

World Sustainable Development Forum  
RSDS 2006 • Shirakawa, Japan

# Policy forum on science and technology for sustainable development

***Summary of the  
First Regional Sustainable Development Summit  
held during 5–6 October 2006 in Shirakawa, Japan***



The Energy and Resources Institute



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## Foreword

**T**he first RSDS (Regional Sustainable Development Summit), the proceedings of which are contained in this publication, was an activity undertaken outside of Delhi where the DSDDS (Delhi Sustainable Development Summit) is held annually. The fact that this Forum was held in Shirakawa-Go at the facility designed and operated by the Toyota Motor Corporation has more than symbolic importance. The event makes a major statement, not only because the facility where it was held is designed as a green and environmentally friendly facility, but also because it was the initiative of what is likely to become soon the largest automobile manufacturer in the world.

Several issues were discussed and many learned presentations were made on the major theme of the Summit, which focused on the relevance of science and technology for sustainable development. Participation in the Summit was by invitation, and the choice of Japan as the host country for this event provided great relevance, given the fact that Japan has been a leader in the development and use of several technologies that serve the objectives of sustainable development.

Various aspects of science and technology were explored, particularly in the context of developments in areas of energy consumption and supply taking place in China and India. The record of Japan, and the capabilities that it has established, requires that China and India learn from it and find means for linking up with Japanese organizations to find solutions with a strong science and technology base in the field of energy.

The WSDF (World Sustainable Development Forum) has a very distinguished set of patrons, and under their support and inspiration,

the Forum is planning to expand its activities to serve the global community by providing information, analysis, and insights on progress being made towards sustainability in different regions of the world. The Forum at Shirakawa-Go in Japan represents the beginning of a journey being undertaken by the WSDF with several milestones to be reached in the future.

The challenge of sustainable development is growing larger everyday as the footprint of human activities keeps expanding and the threat of climate change becomes more real with scientific evidences becoming more compelling. Organizations such as the WSDF, therefore, require not only to be proactive in providing knowledge on various aspects of sustainable development and the means by which this can be achieved globally, but also by disseminating information on a large scale, so that public awareness can be created both on the nature of the problem and possible solutions and answers.

It is hoped that the proceedings contained in this publication would provide a useful source of information and create insights by which science and technology in particular can be mobilized in different parts of the world for attaining the goal of sustainable development on a global scale.



R K Pachauri  
Director-General, TERI, New Delhi



## Acknowledgements

The first RSDS (Regional Sustainable Development Summit) under the aegis of the WSDF (World Sustainable Development Forum) held in Shirakawa, Japan, was possible due to the patronage and generosity of the Toyota Motor Corporation that provided great support to this Summit. We also thank the Toyota Motor Corporation for providing the Toyota Shirakawa-Go Eco-Institute facility for the Summit, and for their supreme hospitality. Delegates travelled long distances to participate in the Summit and the Toyota team went out of their way to ensure a comfortable stay for all the participants.

Despite a short notice, the Summit could bring together participants in time, though a small group, from five different countries comprising Australia, the United Kingdom, Korea, India, and Japan. This was possible with support from the Summit partners: GISPRI (Global Industrial and Social Progress Research Institute), IGES (Institute for Global Environmental Strategies), NEDO (New Energy and Industrial Technology Development Organization), RITE (Research Institute of Innovative Technology for the Earth), and the University of Tokyo.

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We sincerely thank Dr Pradeep Kumar Dadhich, Dr Ritu Mathur, and Ms Prima Madan at TERI, for preparing the background paper and particularly Ms Prima Madan for painstakingly editing all the presentations for this publication. Thanks are also due to colleagues at TERI Press who refined the manuscript meticulously to give it the present shape.

**Annapurna Vancheswaran**

(Coordinator RSDS)

Associate Director

Sustainable Development Outreach Division

TERI, New Delhi

## Inaugural session



### Speakers

- **Prof. Jeffrey D Sachs**, Director, The Earth Institute and Special Advisor to the Secretary-General of the United Nations, USA
- **Dr Shoichiro Toyoda**, Honorary Chairman/Member of the Board, Toyota Motor Corporation, Japan
- **Prof. Akio Morishima**, Chair of the Board of Directors, Institute for Global Environmental Strategies, Japan
- **Dr R K Pachauri**, Director-General, TERI, New Delhi

In its endeavour to spread the benefits of sustainable development, along with an aim to influence mindsets, attitudes, and behaviour of individuals as well as communities for the world to progress in sustainable fashion, TERI established WSDF (World Sustainable Development Forum) in 2005. One of the objectives of WSDF was to organize RSDS (Regional Sustainable Development Summit) annually. In keeping with the forum's aim, the first RSDS was held at the Shirakawa-Go Eco-Institute, Japan, during 5–6 October 2006, under the auspices of the Toyota Motor Corporation. The theme of the first RSDS centred around important issues of science and technology for sustainable development, with main focus on energy and climate change, while not diminishing the importance of other issues of sustainable development.

### OPENING ADDRESS BY PROF. JEFFREY D SACHS [BY VIDEO CONFERENCE]

It is a great honour to be part of this TERI forum on 'science and technology for sustainable development', especially a regional forum that brings together scientists, engineers, practitioners, and policy-makers from across Asia. I cannot think of an event more important than this,

and I congratulate Dr Pachauri for getting us all together to discuss these issues. It is one of his many contributions to the world, through TERI and the IPCC (Intergovernmental Panel on Climate Change).

We are at a juncture in the world where we need these meetings urgently because the challenge of mobilizing science and technology for sustainable development is gaining significance in the world agenda. Even if some of our policy-makers are not yet caught up to that reality, the fact is that the challenges of climate change, energy, water use, habitat, and biodiversity conservation are growing in such significance, and the urgency is mounting on so many fronts, that they will be right at the centre of the global politics for many decades to come. We sometimes are confused about that point because our politicians like to talk about politics more than they like to talk about sustainability. Some of these issues have been neglected, but reality catches up in any event.

In the United States, we just had four days in a row where the water crisis of India was on the front page on New York Times—quite a dramatic story. It was not news exactly for those of us following it, but still news in the sense that American readers might not have otherwise been aware of this crisis. Now, of course, American readers should have been reading more about our own environmental challenges. We are in the middle of a persisting, massive drought in the American mid-west and south-west. The evidence suggests that drought conditions are associated most likely with long-term global warming. We have an old climate record, which shows that the last time there was a long period of such drought in the American western region was during the medieval warming period of about a thousand years ago.

There has been evidence of drought conditions being associated with warming. The United Kingdom Meteorological Office issued a report indicating how a 100-year scenario, using the Hadley and other models, shows increasing drought frequency in many parts of the world. This further confirms what has already been suspected. We know that global warming is going to have tremendous effects on the hydro-meteorological cycles in many different dimensions: melting glaciers, changing seasonality of snow melt, changing precipitation pattern, and so on.

There is a lot more global stress ahead. Before we talk about the energy challenge, let us talk about a couple of general things about the

challenge of sustainable development that is the focus of this workshop. First, I suggest that we always take sustainable development seriously in both components of the phrase. 'Sustainable' refers mainly to resource and environmental issues, but 'development' refers mainly to the challenge of helping the poor on the planet get a foothold in better material life conditions. We need science for both the 'sustainability' and the 'development' challenge. We put the phrase together because we are looking for ways to improve the material conditions of the planet. But, we require specific science, targeted at the needs of the poorest of the poor, because they have specific ecological challenges and specific disease-condition challenges. They often live in conditions such as in drought-prone regions.

The developmental challenges are quite significant. I happened to be at a gathering of the Gates Foundation in Washington where the focus was on global health challenges. Here again, the development needs for science for health were very particular, because poor countries suffer from a set of infectious-disease challenges that are quite distinct from the disease challenges that rich countries are facing. Similarly, with agriculture, the challenges in today's developing world are quite distinct from the challenges of the high-yield agriculture in the high-income world. So, we need science both for the sustainability and development challenges.

The second general point is that the sustainability challenge is already very severe, but likely to get immeasurably worse. We are already on an unsustainable path in the world on many different ecosystem challenges. Climate change is an obvious change, but there are many others as well—the use of water resources; the use of land resources and the continuing encroachment of habitat of multiple species; the changing chemistry of the oceans; the depletion of many important resources, terrestrial and marine; the fishery disasters in most of the world's oceans; and the over-hunting of many of the remaining land mammals of the planet. Almost every ecosystem is under profound stress today—marine, terrestrial, atmospheric, climate, energy, water, nitrogen flux, endangered species, and diseases.

What has happened before our eyes – or maybe not before our eyes because we have not been looking – is that the burden of human activity

on the planet has skyrocketed nearly hundredfold since the start of the Industrial Revolution. During the past two centuries, the weight of human activity has gone up roughly by eight to ten times in terms of population and roughly by eight to ten times in terms of per capita economic resource use. These two scenarios put together indicate that human activities on the earth's ecosystem have increased by sixty to hundred times.

Implications of these human activities are too many and concerns abound. For every ecosystem, we have already eliminated the buffers that we had, so we are pressing against very serious limits. We have already cut down most of the forests. We have already out-fished most of the oceans. We have already filled the atmosphere with carbon dioxide to a level of 380 PPM (parts per million). We are already reaching dangerous thresholds of carbon dioxide concentration. We have already interfered quite decisively in the natural nitrogen cycle. We have already acidified the oceans by about 0.2 pH; this, according to best estimates, has posed very serious risks for the survival of corals around the world. Corals are already under stress because of over-fishing and climate change. We have already arrived at limits that we never had to worry about before. Our societies are not aware of how much we are pressing against these boundaries.

But that is only half the story because we still have a huge amount of change built into the global system through inertia. We are already at an unsustainable pace of human activity but there is lot more to come, due to two reasons. One, there is inertia in the ecosystem's response to what has already happened, and the most dramatic of these is the thermal inertia. The planet is already warmer by six-tenths of a degree centigrade, but thermal inertia gets it further warmer by several tenths of a degree centigrade, even if we did not further change the carbon concentrations. That is because the oceans are still absorbing the radiation, resulting in the long thermal delay in ocean warming.

Two, the extent of human activity is not diminishing. It is going to increase markedly in the next 50 years. The developing countries are growing very rapidly. China and India together have about 40% of the world's population. Both of them are achieving growth to the tune of doubling their incomes every 10 years, if not faster. When you think

about 40% of the world's population on a decadal doubling period, the amount of increase in economic activity built into the system is enormous.

Added to all this is the fact that we have a huge population momentum as well. Even if fertility rates were to come down to replacement levels suddenly, we would still add more than another billion people on the planet simply by virtue of the fact that the age pyramid of today's population is very young. There will be further momentum of population growth. But, the fertility levels are not at replacement level; they are rather well above replacement level in the developing countries. The UN (United Nations) forecasts that another 2.6 billion people will be added to the planet between now and 2050. It forecasts that human population will level off at about 9 billion. Not only are we unsustainable at current pacing of the economic activity but when you combine that with the increases in per capita income level – level that we want with the population increase that we are going to get – we may experience a fivefold increase of global GNP (gross national product) between now and 2050.

In fact that is what would be a success story from an economic development point of view. This would take global GNP from about 50 trillion dollars per year to 250 trillion dollars per year by mid-century. We would hit ecological barriers or geopolitical barriers that could be devastating. For the development challenge, we face an underlying pressure of much greater force on the earth's environment at a point where we have already lost the buffers that we had.

