Industrial Research (CSIR) system and are looking for directed research where they are given a problem they are excited about. He noted that India can cut costs by this university/company collaboration, but cutting clinical costs becomes much more difficult, as populations are diverse and trials need to be tailored accordingly.

Session V – Summary and Conclusions

Chair, ***Prof. Samir K. Brahmachari***, Director General, *Council of Scientific and Industrial Research*

Keynote speaker, ***Prof. Chen Jin***, *Zhejiang University*

Workshop Co-chairs, ***Prof. Mu Rongping***, *Institute of Policy and Management, Chinese Academy of Sciences;* ***Prof. Dilip H. Ahuja***, *National Institute of Advanced Studies;* ***Prof. Richard P. Suttmeier***, *University of Oregon*

Prof. Chen Jin opened his keynote presentation entitled, "A New Innovation Policy towards Open and User Centered Innovation," by noting that China's explosive growth in export-oriented mass manufacturing has made it the factory of the world. However, there are concerns that China may have grown too fast, ignoring issues of sustainability and income distribution along the way. Recent Chinese economic policy is designed to stimulate growth while simultaneously increasing productive employment and being environmentally friendly.

Chen's talk focused attention on the '*open innovation*' paradigm that is increasingly gaining attention as the way forward to manage innovation, given its increasing complexity and risky nature. Open innovation is essentially 'bottom up' in that it acknowledges the role of the most humble employee of the organization as a potential generator of ideas. The origin of the idea is of little relevance according to this paradigm: institutions are encouraged to be more inclusive in their incorporation of ideas from various sources. Thus, the ideas should *not* be the sole preserve of top management, but could just as easily come from outside the organization or from employees within the organization who are not in leadership positions. Several companies such as Proctor & Gamble, General Electric, Wal-Mart and 3M have enthusiastically embraced this radically new approach.

The "*innovation from outside*" approach has gained traction in the manufacturing sector. Manufacturers are increasingly working with end users of their products from the design stage itself. This, in turn, has enabled them to acquire new technical competencies, learn about relevant technological trends and extend their innovation and technologically related networks.

Chen concluded his talk with suggested policies that the Chinese government could initiate to foster open and user-centered innovation policies in China. They include introduction of a "*respect all innovators*" policy that is essentially a bottom-up approach to user-centered innovation, continued investment in IT related infrastructure to enable the free exchange of information and ideas, and reformation of the Intellectual Property Rights (IPR) regime. Protection of intellectual property is still a serious problem in China. Poor enforcement of IPR has hampered innovation and the diffusion of knowledge by weakening the incentive structure for innovators. Prof Chen recommended that loosening the IPR regime for knowledge generated in Public and State Research

universities would allow the dissemination of this knowledge among potential innovators, thereby preserving the public good characteristic of this knowledge.

Prof. Brahmachari's talk provided a general overview of the innovation process in India. He spoke about the limitations of India's modern education system which he claims has "killed the ability to question" and in doing so has directly hindered the development of a next generation of innovators. **Brahmachari** identified the four leading characteristics of innovators as follows:

- The ability to connect the 'unconnectables'
- The ability to see beyond what is visible
- The ability to expect the unexpected
- The ability to celebrate naivete

Bramachari acknowledged that the Indian government recognizes the limitations of its education system in fostering innovation but proposed that innovativeness must be cultivated both in schools and at home. He stated that cultural changes such as allowing children to question their parents must accompany improvements to the formal education system.

Because much of India's population does not have access to formal education, the Indian government supports two programs, namely the National Innovation Foundation and the Mariko Foundation, to promote innovation outside of the formal education system. Among other innovations, the National Innovation Foundation supported the development of two products that could be very useful in rural Indian conditions. A special cycle, which was propelled forward each time it hit a bump in the road and a pesticide sprayer that could be attached to the sprayer's shoes were both developed with local conditions in mind.

A unique feature of the National Innovation Foundation is that it has always focused on designing user friendly products by involving end users in the development process. The development of the pedicab, designed in Calcutta, involved close to 200 end users, most of whom had no formal education. Bramachari concluded that the key to innovation is tapping knowledge and ideas from all sources.

Closing remarks:

Prof. Mu Rongping expressed his gratitude for India's participation in this year's conference and talked about ways to continue the three-way dialogue among India, China, and the United States. He suggested choosing specific topics for another tri-national workshop which could result in a book or journal issue. **Rongping** also thanked the numerous younger scholars who had come to Bangalore to participate in the workshop, and recognized them as the next generation of innovators.

Prof. Richard Suttmeier restated that the objective of the workshop was to explore the innovation systems of three countries though three case studies. He congratulated the

participants for meeting that objective and stated that he expects long-term collaboration among the scholars from all three countries to result.

Prof. Dilip Ahuja wrapped up the session with the following quote: "Whatever one may say of India, it is true, and equally true is its opposite." He cited statements from the various workshop sessions in support of this observation, and reiterated the importance of collaboration among China, India, and the United States in developing new approaches to global innovation.