Now as for the climate issue, we know that we are already on a path of unsustainable climate change with about seven billion tonnes of carbon being burned every year and roughly 25 billion tonnes of carbon dioxide being emitted every year. We are on a path of increasing carbon concentration in the atmosphere by about 2 PPM on an annual basis because of the economic activity that is bound to arise along any business-as-usual baseline. Almost every scenario that is worked out right now predicts that by 2050, we will surpass doubling the pre-industrial carbon concentration—from 280 PPM in the pre-industrial period to more than 560 PPM probably by mid-century. Not only that, on a business-as-usual course, it could go beyond quadrupling the

pre-industrial level by the end of the 21st century. The baseline is really a very stark one. What the scientists are telling the consumers of the science, such as myself, is that the dangerous anthropogenic limits for carbon are probably lower than we thought.

My colleague Prof. Jim Hanson of Goddard Institute of Space Studies has recently been writing that the really dangerous anthropogenic threshold is probably low with a further increase of 1 °C. That means probably something like 450 PPM, which, on any life-like scenario, seems almost attainable right now. But Dr Hanson's argument is that even that low threshold level, which is well below the carbon-doubling level, is likely to be consistent with the melting of the great ice sheets. The evidence shows that the melting of Antarctica ice sheets and the Greenland ice sheets is proceeding more rapidly than was believed, because the physics of melting is somewhat different from what it has been understood before.

If one looks at the risks of significant rises of sea level in the 21st century, they look much more likely than they did five or ten years ago. That is one example of reaching dangerous anthropogenic level even at what was considered as fairly modest overall level of carbon concentration.

Now it is going to be extremely hard to keep under a carbon-doubling scenario, and many of my colleagues think that it is impossible to keep under 450-PPM scenario, even though Dr Hanson is really emphasizing that it may surpass the threshold for anthropogenic danger.

If we were going to find sustainability on rising carbon concentration, given what the baseline scenarios are telling us, we need rapid advances on two fronts quite clearly. One is on energy efficiency, so that we can get more economic and material well-being per unit of energy for more GNP per unit of energy.

Two, that is even not going to be enough. If GNP rises by five times between now and 2050, and we have energy efficiency consistent at about 1.5%–2% a year, and if we double the energy efficiency by mid-century, we still have more than twofold increase of total energy use—almost double of which on a business-as-usual path would be relative to a continuing high concentration of fossil-fuel independence. So, we have

to do much more than simply carrying on with 2% of energy efficiency. We also have to do much better than keeping the current mix of energy systems.

We have to increase energy efficiency faster and also de-carbonize the energy system. These are huge scientific challenges and I am sitting in awe and honour in front of Dr Toyota who has done perhaps more than anybody else in making advances on this through the hybrid technology, and I am so happy to see that finally Americans are going for fuel efficiency pretty dramatically. But, the point is, we are going to have to do even better and it is going to require some dramatic improvements of science and of the technology of energy use.

You are all experts in this field. I do not have to belabour too many of these points except to give you sense of what my colleagues at the Earth Institute are thinking about this challenge of de-carbonizing the energy system; what we know about energy use; and what we can project about the energy use till mid-century.

About 40% of current carbon emission comes from electricity generation. And, that is likely to remain at least as high, and on the IEA (International Energy Agency) scenario, is to rise to about 45% of total carbon emission by mid-century under the business-as-usual baseline path. So, electricity production is the dominant sector where energy emission is occurring and where we are likely to place urgent needs for new energy system design. The transport sector currently contributes about 20% of the total carbon emission, and it is expected to rise, especially with the automobile boom coming to India and China, to 25% by mid-century on a business-as-usual path. The energy production sector and the automobile and airplane sector contribute about 70% of total carbon emission. Another 20% or so comes from industrial processes. Of course, steel, cement, material transformation, petro-chemical, and refinery industries account for the lion's share in carbon dioxide emissions.

But, the predominant consequences are going to come from transport and electricity production. Quantitatively, we need significant advances in electricity production, generation, and distribution. What do we know about that? We know that there are multiple technologies possible for

de-carbonization. Renewable energy is one whole category. Most scenarios show that both nuclear energy and renewable energy are going to play a role, though not a dominant one, certainly by the mid-century.

The energy system cannot be retooled to undo the dependence on fossil fuels, given that China and India are going to depend very heavily on their coal resources both for electricity generation and for the production of petroleum and gasoline. So, we have to look at ways to use fossil fuels for electricity generation.

That brings us to various models for carbon capture and sequestration from fossil-fuel use. I believe that the technology in carbon capture and sequestration is probably the most critical factor in the global decision tree with respect to electricity generation. But, we have to know globally how much carbon capture is feasible and in what ways. Is it really plausible to think about sequestering several billion tonnes of carbon per year in geologic deposits? Will it be safe? Will it be publicly acceptable and does the geology permit it? Will China, India, and other major new users and major sources of electricity adopt this technology?

Those are very big questions. Shockingly, we have almost no real answers to them right now. Though the IPCC and the IEA both issued very optimistic accounts of the potential for carbon capture and sequestration, we do not have enough demonstration projects under way.

The first thing I would recommend on science and sustainable development for climate is that we dramatically increase the number of demonstration projects on carbon capture and sequestration, because we need to know within the next five to ten years whether it is environmentally feasible, as we hope to continue to use fossil fuels on very large basis. If the answer turns out to be 'no', we have very serious trouble; much more serious than if the answer turns out to be 'yes'. Of course, every other sector that I mention in addition to power generation requires its own science.

Automotive technology needs to get us to perhaps a hundred-mile-a-gallon convenient level in the not-too-distant future, and if anybody can do it then I would say, we are already halfway there. The question is whether the various fuel-mix scenarios and engine designs being explored could reach the level of fuel efficiency we need so as to avoid those dangerous anthropogenic levels. Again, my understanding is that the engineers are pretty optimistic about the potential.

Indeed, there are cars on the road that do get a hundred-mile-a-gallon efficiency right now. They are just not purchased by the consumers, and we have to find the models to bring these much higher efficiency vehicles into mass use. I think there is willingness in China and India certainly to look for those very high fuel-efficient vehicles.

Turning to the other sector, there are promising scientific advances on industrial carbon capture and sequestration at major power plants. There are also potential advances in green buildings, more efficient insulations, and high-efficiency illuminations. All of this shows that the range of promising technologies is probably close to be at hand, and we can already identify the portfolio technology that could keep the carbon level from reaching very dangerous limits.

What will it take actually to get the world to move in that direction? First, it is meetings like this, where scientists, engineers, and business leaders reflect on the promising technologies that can be scaled and that are within reach in a matter of decade.

Second, we need global agreements with needs-centred targets. The current system like the Kyoto Protocol is not going to be effective enough, where you set targets only at five- or ten-year intervals. We need to agree that, by 2050, we keep thresholds well under 560 PPM, maybe under 500 PPM, and then to orient global policies around a shared mid-century targets, because the planning that needs to be done can't be done on a five- to ten-year basis. We need power plants that last half a century, and we need research and developmental strategies that may have a 20-year demonstration and implementation period. We have to think far ahead and give clear signals to the industry.

The third aspect of this is that we need global price on carbon emission and global incentives for carbon sequestration. Based on the evidences, a plausible level of taxing carbon emissions for the long term would be about \$25 per tonne, which would be 20–25 cents per gallon of gasoline and would be 1–2 cents per kilowatt-hour for electricity generation.

It seems that if we increase public investment in research and development and private incentives for carbon capture and sequestration and for other low-carbon technology at about \$25 per tonne, we have a very good chance of creating proper long-term incentives for the business sector. They will be roughly adequate to

provide the economic incentives for this long-term transition to higher energy efficiency and to de-carbonization of the global energy system.

We know that, in the US, this idea of carbon-dioxide-emission tax has been a political non-starter; the US administration has been absolutely hostile to this kind of idea. But, I believe that US politics and society is way ahead of the White House in this regard. The US politics is changing and chance of reaching such an agreement is becoming more likely. Another point on global agreements is that we have to end this distinction between the high-income countries that undertake the responsibility in the low-income countries.

There will be no way to reach these limits just arithmetically. It is important that China, India, Brazil, and other middle-income countries also become part of the global emission control system. After 2012, we would need universal agreement and universal participation. Now, that does not mean that poor countries have to pay for all of it, because part of the payment in many different ways can come disproportionately from the rich countries.

But it does mean that all countries will have to be part of a global target and global implementation system, even if the disproportionate payment comes from the rich countries. So, we need global agreement to achieve a target of may be 500 PPM by mid-century, a tax on the order of \$25 per tonne of carbon dioxide, an incentive for sequestration at the same level of about \$25 per tonne of carbon dioxide, and then massive research and development effort aimed at all four end-user sectors. I again stress on automotive and power generation sectors as the two highest priority sectors. We need technological breakthroughs there. I believe that the level of funding for this kind of effort needs to be around 20 billion dollars per year, most of it paid for by the rich countries.

Part of that should go for early demonstration projects, testing the feasibility of carbon capture and sequestration, power-plant-integrated gasification, combined cycle power plants for coal with carbon capture and sequestration capacity, and so on. I believe that China, India, the US, Europe, Brazil, Indonesia, and Australia should be adopting such

demonstration plants to see the feasibility on many different fronts—economic, geologic, regulatory, and public acceptance.

Finally, let me say that no matter what we do, there is going to be a great deal of climate change ahead. It is going to be very difficult for the poor countries. They are already experiencing tremendous stress from global warming and from changes of precipitation patterns. That stress is going to increase. We are going to have very serious droughts, heat waves, loss of the snowmelt for summer agriculture, and we are going to lose a lot of parcel water locked up in glaciers that are disappearing.

India is going to bear the tremendous burden from this, because the Himalayan river system is going to come under tremendous stress. Perhaps, even the monsoon cycle will come under stress, because evidence says that if there is a shift towards more El Niño kind of Pacific Ocean warming, this could heavily impact the monsoon cycle in Asia.

We need, in addition, mitigation strategy and global adaptation strategy system. This is another area where the high-income countries are going to bear special responsibility, since they have been the bigger contributors to the burden so far. Unfortunately, I cannot end with the statement that all of these are easy. I often talk of things that could be done to save lives of the poor using existing technologies. But, with climate change, there is no simple solution. The best evidence, however, suggests that this is a feasible transition.

This will require real spending—hundreds of billions of dollars per year by the mid-century. But, the good news is that it is only less than 1% of the world income, but vastly more than what we are spending right now. We have to get started; we are running out of time, we have long tedious times ahead.

I think the outstanding group of participants in this meeting that TERI has inaugurated today plays a major role to help the planet move forward. We go from this meeting to the Delhi Sustainable Development Summit, and I hope we have more and more news of the world mobilizing to finally take action on the scale, and with the sense of urgency, that is required to achieve this vital goal of sustainable development.

## HIGHLIGHTS OF OTHER ADDRESSES

After Prof. Jeffrey D Sachs' enlightening address, the opening session of the Summit restated the growing importance of the role of science and technology in sustainable development pursuits. In his welcome address, Dr Shoichiro Toyoda, Honorary Chairman, Toyota Motor Corporation, highlighted the need for initiatives in three areas so as to improve the global environment and create a sustainable society. These three areas include the creation of new rules including societal norms and laws, technological innovation, and raising environmental awareness. He emphasized that technological innovation is certainly a top-priority issue at Toyota.

'Technology is like a two-edged sword, which can solve and create problems; we need to seek better ways of planning, developing, and applying it', said Prof. Akio Morishima. It is essential to develop ESTs (environmentally sound technologies). ESTs need not always be totally new and high-tech, but ought to sometimes re-visit, re-vitalize, and/or improve conventional technologies. Within Asia, there are examples of successful development of ESTs, along with measures that facilitated the development and dissemination of such technologies. Notable among these are the hybrid cars and FGDs (flue-gas desulphurization) in Japan, wind technology in India, and biogas in China.

For furthering technology development and creating an enabling environment for ESTs and their diffusion, it is crucial to have right policies in place. Some quantitative targets set along with financial measures to create/stimulate economic incentives are the common features of successful cases. Protection of IPRs (intellectual property rights) to ensure rewards for investors and innovators, is another important aspect for further promoting ESTs.



## ENERGY TECHNOLOGIES AND SUSTAINABLE DEVELOPMENT: INDIA AND CHINA

*Background paper presented by Dr R K Pachauri, Director-General, TERI*

While focusing on the need for technology leapfrogging and policy interventions to face the daunting challenge posed to the world economy, due to the ever-increasing demand for energy, the background paper for the event exemplified the role that energy technologies can play to meet the energy demands of the two rapidly growing giants, India and China, in a sustainable fashion. The paper in its conclusion, based on the studies conducted on India and China, stated that the technological change for India seems to be more relevant and crucial in the power generation and in the transport and residential sectors from the demand side. Similarly, for China, it is the end-use efficiency improvements that would provide least-cost options for meeting energy service demands, regardless of the energy-supply strategy. The paper highlighted the importance of Japan that is an excellent example of a country successfully embarking on a sustainable development path. The paper also discussed lessons with regard to energy technologies that countries like India and China must learn from Japan.

*(For the full paper, refer to page 71)*



## Keynote address



### ***Global environmental policy and public–private partnership***

#### **Keynote address by**

**Mr Shinji Fukukawa**, Senior Adviser, Global Industrial and Social Progress Research Institute, Japan

**P**ublic–private partnership or PPP, although necessary, is unfortunately not very well developed in Japan and other countries. While dealing with environmental issues, two different standpoints may serve as the basis for initiatives required in Japan.

The first is to utilize market forces, stimulating self-supporting measures both at the demand and supply sides. The second is to apply regulatory measures through government administration. As the former standpoint is not endorsed by the business sector, it is imperative that some other citizen groups take up the latter one.

However, both the business sector and the government have not yet discussed the merits and demerits of both the standpoints so as to reach a consensus on a better solution.

There is a need to take a comprehensive approach towards the growing environmental concerns through partnership between the public and private sectors. To address global environmental issues, four major approaches or challenges can be adopted. The first is to restructure the market framework. Policy tools for the environmental issues in relation to the market framework may comprise international rules such as the Climate Change Convention and Kyoto Protocol.

The second approach is to set up regulatory measures like anti-pollution measures. These measures would ensure the selection of energy sources that cause less damage to the environment and are chosen by the consumers. The attitude of consumers while consuming energy and selecting goods and services that cause less adverse impacts on the environment plays an important role as well.

With the change in the attitudes of consumers, the selection of the energy conservation directions would also change. In keeping with this, the suppliers may be required to change the designing of the product, while continuing to supply goods and services as per the consumer requirements. In Japan, for example, energy efficiency of electronic household appliances has risen remarkably. The habit curve given by Dr Toyoda has become very popular not only in Japan but also in the other parts of the world. Such trends are a reflection of choice of the consumers, supported by the dynamic technological challenges by the related manufacturers. Some of the important factors that can drive changing consumer choices are: providing necessary and authentic information on the environment; enhancing understanding on the environment through environmental education programmes; implementing policy measures that give fiscal, financial, and tax incentives; and stimulating political innovation to strengthen these factors.

The Toprana system in Japan is working quite well. Under this system, by providing information and giving some technical advice, the government motivates the manufacturers to innovate for improving energy efficiency of their products.

Another approach under the second approach is that the corporate houses need to give top priority to the preservation of global environment while laying down their business strategy. The objective of the enterprise should be to subscribe to the values that society needs. Ideally, the enterprise should uphold values consisting of economic values to heighten the profit, customer values to satisfy the demand of the customers, and social values to maintain sustainability or continuity of efforts that ensure environment order, safety, and peace. The corporate management should focus on imbibing simultaneously these three values.

The current unfortunate characteristic in the Japanese society with regard to the enterprises is that the enterprises that look only for profit without respecting the customer values will be ignored by the consumers. On similar lines, the enterprises that try to profit by neglecting the social values will not be endorsed by the society. The value of the enterprise is to be validated finally by the current capitalization. It may be reduced if the enterprises ignore customer values while giving importance to social values.

The Japanese industrial sector has established a voluntary programme supported by the government to achieve the target set by the Kyoto Protocol, and is making utmost efforts to implement the programme. Such an approach may motivate the corporate management to put high emphasis on environmental concerns. The number of enterprises that publish environment reports and apply environmental accounting system has been increasing in the country.

On similar lines, CSR (corporate social responsibility) is increasingly being discussed in the Japanese society. The enterprises that lay sufficient emphasis on environment protection while deciding on their products, product manufacturing processes, technological development, and procurement of resources and materials may have a competitive edge in the market. Such efforts have resulted in high energy efficiency, typically seen in the energy-consuming industries such as iron and steel, cement, paper and pulp, petroleum, and chemicals in Japan. It is also worth noting that the rate of energy consumption to gross national product in Japan is one-eighth of that in China.

The third approach is to innovate the technological paradigm. Until now, mankind has developed the technology and the industry with the aim of achieving highest living benefits. But keeping environmental concerns in mind, we are now forced to change our industrial system from mass production, mass consumption, and mass waste to efficient production, effective consumption, and extensive recycling. For this purpose, we have to promote technological innovations in both the demand and supply side of energy, in recycling, and also in restoring environment. There are challenges involved in using solar energy, batteries, hydrogen, energy-efficient cars, and so on. The development of superconductivity and biochemistry field is now being undertaken.

It is increasingly being recognized that technological innovation would be accompanied with risk. This implies that in order to reduce the risk involved, government support and international cooperation are required. This approach will also ensure that technological achievements in different phases come together.

The fourth approach is to establish reasonable international rules, although there is a serious argument with the caps system applied in the Kyoto Protocol with regard to its feasibility. But Kyoto mechanism such as joint implementation on emission prevention and CDM (clean development mechanism) are widely accepted since they follow the market mechanism. Therefore, the partnership between the public and private sectors is necessary to scale up the Kyoto mechanism to other more refined and efficient system. International PPP is also needed now to establish post-Kyoto mechanism, and the transfer of technologies to developing countries is also strongly expected.

Currently, the nationalism on the oil and natural resources is gaining momentum, and again here, the partnership between the public and private sectors assumes importance. This is mainly triggered by the increased demand from the oil-consuming countries and limited supply of resources. In view of solving energy security, energy nationalism, and environment protection concerns simultaneously, both the public and private sectors world over should make efforts to find the best energy mix.

The Japanese government, at the moment, is undertaking various policy measures for protecting the environment by enacting basic environmental laws related to degradation. Specifically, the government's efforts are concentrated on the policy efforts to reach the target set by the Kyoto Protocol. The need of the hour, in my view, are the efforts to make best use of the market mechanism in dealing with the environmental issues on the same lines as the general economic management. However, it is well known that market is not always perfect and may fail to secure optimal distribution of resources and distort social welfare. Thus, what is then required is a policy-supplemented adjustment. In my view, an apt industrial policy is one in which market is allowed to work effectively and policy adjustment is provided for the issues in which market fails. This logic can be applied to the environmental issues as well.

However, it also needs to be mentioned that the government can also fail in making a proper policy. What needs to be emphasized is that the government ought to put the basis of the economic cooperation needed on the market mechanism. The government intervention to supplement the market imperfection should be there only when necessary, and the tools applied should be as indirect and soft as possible. Generally speaking, some government interventions include

- provision of the future vision of basic policy;
- establishment of international rules;
- introduction of direct regulation;
- provision of financial, fiscal, and taxation incentives;
- levying of tariffs and surcharges;
- administration of guidance;
- development of technology and disclosure of information; and
- setting up of an agenda.

Now the question is how to combine these policy tools for optimal utilization through PPP. The number of participating entities in the government environmental issues is rather large. These include, the local authorities, academia, engineers, universities, enterprises, citizens, NGOs (non-governmental organizations), and other such related entities. These entities have different interests, and a mutual trust among them has not been cultivated as yet. I believe that the PPP can be approached in the following stages.

The first stage relates to the confidence/consensus building in the policy while selecting policy direction and tools. While making the choice of policy tools, policy-makers should evaluate the necessity, effectiveness, and the emerging side effects of the said policy tools through extensive research and exchange of views among the related entities. In most cases, the issues are studied and evaluated by the related government authorities, interested parties, and advisory committees through the related ministries, public comments, and consultation with the coalition parties. It also needs to be realized that only the government bureaucrats alone cannot reach a reasonable conclusion. Thus, what is required is a partnership between the public and private sectors.

The second stage is to evaluate the effectiveness of the policy implementation. With regard to this, positive attitude of the enterprise is of utmost importance. As in the guarantee programme of the industrial sector, introduction of environmental accounting, issue of environmental report, and disclosure of the related information can be effective only if the enterprises work in a cooperative manner. It goes without saying that the fiscal, financial, and tax incentives as well as provision of useful information by the government may motivate the enterprise into taking positive initiatives. In Japan, the government and the industry, for example, are undertaking a three-hour movement to establish a food recycling economic system. For this purpose, cooperation of the citizens is indispensable.

The third stage mainly comprises keeping a close watch on the rules and regulations. Where the regulatory measures are in effect, the related private sector, especially citizens or NGOs, may play the role of a watchdog, keeping a close eye on the policy tools. If the pollution issues become quite serious, the citizens residing in the vicinity of the polluting industries may take stock of the situation to find a viable solution.

Also, environment assessment for the big projects is now becoming mandatory. This may facilitate in making the citizens, especially the people living in and around big projects, more aware, which in turn will make surveillance process more effective. Currently, the evaluation system for CSR and the environmental issues is becoming more effective and efficient, and it is believed that enterprises will adhere to the rules and regulations by becoming more transparent.

This initiative has many takers in Japan. There is an increasing feeling that the market mechanism has to be adjusted from the standpoint of social values. Here again, partnership between the public and private sectors has to be established in an appropriate manner to avoid any kind of failure. For this purpose, authentic information has to be provided. Although, to some extent, the overall situation has improved in Japan with technological innovation, advancing academic analysis, and alterations in the surrounding conditions, fresh input in the form of new information and knowledge would be a pre-requisite for establishing the PPP mechanism. Also, attempts should be made to intensify the communication between the public sector and the private sector.

In this regard, the communication should essentially be between the central and the local governments as part of the public sector, and business houses and citizens as part of the private sector. This will enable mutual trust and provide a firm ground for the development of PPP.

Further, the level of discussion should be raised, and it goes without saying that the level may depend on the status of environment education in society as a whole. We have to ensure that the technology and knowledge advance everyday. Both the public and private sectors should contribute in improving and innovating the way of analysis, enhancing scientific knowledge, and increasing the level of understanding.

Thus, it can be safely said that integrating nature with human intelligence will successfully lead to sustainability. The ITEXPO held in 2005 under the auspices of Zoichulu Enamori achieved greater success and was a remarkable sight for visitors. It surely is a successful example of PPP.

Thus, the need is to improve the PPP system for enriching the environment-related policy framework and serve the purpose of solving serious environment-related concerns.



## SESSION 1

# Panel discussion



### *The role of technology in sustainable development in emerging economies*

#### Panelists

- **Dr Kazuhiko Takeuchi**, Deputy Executive Director, Integrated Research System for Sustainability Science (IR3S), University of Tokyo, Japan
- **Mr Kazuaki Koizawa**, Executive Director, New Energy and Industrial Technology Development Organization, Japan
- **Dr Alok Adholeya**, Director, Biotechnology and Management of Bio-resources Division, TERI, India
- **Mr David Ockwell**, Research Fellow, Science and Technology Policy Research, University of Sussex, UK
- **Dr Hameed Bhombal**, Senior President and Chief Technology Officer, Aditya Birla Management Corporation Ltd, Aditya Birla Group, India

The session discussed in detail the role of technology in sustainable development. Each panelist gave a laconic picture of the emerging significance of technological innovation, along with specific technology development and transfer, and initiatives undertaken by various institutes or country as a whole.

Dr Kazuhiko Takeuchi elaborated on the establishment of resource-recycling society in Asia. He stressed on the fact that the recycling of waste material is critical to the sustainability of mankind. This is reaffirmed from the fact that the amount of waste material in the world is expected to more than double from 12.7 billion tonnes in 2000 to 27 billion tonnes in 2050. According to the basic law delivered in June 2000, Japan, a sustainable society, reduces consumption of natural

resources and minimizes environmental load by reducing waste generation and adequately recycling/disposing the wastes. According to the law, a 3R initiative has been promoted, where 3R stands for reduce, reuse, and recycle. According to the data from the Ministry of Environment, the migration volume of hazardous wastes across borders especially among Japan, China, and Korea has increased significantly; therefore, it is essential to look up to ideal resource-circulating society where products and wastes are managed in an integrated manner. Dr Takeuchi emphasized that Japan, as a country belonging to East Asia, should cooperate in formulating a vision towards sustainable society including promotion of a resource-circulating society in China.

Mr Kazuaki Koizawa gave a succinct account of NEDO's (New Energy and Industrial Development Organization) activities in technology development and energy conservation. Highlighting efforts at developing and further advancing the photovoltaic technology, for example, in Japan, he asserted, 'Though the costs of the technology have declined, further research and development efforts are required for practical application of this technology.' The particular challenge facing the government of Japan is to achieve the target under Kyoto Protocol. Thus, efforts have been made to identify areas for energy conservation, particularly in the industry and transport sectors. Accordingly, for encouraging technological efforts in this direction, the right fiscal, policy, and regulatory environment is being set. EAGLE (Coal Energy Application for Gas, Liquid, and Electricity), a project initiated by Japan, aims towards effective utilization of coal, as it poses one of the major challenges for energy utilization. Initiatives are being taken not only with Japan in focus, but a spread of technologies to other Asian countries is also being considered. He again emphasized mutually benefiting partnerships among India, China, and Japan.

Dr Alok Adholeya brought forth the fact that technological development meets the economic and environmental needs of the present while enhancing the ability of future generations to meet their own needs. A look at *UNIDO Outlook* shows that a small number of industrialized countries provide practically all the world's technology innovation. Some developing countries are able to adopt these

technologies in production and consumption, while the remaining part is technologically disconnected—neither innovating nor adopting external technologies. There is a need to break this trend in view of the rising greenhouse gas emissions. The need of the hour is environmental technologies that make sustainable development possible by reducing risk, enhancing cost-effectiveness, improving process efficiency, and creating products and processes that are environmentally benign. One such technology is the Arbuscular mycorrhizal biofertilizer, which is an innovative technology developed by TERI for the fields of forestry, agriculture, horticulture, and environment conservation. In view of rapidly declining fossil fuels and increasing world energy demand, alternative sources of energy are being researched and developed. One such example is bio-diesel from jatropha, which has immense potential. It is now essential to think of environment and economics, along with technology, to make technology viable for the future.

An important feature of this session was the paper presented by Dr David Ockwell on the Asian launch of the G-8-Summit-commissioned Indo-British study, to assess the barriers to transfer of low carbon energy technologies between the developed and developing countries. Presenting major considerations and recommendations that emerged from the study, he pointed out that what needs to be realized is that technology transfer does not happen in isolation; it needs to take place as part of a broad approach to technological change within emerging economies. Technology transfer is not just about the transferring hardware; what is integral to the concept is the flow of knowledge and expertise, which stimulates technological capacity.

Addressing issues of historical high cost of energy in emerging countries and sustainable industrial technologies, Dr Hammed Bhombal pointed out to the panel that the question is how to make the step change in sustainable technologies? How to utilize the high scientific base and rich research history of United States, Japan, and Europe to develop the next generation of industrial processes for a more sustainable global economy.

It was commented during the session that along with technological innovation, it is essential to have a change in the socio-economic

structure of emerging economies. A change in the mindset and expectations of people, coupled with technological innovation, is required. A broader view of technology, encompassing society, human behaviour, and certain basic value systems, needs to be taken. It is required that there is international consensus with regard to the undesirability of the path the world today is treading on.

## SESSION 2

# Keynote address



### ***Toyota environmental technology strategies towards sustainable mobility***

#### **Keynote address by**

**Mr Tetsuo Hattori**, Senior Managing Director,  
Toyota Motor Corporation, Japan

A plot of GDP (gross domestic product) per capita and average passenger travel in various countries over a number of years from the *WBCSD (World Business Council for Sustainable Development) Mobility 2001 Report* indicates that in all countries, as per capita GDP increases, average passenger travel grows. 'Mobility' can be thought of as an essential factor of sustainable economic growth.

The global population is currently 6.3 billion, and a total of 840 million automobiles are in use around the world. But there is a large difference in the ownership rates between the developed and the developing countries. According to statistics, the global population will reach 9.1 billion mark in 2050.

If we assume that ownership rates will remain the same as what they are today, global automobile ownership will exceed one billion mark. If, however, we assume that the developed and developing countries will have the same rate of automobile ownership, then the number of vehicles worldwide will increase by approximately seven times its current figure.

The increase in motor vehicles, in line with the increasing global population, leads to economic growth and an improved standard of living. However, it also results in a number of negative factors including concerns on energy issues, increased CO<sub>2</sub> (carbon dioxide) emission, atmospheric pollution, and increase in traffic congestion and accidents.

Eliminating these negative aspects while enhancing the convenience and comfort of automobile ownership is the objective of achieving sustainable mobility for the 21st century. Toyota's approach to environmental technology strategies related to automobiles is to address three fundamental issues: energy, CO<sub>2</sub> emission reduction, and air pollution prevention.

A look at the energy issues reveals that in the future, global energy demand will continue to increase, and it will be necessary to utilize energy sources other than fossil fuels. Today, motor vehicles depend almost entirely on petroleum. But we think that automotive fuels will also have to diversify in response to soaring petroleum prices, rising concern about depletion of petroleum reserves, and other pressures.

The concentration of CO<sub>2</sub> in the atmosphere has been increasing rapidly since the Industrial Revolution. About one quarter of the world's CO<sub>2</sub> emissions come from the transport sector, and most of this is from automobiles. This is why Toyota, as an automaker, is making an all-out effort to improve fuel efficiency and reduce energy consumption in the automotive manufacturing process.

A look at NO<sub>2</sub> (nitrogen dioxide) emissions in Japan reveals that the environmental impact from motor vehicles, particularly diesel vehicles, is still very large. Changes in exhaust emission regulations on gasoline and diesel vehicles point to the fact that numerous measures to control emissions have been taken in the past. But it is necessary to reduce NO<sub>x</sub> (oxides of nitrogen) and PM (particulate matter) from diesel vehicles even further. The Toyota Group is taking steps towards this end.

## TOYOTA'S EFFORTS

The company believes that automotive fuel diversification will be the inevitable result of structural changes in global energy demand. For the time being, the mainstream automotive fuels will continue to be gasoline and diesel fuel. In the future, we are likely to enter a period when suitable new automotive fuels will be selected and utilized from among the wide array of alternative fuel categories of synthetic fuels, biofuels, gaseous fuels, hydrogen, and electricity. However, for the next two to

three decades, we believe that the mainstream automotive fuel will continue to be petroleum.

It is imperative that we curb the consumption of precious petroleum by pursuing technological innovation in our gasoline and diesel vehicles, which will also reduce CO<sub>2</sub> emissions. At this time, however, there are many 'barriers' with respect to alternative fuels, for which there is no magic solution. These barriers include the difficulty of using such fuels for automobiles, an inability to supply sufficient volumes of fuels, and the generation of large volumes of CO<sub>2</sub> during the manufacturing process. For the future, we think, we should continue to explore the potential of all alternative fuels, while supporting the popularization of those with the greatest potential.

Since gasoline and diesel will continue to be mainstream fuels, it is imperative to describe the situation regarding the development of technology for gasoline and diesel vehicles. Toyota is working towards increasing the efficiency and performance of gasoline engines through measures such as fundamental combustion analysis, thorough friction reduction, weight reduction, and further advances in VVTI (variable valve timing injection system) and direct injection.

For diesel engines, Toyota is employing inline four-cylinder engines with piezo injector technology for clean performance and high output together with quiet operation. And we are utilizing our clean diesel DPNR (diesel particulate NO<sub>x</sub> reduction) technology. In the future as well, we think it is necessary to continue developing clean diesel technology.

For transmissions, we are making advances in enhancing efficiency and the 'acceleration feel' through multi-range automatic transmissions and switching to CVT (continuously variable transmission).

The company is continuing its efforts to improve engine performance. At the same time, it is also working to improve fuel economy through increasing the thermal efficiency of both gasoline and diesel engines.

Toyota's efforts in using alternative fuels also need to be mentioned. It is believed that smaller the volume and mass of the energy source that moves automobiles (in other words higher the energy density), better the energy source. On comparing the energy densities of various liquid fuels, gaseous fuels, and batteries, it is evident that for automotive use, liquid fuels have an overwhelming advantage. Accordingly, the company

believes that it is appropriate to begin utilizing compressed natural gas, electricity, and hydrogen, which have relatively low energy density, for short travelling distances.

A comparison of the well-to-wheel CO<sub>2</sub> emissions of various fuels, when gasoline is set at 1, that is to say, the total volume of CO<sub>2</sub> emitted from the point of making each fuel through consumption of that fuel by motor vehicles, indicates that among the alternative fuels, biofuels offer encouraging prospects. This is mainly because of the fact that biofuels are manufactured from plants that absorb CO<sub>2</sub> from the atmosphere as they grow. This offsets the volume of CO<sub>2</sub> emitted during production and reduces the well-to-wheel CO<sub>2</sub> emission volume. In addition, fuels have high energy density. However, the major issue of insufficient supply remains unaddressed.

Toyota has been making some efforts to use biofuels. As mentioned earlier, one problem about biofuels is their limited supply. For example, current bio-ethanol production capacity covers only about 1.8% of the world's total gasoline consumption. Even by 2020, bio-ethanol production capacity is expected to cover less than 10% of the world gasoline consumption. The prospects for bio-diesel fuels are even lower, with supply capability expected to reach less than 5% of the world's needs by 2020.

The fact that the raw materials of bio-ethanol production, such as sugar cane, are also consumed, presents significant difficulty in maintaining sufficient supply volume, stability, and a low price. As a solution, cellulose bio-ethanol technology is now under development around the world, which would enable the use of grasses and wood as raw materials. However, commercialization of such processes is still a far off dream. To handle bio-ethanol at high concentrations, measures are also needed to enable vehicles and filling stations to avoid adverse effects such as corrosion of metal. Consequently, we believe that the most effective message for the time being will be the use of gasoline with low concentrations of bio-ethanol—10% or less at existing gas stations.

Toyota has made all its gasoline engine vehicles currently in production technologically compatible with gasoline, which includes using up to 10% bio-ethanol so as to ensure durability during use. We believe that when cellulose ethanol and other technologies will be

further developed and supply of large volumes at low cost will become possible, the creation of exclusive ethanol gas stations and the widespread use of high-concentration ethanol fuels will become feasible solutions. In the Brazilian market, where bio-ethanol is widely available, we will introduce FFVs (flex-fuel vehicles) during the spring of 2007, which can operate on 100% ethanol. In the United States also, we are considering introduction of FFVs in the near future.

Let's have a look at hydrogen fuels. Hydrogen has several advantages, including its ability to be produced from any primary energy source and lack of any hazardous emissions or generation of CO<sub>2</sub> during operation. However, there are many challenges to overcome, so we believe it will take some time before the use of hydrogen becomes a viable option.

Toyota's research and development in fuel cell technology is also wide ranging. The fuel cell stack forming the heart of our fuel cell vehicles is developed in-house. In addition to use in passenger cars and buses, we, together with the Toyota Group companies, are developing it for a variety of applications, such as residential cogeneration systems and forklifts.

Toyota is making a steady progress in overcoming the technical challenges presented by fuel cell vehicles. For example, it has verified start-up and driving in an actual vehicle at temperatures as low as -30 °C. Moving forward, the company is continuing technological development to shorten the start-up time and enhance fuel cell stack durability, among other issues.

We are making progress on solving these technology issues, but as an auto manufacturer, the biggest issues we face are reducing costs and increasing cruising range so that we can actually commercialize fuel cell vehicles. At the same time, building infrastructure for a hydrogen-based society is also a major issue. We think that fuel cell vehicles will move to the level of widespread use once these issues are resolved and demand from society grows.

Let's focus on what the company is doing with regard to electricity. Electric cars have a long history, but issues of cost and cruising range remain unresolved even with the latest technology, thereby limiting them for short-distance urban use. When it comes to using electrical energy for a car for everyday use, one approach – plug-in hybrid that incorporates our hybrid technology – which we are researching and

developing, has a real potential. The plug-in hybrid usually recharges its batteries at home using off-peak electricity. Running on just this stored electrical energy, it operates as an electric vehicle for short trips around town. But for longer trips and high-speed driving, it operates as a conventional hybrid vehicle.

Although the benefits differ depending on a country's electric power situation, plug-in hybrid vehicles are considered to offer tremendous future potential, including advances in alternatives to petroleum, reduction in CO<sub>2</sub> emissions, lower fuel costs for users, and reduction in atmospheric pollution through the use of electric vehicles in urban areas.

However, this is not a technology that can be put to immediate practical use, and development of innovative batteries is still necessary. When we consider travelling 60 km on battery power, approximately 12 times the battery capacity of the current Prius would be necessary, making it infeasible as a vehicle.

It is essential to explain Toyota's hybrid technology, which it has positioned as a core technology that can be used with all of the other technologies. Hybrid systems combine two different power sources, an engine and an electric motor, making use of the strong points and supplementing the weak points of each to achieve high-efficiency driving.

While the engine operates at maximum efficiency, energy stored in the battery is reused during acceleration, and energy is stored in the battery during deceleration and when there is surplus energy. By doing this, hybrid vehicles can increase fuel efficiency, reduce CO<sub>2</sub> emissions, achieve cleaner emissions, and improve acceleration performance. As a result of these advantages, the CO<sub>2</sub> emissions of gasoline hybrids are approximately 50% lower than those of conventional gasoline vehicles.

From the time the Prius was launched in 1997, it seeks to combine environmental aspects with driving performance. By combining suitable features and styling particular applications and markets, Toyota hybrid cars have been acclaimed highly throughout the world. In 2005, Toyota's global sales for hybrid vehicles were 230 000 units, and as of August 2006, the cumulative sales had passed the 750 000 mark. With the rising worldwide trend towards energy conservation, expectations from hybrid vehicles are growing ever stronger. We look forward to achieving sales of one million hybrid vehicles by 2010.

## Towards the ultimate eco-car

Toyota is committed to technological development in the quest for the ultimate eco-car that will contribute to realizing sustainable mobility. Toyota believes that it is important to take not just one path, but to base its approach on the concept of ‘the right car, at the right place, at the right time’, in accordance with energy trends, taking into consideration the global market.

The company believes it will come close to the ultimate eco-car by its efforts towards improving the fuel efficiency of gasoline and diesel vehicles, further utilizing biofuels or electricity, and applying hybrid technology to each of these, such as plug-in hybrids and fuel cell hybrid vehicle. From this perspective, we are convinced that hybrid technology will truly be a core technology in the future as well.

Toyota is seeking to completely eliminate the negative impacts of vehicles – such as environmental pollution, and traffic accidents and congestion – and maximize the fun, excitement, and comfort they provide. In other words, we are seeking to balance ‘zeronize’ and ‘maximize’ in order to contribute to the realization of sustainable mobility.

As showcased at last year’s EXPO 2005 AICHI, Japan, automobiles are progressively becoming more and more personalized and automated; and there is also a need for a change in the traffic infrastructure, such as roads.

Toyota is undertaking technological innovation that will contribute towards the realization of an ideal mobile society—a society which produces zero emissions and is super energy efficient; a society without traffic-accident-related injuries and casualties; a society without traffic congestion; and a society where transport offers a high level of fun and comfort.

## SESSION 2

# Panel discussion



### *Setting technology goals for 2050*

#### **Panelists**

- **Mr Teruaki Masumoto**, Vice Chairman, The Federation of Electric Power Companies, Japan
- **Mr Mark Runacres**, former acting High Commissioner of the United Kingdom in India (currently Visiting Senior Fellow, TERI, India)
- **Dr Leena Srivastava**, Executive Director, TERI, India
- **Dr Graham Baxter**, Vice President, Corporate Responsibility, BP plc, United Kingdom

**M**r Teruaki Masumoto accentuated on the need for a 'paradigm shift' in the wake of rising concerns for climate change and energy security. The envisioned shift is to change our society from the one in the 20th century characterized by 'mass consumption and heavy reliance on hydrocarbons' to the 'low-carbon and high-energy efficient society'. The society needs to move in the direction of 'ultimate resource productivity'; while recognizing the diversity among regions and countries. The 'present lifestyle' has developed in the last 50–60 years. So, for the 'paradigm shift' to bear fruits in the future, it is the responsibility of the present generation to start now.

A move towards a low-carbon and high energy-efficient society would require implanting energy efficiency in the infrastructure, thus demanding technological solutions. No technology, on a stand-alone basis, can achieve the paradigm shift. There is a need to bring segments of knowledge and expertise together, and propel them to move in one direction. This, in itself, cannot be achieved without enhancing cooperation among various stakeholders. It is essential to create platforms for bringing together all stakeholders to enable

communication, information sharing, and co-working for realizing the paradigm in the next 50 years.

Mr Mark Runacres brought out the important role of leadership in setting technology goals for 2050. 'We need leadership, which goes beyond the average, beyond the national, and often beyond the routine international.' The need is to change the fundamental way the society uses technologies rather than just a change in the technologies themselves. There is a need to carefully look at financial underpinnings of our technology targets for sustainable development, especially with regard to developing countries such as India, where finance is the need in other critical energy areas.

Another issue in setting technological goals is 'taking account of the appropriateness of technology'. At present, there is enormous failure on part of both the developing and developed worlds to grasp that, for the success of their technologies, it is critical to have joint ventures. Issues of IPR (intellectual property rights) still very much surround us. Another area that needs impetus is the confidence between the civil society and business. These are some extremely important issues that need consideration while drawing the technology agenda.

'Energy drives development and energy technology drives sustainable development,' opined Dr Graham Baxter. Energy's role as a driver of development, including in the fast-growing economies of India and China, cannot be underestimated. The UNDP (United Nations Development Programme) also observed that none of the MDGs could be met without major improvement in the quality and quantity of energy services in developing countries. Dr Baxter emphasized that use of energy is inevitable for development and the reason we don't run out of oil and gas is that we keep developing technology to find it, reach it, and deliver it.

There are now new ways to use renewable technology to provide people with energy access. For instance, BP has helped five million people have access to energy through rural solar energy over the past five years. Thus, energy can be made sustainable through technology. He emphasized that there are resources to provide energy for development and the good news is that there are key technologies at present to make its use sustainable. For example, in India, BP works with

its partners to develop pioneering efficient and low-cost *chulha* (stoves) that reduces air pollution dramatically. To address the larger challenge of climate change, BP is developing solutions for three key sectors emitting carbon dioxide: power, buildings and industry, and the transport sector. In the transport sector, for example, it is closely looking at biofuels—working with TERI on this for jatropha plantations on semi wastelands. In solar energy, BP has particular plans. The solar business plans to increase sales of solar panels from 110 MW (megawatts) of capacity in 2005 to 300 MW in 2008.

Dr Leena Srivastava mentioned that we should be aware of the existing background in which we are setting up technology goals for 2050. By 2050, India would certainly be a more populous country and probably a more prosperous one. But food security and energy security – due to the enormous pressure that progress places on natural resources, such as land, water, solid waste, and fossil fuels – would be key concerns that would have to be addressed by the technology goals and technology priorities that are set.

Technology and management inputs for achieving food and energy security would have to be made in conjunction with terms of policies, terms of finance, governing structure incentives, etc., that would provide a conducive environment in which these technologies can thrive. The use of cleaner fuels, solar energy, and biomass would definitely reduce the ecological footprint set by progress on our natural resources. She concluded by saying that it is most important that technology goals set for 2050 focus on natural resources as well as material users efficiency.

It was stated during the course of the session that the issue of urbanization needs to be highlighted in the sustainable development agenda. Urbanization has been happening at a rapid pace and India and China are no exception to this phenomenon, thus disrupting the environment and worsening living conditions. In wake of the rising urbanization, proper planning for the cities, ensuring environmental sustainability, and developing appropriate technology, is crucial.

Another issue of concern is that, in addition to financial underpinnings of required technological change, one also needs to look into securing enough human resources. This includes the need for scientists, engineers

and planners, experts, and apt leadership. These assume enormous importance, and need to be available to give us the technology path that we are looking for in the future.

The cost of renewable energy was yet another issue of concern. Though a number of programmes have been initiated for renewable energy, costs certainly pose a major challenge for these alternative sources of energy. It is imperative that we take proper cost–benefit analysis of different energy sources and internalize the environmental costs associated with the conventional sources while comparing with the renewables.



## Keynote address



### ***Pathways for sustainable development and energy future***

#### **Keynote address by**

**Dr Tsutomu Toichi**, Senior Managing Director and Chief Knowledge Officer, Institute of Energy Economics, Japan

The keynote address succinctly covered the global energy scenarios by IEA (International Energy Agency), along with a case study of Japan undertaken by IEEJ (Institute of Energy Economics, Japan), and concluded with the policy implications.

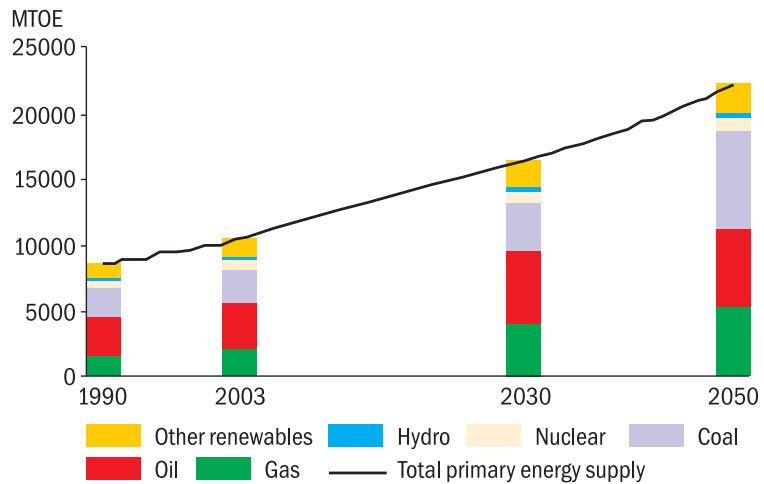
Amongst many other issues, the DSDS (Delhi Sustainable Development Summit), held in early 2006, highlighted two major ones. First related to energy: the missing MDG (Millennium Development Goal). It was stated that despite modern energy sources being important units of basic sustainability, 1.6 billion people have no electricity in their homes and 2 billion people use traditional fuel sources for cooking and heating. The second issue brought up was with regard to energy for sustainable development. Here, the importance of renewable energy sources and energy efficiency was emphasized. Since the world will continue to rely on fossil fuels, advanced energy technologies, including fossil fuel technology, should be developed on a priority basis.

At the Gleneagles Summit, July 2005, it was decided to act with resolve in meeting the goals of reducing greenhouse gas emissions, improving the global environment, enhancing energy security, and cutting air pollution, in conjunction with vigorous efforts to reduce poverty.

It was expected that 'IEA will advise on alternative scenarios and strategies aimed at a clean, clever, and competitive energy future.'

Three scenarios were analysed by IEA: baseline, ACT (accelerated technology), and TECH Plus. In the baseline scenario, it is expected that if the current trends continue then the energy demand world over would increase by more than 1.2 times by 2050. Fossil fuels like gas, oil, and coal would account for an overwhelming share, nearly 90% of the total demand, implying an unsustainable future (Figure 1).

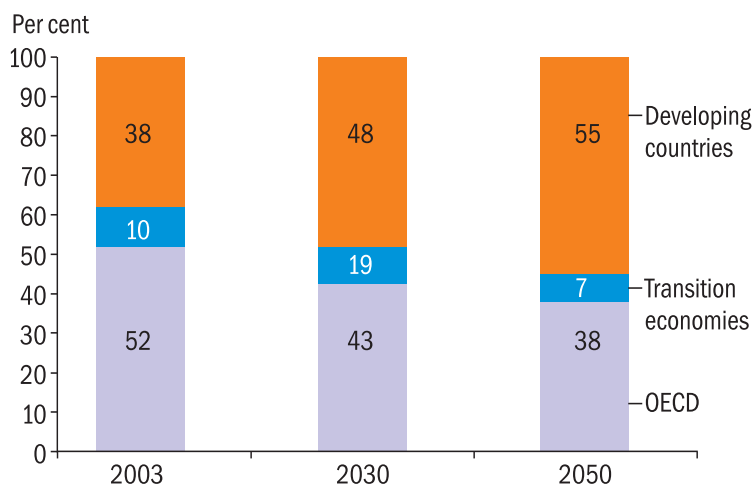
**Figure 1** Total primary energy supply by fuel for the world in the baseline scenario



**Source** IEA (International Energy Analysis). 2006. *Energy Technology Perspectives*. Paris: IEA

Therefore, one of the aims of the IEA studies is to analyse ways of setting right such a trend. A look at the energy demand by region in the same scenario reveals that by 2050, developing countries would account for 55% of the global energy demand (Figure 2). Maximum energy demand is likely to come from India and China that have burgeoning populations.

The ACT and TECH Plus scenarios, as part of their assumptions, analyse the impacts in terms of R&D (research and development), demonstration and deployment measures, and incentive equivalent to \$25/tonne of CO<sub>2</sub>

**Figure 2** Primary energy demand by region in the baseline scenario

Source IEA (International Energy Analysis). 2006. *Energy Technology Perspectives*. Paris: IEA

(carbon dioxide) for low-carbon technologies, which will be implemented world wide from 2030 onwards. However, individual scenarios differ in terms of assumptions for key technology areas, as exemplified in Table 1.

**Table 1** Technology assumptions

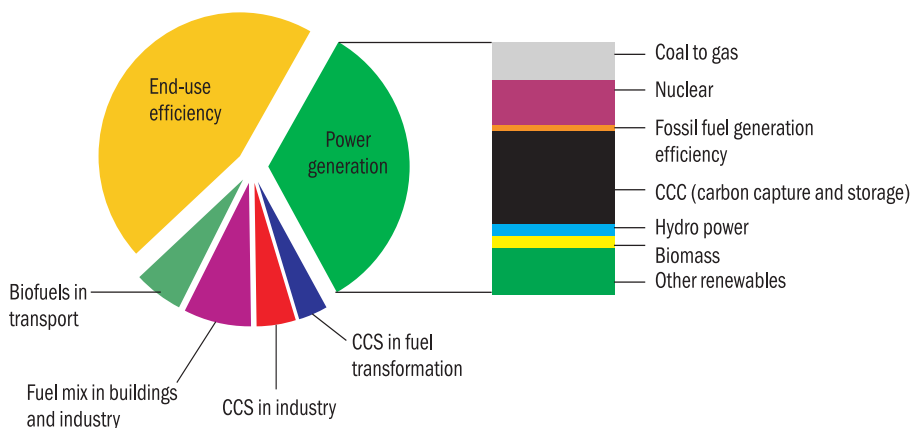
Technologies	ACT Map	TECH Plus
Renewables	Relatively optimistic across all technology areas	Stronger cost reductions
Nuclear		Stronger cost reductions and technology improvement
CCS (carbon capture and storage)		Breakthrough for fuel cell
H <sub>2</sub> fuel cells		
Advanced biofuels		
End-use efficiency	Two percent per annum global improvement	

Table 1 depicts various technologies representing the supply side and the end use efficiency. Assuming that the world GDP (gross domestic product) would grow by 2%, 3%, or 4% up to 2050, the end-use efficiency would have to improve by 2% per annum. This is rather ambitious under both the ACT and TECH Plus scenario. On the supply side as well, the assumptions across all technology areas is relatively optimistic for the ACT Map scenario. Technological advancement and applications are assumed to be even more accelerated in the TECH Plus scenario.

The IEA analysis results for the global CO<sub>2</sub> emissions for the period 2003–50 for the three scenarios reveals that in the baseline scenario, the CO<sub>2</sub> emission would increase by 137% by 2050, with the transport and the power sectors accounting for the major share. It is also evident from the analysis that under the ACT Map scenario, it is possible to revert to the emission levels of 2003. This is especially possible because of a drastic reduction in the emissions from the power sector as well as the industry and transformation sectors. Transport sector is yet another area in which a major reduction in the emissions can be expected. In the ACT scenario, without CCS (carbon capture and storage), and the low efficiency scenario, the emissions could be more than the 2003 level in 2050. In the TECH Plus scenario, with the application of all the technologies currently available, it is possible for the emissions to fall even below the 2003 level.

Emissions reduction by technology area in the ACT Map scenario shows that it is the end-use efficiency that would hugely contribute in reducing the CO<sub>2</sub> emissions (Figure 3). The power sector is yet another area contributing largely to emissions reduction. CCS followed by nuclear and other renewables also contribute significantly towards reduction in emissions. As has been repeatedly discussed, the transport and power sectors are the crucial sectors for reducing the emissions according to the scenario analysis.

It is essential to look at liquid fuel supply, especially when 98% of the transport sector relies on liquid fuels. According to the IEA baseline scenario, if the current situation is maintained then the liquid fuel supply would increase to seven billion tonnes of oil equivalent by 2050. Despite adding the synfuels, the conventional oil demand would continue to increase. However, according to the ACT Map scenario, in spite of limiting

**Figure 3** Emissions reduction by technology area: ACT map scenario

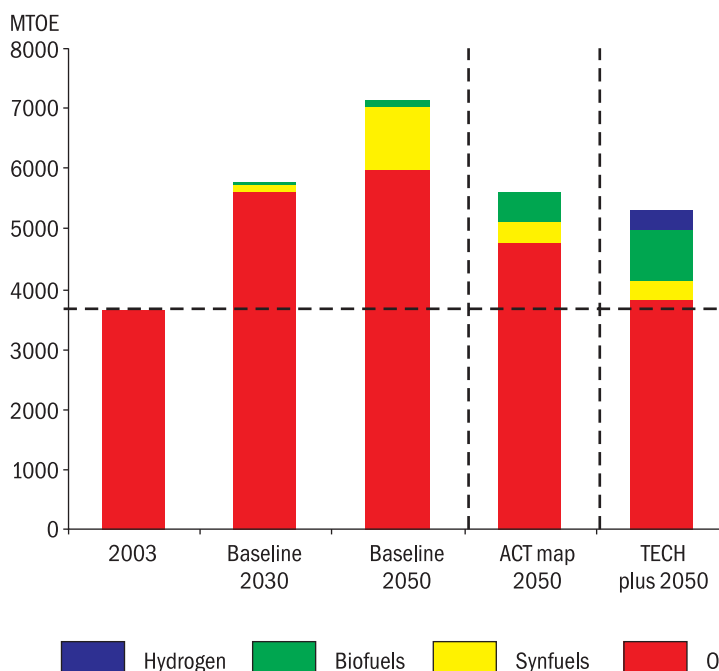
**Source** IEA (International Energy Analysis). 2006. *Energy Technology Perspectives*. Paris: IEA

the growth in oil consumption, it would grow in comparison to the 2003 level. However, production of, and dependence on, both biofuels and synfuels would increase by 2050.

The trends for the TECH Plus scenario reveal that total fuel supply would increase by less than 10%, and there is more of an increase in hydrogen and biofuels in this scenario. It is evident from the scenario analysis that the supply of liquid fuels increases slightly. It is, therefore, expected that it is only in the second half of the 21st century that one can expect a reduced dependence of the transport sector on oil and liquid fuels. The IEA scenario results show that although there will be less reliance on liquid fuels in the transport sector, their consumption cannot be reduced even with the introduction of new forms of fuels (Figure 4).

Key findings of the IEA scenario analysis are summarized below.

- CO<sub>2</sub> emissions can be reduced to today's level by 2050.
- Most energy would come from fossil fuels even in 2050.
- Growth in oil and electricity demand can be halved by way of end-use efficiency and energy saving.
- Power generation can be substantially de-carbonized by 2050.
- De-carbonizing the transport sector will take longer but must be achieved in the second half of the century.

**Figure 4** World liquid fuel supply by scenario (2003–50)

**Source** Adapted from IEA (International Energy Analysis), 2006. *Energy Technology Perspectives*. Paris: IEA

The policy implications emerging from the analysis imply that a more sustainable energy future is possible with the known technologies and the costs are not out of reach. However, what are needed are urgent actions in the public and private sectors. Efforts are required to overcome barriers for adopting energy-efficient technologies; enhancing R&D; accelerating demonstration and deployment; and also providing clear and predictable incentives to encourage adoption of new technologies. A strong partnership between the private and public sectors and between the developed and developing countries is immensely essential to stimulate such efforts.

Similar to the IEA study, The Institute of Energy Economics, Japan, studied the sustainable energy future in Japan. The main assumptions and conditions of the study took into account the socio-economic structure, crude oil price, energy conservation, nuclear power, and new

energy. The reference case and technology development case were the two scenarios analysed in the Japanese study.

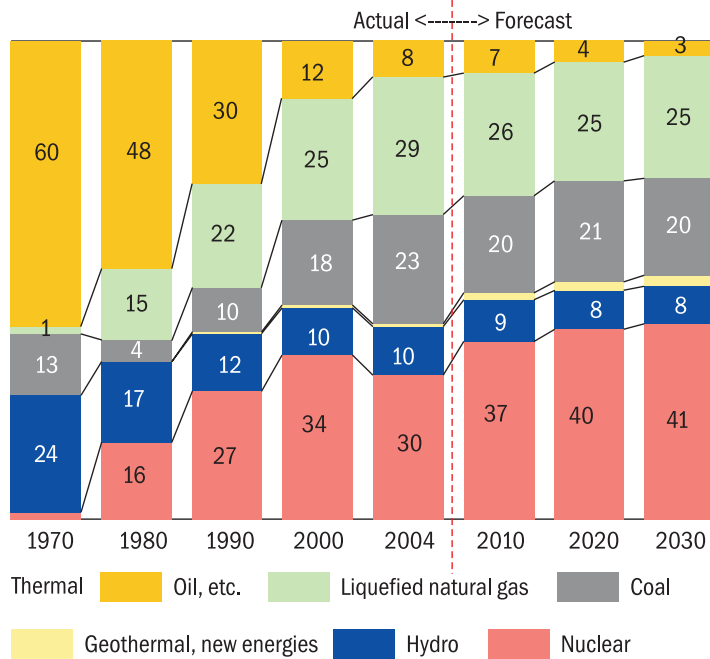
As to the Japanese socio-economic structure, the population reached its peak level of 128 million in 2004 and is forecasted to decline to 117 million in 2030, implying a 10% reduction. While the world economy is assumed to grow at 3% annually from 2004 to 2030, the Japanese economy would grow at 2% up to 2010, 1.5% up to 2020, and 1.1% by 2030. The economy would be shifting to higher value-added industries and progress in services and IT industries.

Although an analysis of the prospects of primary energy price shows a correction in the high price trend of oil, the price would go up and by 2030, it would reach \$45 or in nominal terms it would be \$70–\$75. On the other hand, the prices of coal would continue to be rather low. According to the study results, for the reference case, the percentage of coal in the primary energy mix for Japan would come down to 18% by 2030. As for oil, currently at 47%, the figure would come down to 37% by 2030, and the share of natural gas and nuclear energy being 18% and 20% respectively. The share of renewables mainly comprising hydro power, solar energy, wind energy and so on would be mere 7%. Thus, in reference case, their share does not increase dramatically.

The study also reveals that in the power generation mix, nuclear energy would comprise a share of 41%, hydro power 8%, and liquefied natural gas 25% by 2030. It is clear that the Japanese power generation mix will go for decarbonization in a rather stable and steady manner (Figure 5).

In the technology development case, without going into the details of the assumptions, the energy use technologies are more advanced than the reference case. In the technology development case future energy conservation technologies are assumed to be installed for final energy consumption sectors. High efficiency is assumed for power generation, as there would be more distributed power generation and introduction of new energy sources like PV, wind power, biofuels, and so on.

A comparison of primary energy supply and final energy consumption shows that the impact of the primary energy supply is larger than that of the final energy consumption. That would be because of the efficient use

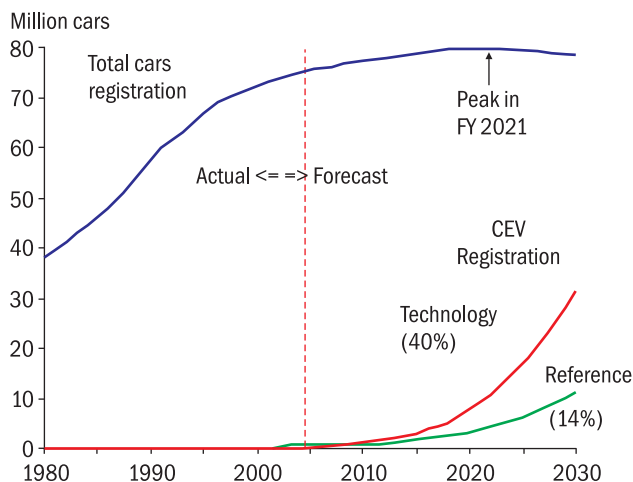
**Figure 5** Power generation mix

**Source** Results of a study conducted by IEEJ (Institute of Energy Economics, Japan)

of energy in the transformation sector (for example, saving electricity, energy conservation in the coke manufacturing process, and popularization of distributed power generation system).

The results of the study for CEV (clean energy vehicles) in Japan show an increase in hybrid vehicles to the tune of more than 10 million units by 2030 in the reference case and more than 25 million units in the technology development case. Similarly, fuel cell vehicles will increase to 5.6 million in 2030. All in all, hybrid, fuel cell, and natural gas vehicles, and liquefied petroleum gas trucks show an increase of more than 30 million units by 2030 in technology development case (Figure 6). Thus, by 2030, in the technology development scenario, in terms of stock of vehicles, 40% of total cars would be CEVs and in the reference case the figure is 14%.

The fuel efficiency of passenger cars is also expected to increase by 33% in 2030, as indicated by the study results. The results on the

**Figure 6** Clean energy vehicles

	Actual forecast				
	FY 2003	FY 2004	FY 2010	FY 2020	FY 2030
Hybrid vehicles	133	196	705 1 009	3 135 7 021	10 673 25 532
Fuel cell vehicles	0	0	5 6	30 477	75 5 616
Natural gas vehicles	21	25	43 43	128 128	342 342
LPT trucks	29	31	57 57	112 112	149 149
<b>CEV total</b>	<b>183</b>	<b>252</b>	<b>811</b> <b>1 116</b>	<b>3 405</b> <b>7 738</b>	<b>11 238</b> <b>31 638</b>

**Source** Results of a study conducted by IEEJ (Institute of Energy Economics, Japan)

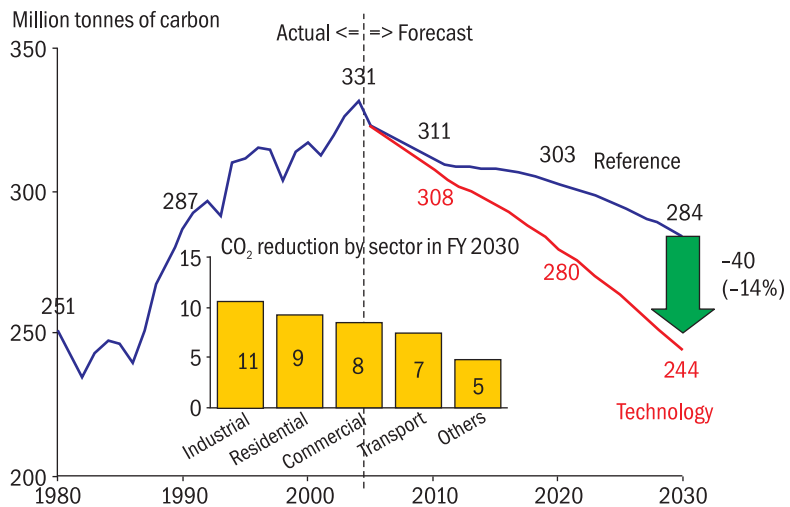
efficiency of electrical appliances show that there is ample room for energy conservation as depicted by the two scenarios.

Next let us consider the potential CO<sub>2</sub> emissions reduction of Japan. Currently, according to Kyoto Protocol, compared with 1990 baseline, Japan's CO<sub>2</sub> emissions are 7%–8% times higher than the baseline.

While in the reference case, the emissions revert to the 1990 level by 2030, in the technology development case, the emissions are further reduced by 14% below the 1990 level, thus implying a drastic reduction in CO<sub>2</sub> emissions (Figure 7). However, for such a reduction in CO<sub>2</sub> emissions, it is important that there is technology advancement and also greater uptake by society.

It is also essential to look at CO<sub>2</sub> emissions for the Asian region as a whole. Our institute estimated an increase of 300 million tonnes of carbon equivalent by 2030 in the Asian region. Japan's share in emissions does not increase, whereas it increases for India, China, and other Asian countries. The exclusive increase in emissions from China and India is because of the dramatic increase in the crude oil consumption in both the countries.

**Figure 7** CO<sub>2</sub> emissions



**Source** Results of a study conducted by IEEJ (Institute of Energy Economics, Japan)

Such results imply that no matter how much efforts are made in Japan to control the emissions, it still won't be responsible globally for CO<sub>2</sub> emissions reduction. So, in terms of energy efficiency, Japan is certainly the top runner compared with the rest of the world. According to current exchange rate, the per capita energy efficiency of Japan is six times

higher compared to India and China. Thus, this implies that Japanese energy conservation technology is very advanced and needs to be transferred to other countries, which in itself is a big challenge.

Thus, emerging from this analysis, trends, figures, and so on are some policy implications for Japan to move ahead on a sustainable energy future path. The three main policy implications are as follows.

- 1 Technology development as a key
- 2 R&D in the transport and power sectors
- 3 Energy conservation to be given a top priority

Technology development is certainly a key for a sustainable future. For this, government support, along with international cooperation, is indispensable. Ample human resources and funds are extremely essential, and the role of market for the short and medium term cannot be undermined. Sole dependence on government efforts may not be sufficient. So the answer is to fully utilize the market mechanism and in the long term of course the role of the government is bigger.

R&D in the transport and power sectors is quite important as well. Unconventional oil of GTL (gas to liquid), CTL (coal to liquid), biofuel, and hydrogen fuel assume importance today than ever before. Coal- or gas-fired power generation with CCS is important, although its acceptability by the society is questionable. But what needs to be realized is that it is extremely important to make carbon level stable. Of course, peaceful use of nuclear power as a clean energy in post Kyoto is certain to gain momentum.

Energy conservation undoubtedly needs to be a top priority. Both top-down and bottom-up approaches by the governments need to be suitably combined. And, as has been repeatedly emphasized, the transfer of energy conservation technology to the world is an inevitable requirement.

And, lastly, the progress towards low-carbon society can be explained by means of an interesting identity.

Global capacity of fossil fuel or environment =  $P \times A \times T$

where  $P$  = population

$A$  = affluence (GDP per capita)

$T$  = technology (fossil fuel use or  $\text{CO}_2$  emission/GDP)

T also includes individual technologies, mass transport system, urban system, industrial systems, and so on.

Certainly, P is going to increase – so are the affluents – in the future and by 2050, it is expected to reach nine billion. Thus, it is the T (or technology) that will have to suppress CO<sub>2</sub> emissions from use of fossil fuel. Therefore, the role of technology can by no means be undermined; it holds the key to our sustainable energy future.

In Mahatma Gandhi's words:

*The world has enough for man's need, but not for man's greed.*

However, in today's society it is difficult to put a limit to man's greed. Thus one has to manage the excessive greed of mankind.

## SESSION 3

# Keynote address



## *How to secure sustainable energy supply in the long run*

### **Keynote address by**

**Prof. Yoichi Kaya**, Director General, Research Institute of Innovative Technology for the Earth, Japan

**W**hile addressing the future choice of energy supply, particularly with special reference to global warming, it is essential to highlight the urgent needs of decarbonization, and roles of nuclear power, renewables including PV (photovoltaic) technology, wind energy, SSPS (space solar power systems), and CCS (carbon capture and storage).

There is a necessity to reduce CO<sub>2</sub> (carbon dioxide) emissions in order to stabilize its concentration in the air. To achieve a CO<sub>2</sub> concentration of 550 PPM (parts per million) in the air, it would be necessary to reduce the CO<sub>2</sub> emissions by 80% until 2030. So, it is imperative to introduce various kinds of non-carbon energy resources.

The energy model examined by RITE (Research Institute of Innovative Technology for the Earth), Japan, gives the technology options for 550-PPM stabilization. These options include energy saving, fuel switching, using PV technology and other renewables, CO<sub>2</sub> sequestration, and so on.

A non-carbon energy future would involve the basic energy including nuclear power; renewables such as wind power, PV technology, biomass, geoheat, and other ambient energy sources; SSPS; and fossil fuels with CCS.

In order to gauge the contribution of nuclear power in mitigating global warming, carbon intensity is calculated, which is CO<sub>2</sub> emission divided by the primary energy. Looking at the real data between 1980 and 2000 in case of OECD (Organization for Economic Cooperation and development) countries, the carbon intensity decreased at an average rate of -0.6% per year. Considering the introduction of nuclear moratorium in 1980, or in other words fixing the level of nuclear power in 1980, the carbon intensity comes to 0%, that is, nil. The situation is much worse in Japan; the intensity was about -0.5% per year between 1980 and 2000, but again after introducing nuclear moratorium, increased to 0.3% per year. These calculations imply that nuclear power played a significant role in reducing carbon intensity.

The relative importance of nuclear power is underlined by the fact that it forms quite a major portion of power generation in most developed countries, starting from France to US.

However, future of nuclear power poses a number of questions, the first question being how to deal with the nuclear waste in the long run? There are essentially two ways of dealing with nuclear waste. One is to use uranium at once and then dispose it, and the other involves reprocessing of fuels and extra plutonium for breeder reactor. Japan has undertaken the second option, but it still is in the process of establishing such devices in various parts of the country. There are also problems concerning location of waste sites around the world. Yet another question is how to minimize risks, particularly in developing countries. For example, India, China, and some other developing countries have established nuclear power plants. But there are risks associated, particularly with regard to knowledge and experience of operations. And lastly, one has to find ways of improving public acceptance of nuclear power.

The future of renewables cannot be ignored while talking about non-carbon energy future. Wind power and PV technology are increasingly being looked upon as a viable option against global warming. But what

needs to be realized is that wind power and PV technology are of course important but within limits. In other words, total capacity should be much smaller than the total grid capacity, mainly due to their time changeability.

A look at the pattern of development of wind power and PV technology shows how widely distributed and accepted they are. Take the case of Germany where total capacity of wind power in 2004 was about 17 GW (gigawatts). Similarly, for other countries also the capacity is quite large. The world's total wind capacity is also quite remarkable. The share of PV technology in total capacity generation is smaller than that of wind power. Japan's PV capacity exceeds 1 GW and is increasing quite rapidly.

A survey of countrywide objectives for PV technology and wind power reveals ambitious targets. In case of Germany, for example, about one quarter of total power supply should be covered by wind power by 2025. With regard to PV technology in Japan, the present total capacity generated is 1.13 GW (2005) and is expected to grow to 4.8 GW by 2010 and 82.8 GW by 2025. Looking at the Japanese demand side, it requires an output of 160 GW, and if PV technology is expected to grow to 82.8 GW, meeting half of the total demand, the question that arises then is whether PV technology would be able to generate such a huge capacity. Both wind power and PV technology look promising, but there is a barrier of time changeability. Output of wind power and PV technology changes randomly with time, and this has serious impacts on the operation of electric power systems.

Their output changeability inevitably requires installation of those power plants that adjust their output so as to satisfy the condition of total supply equalling total demand. The facility costs of these power plants are additional costs of the grid, solely due to the introduction of wind power or PV technology. Thus, these energy forms accrue a large external cost due to the connection to the grid.

This can be exemplified in the case of Japan. The corresponding power plants – oil-fired power plants – have a capacity utilization ratio of 20%–30%. The external costs from wind power and PV technology for these plants amount to be 10–14 Yen per kWh (kilowatt-hour) (8–11 cents). These compare with the normal average cost of the electric power in

Japan, which is about 8 Yen per kWh. Thus, the costs from either of these sources are higher. Thus, these imply a heavy economic burden. In order to keep the burden low, the capacity of wind power and PV technology has to be kept much smaller than grid capacity.

Keeping in mind the high external costs in wind and PV energy forms, one needs to explore other kinds of renewable energy sources such as biomass and biofuels. The two sources that need to be mentioned are the ambient energy resources for low-temperature heat supply (residential) and SSPS for large-scale stable power supply in the long term.

A look at the share of heat in the residential energy demand shows a high percentage. For example, in the UK, it is more than 80%, even for Japan it is more than 60%, and at the moment, more than half of the heat requirement is being met by fossil fuels. The temperature required to meet this heat demand is not very high, being just 50 °C or 60 °C. Therefore, these heat demands can be met by some of these renewable sources such as the passive or active use of solar power, and also by utilizing ambient energy resources as low-temperature heat source for heat pump. These ambient energy sources have large heat capacity and are available almost everywhere. These include water in oceans, rivers, reservoirs, and so on; air; and also shallow underground geoheat.

Geoheat is already being utilized in various countries. It has certain merits as it is available almost everywhere, and its temperature is higher than that in other ambient energy resources. For example, in Sapporo city of Japan, the temperature is 10 °C at the depth of 10 m even in winter. However, its only demerit at present is its high cost.

The number of houses utilizing geoheat in the US is 500 000 and in Japan it is quite low, only 200. Studies show that the reasons for a low utilization of geoheat in Japan are the high construction and piping costs, thus requiring an improvement in the cost structure. On the basis of some calculations, if one makes an optimistic assumption that every house in Japan will utilize geoheat, then geoheat will provide 6%–7% of the total primary energy in Japan. Thus, there is a lot of potential in ambient energy resources, particularly geoheat.

The PV technology offers a viable option for the same only if its output is stabilized. The SSPS is another such example. In this case, solar panels

are located above 30 000 km. The SPSS undoubtedly can be a source of stable power supply with little output changeability and also has the potential for large-scale power generation. But, of course, one cannot ignore the high costs associated with transportation of materials, for example, and the related construction technologies are still premature. But it is certainly essential that we start discussing and investigating such possibilities for bringing in a reduction in CO<sub>2</sub> emissions.

Lastly, it is essential to mention about the CCS technology. RITE is particularly engaged in developing this technology in Japan. The basic process in CCS is to recover CO<sub>2</sub> from the flue gas of large-scale CO<sub>2</sub> emitters such as power plants and thereby store the CO<sub>2</sub> recovered into aquifer or other underground storage sites.

CCS can be termed as an end-of-pipe technology that disposes pollutants after their emission. It is not a new technology but comprises known technologies, and therefore, can be easily put into practice. CO<sub>2</sub> capture is similar to separation of CO<sub>2</sub> from natural gas, and CO<sub>2</sub> storage is similar to injecting CO<sub>2</sub> for enhanced oil recovery from petroleum fields. It is a technology with a high potential for reduction in CO<sub>2</sub> emissions. However, given the fact that fossil fuels now occupy about 87% of the world primary energy, it will take time for the world to transit into a decarbonized society. In this sense, CCS can be a technology bridging the present and the future decarbonized society.

Thus, on the whole, it can be concluded that decarbonization of primary energy is a 'must'. And to achieve this, nuclear power is indispensable. Wind power and PV technology, due to their changeability, should be developed with limited capacity compared with the demand size of the grid. It is essential to promote the use of ambient energy sources such as geoheat and SPSS in the long run, and finally, CCS can play a role of bridging technologies.

## SESSION 3 Panel discussion



### ***Technology partnerships for sustainable development***

#### **Panelists**

- **Prof. Jong-dall Kim**, Professor, School of Economics and Trade, Kyungpook National University, South Korea
- **Dr John Wright**, Director, CSIRO Energy Transformed Flagship, Australia
- **Mr Shigeru Muraki**, Senior Executive Officer, Tokyo Gas Co. Ltd, Japan
- **Prof. Yoshihisa Murasawa**, Project Professor, The University of Tokyo, Japan
- **Ms Annapurna Vancheswaran**, Associate Director, Sustainable Development Outreach Division, TERI, India

The session, presided over by Prof. Yoshihisa Murasawa, brought together a variety of stakeholders including the academia, industry, and the development sector, providing diverse perspectives towards the issue under review.

Prof. Jong-dall Kim presented his study titled 'Sustainable Energy Development: Asia's challenge for economy and environment'. Since the early 1970s, Asia has economically grown faster than any other region in the world. It is obvious that Asian countries will have to increase their energy consumption to sustain economic growth. In this respect, the key question facing Asian countries is whether this increase will occur within a sustainable and peaceful path or whether it will reproduce the past of the already industrialized countries. Therefore, it is critical for policy-makers and consumers to see how the region de-links economic growth from energy consumption through energy-efficient technologies and renewable energy sources.

Prof. Kim also shared major outcomes of the study on South Korea, analysing energy efficiency and savings for the country for business-as-usual and efficiency scenarios. He mentioned about various programmes, initiatives, and a 50-year plan in the City of Daegu, undertaken to promote renewable energy technologies, mainly solar energy. He concluded that it is rightly felt that energy cooperation in Asia will have a far-reaching impact on the global effort to improve environment quality and enhance development. Not only that sustainable energy in the region is a technology option, but what is also required is interaction and communication between interrelated forces.

Dr John Wright, elaborating on the technological partnerships for sustainable development, provided examples of such forums, programmes, and institutions within Australia. One of the flagship programmes undertaken by the CSIRO, is 'The Energy Transformed Programme', with a mission to halve emission of GHGs (greenhouse gases) and double the efficiency of the nation's energy generation, supply, and end use, and to position Australia for a future hydrogen economy. Among other enduring partnerships in Australia, he mentioned, is the Energy Futures Forum consisting of 22 partners from industry, government, communities, and environmental groups. The Centre for Low Emission Technology and the National Solar Energy Centre are among others. He emphasized that partnerships are essential for implementation a of sustainable future, as no single organization can do it all.

Mr Shigeru Muraki, emphasizing on the need for integration of various technologies for enhancing the mitigation of CO<sub>2</sub> (carbon dioxide) emissions, explained in detail the Holonic energy system for sustainable development, which integrates various technologies effectively. The ultimate goal of the Holonic system is to move towards a zero-emission society involving key technologies of cogeneration, fuel cell, renewables, power storage, integrated control system, and CO<sub>2</sub> capture and sequestration. Such an energy system necessitates partnerships between the industry, the government, and the academic society as well between different countries for technology transfers coupled with apt policy-making.

Prof. Yoshihisa Murasawa reiterated in his presentation that Japan presently is at the frontier of problems ahead of the world. These include shortage of resources, increasing wastes, environmental contamination,

and advancement of the ageing section of society with a declining birth rate. But, as in the past, it seeks to play a leading role to find solutions and disseminate the Japan-originated sustainable development model to the world. It has already forged on the said path. For example, it has achieved improvement in energy efficiency and cars made by Japanese manufacturers are about 20% or more fuel-efficient than those made in America and European. Not only this, continuous efforts are being made in the country towards reducing hazardous emissions.

Yet another example of Japan's efforts to counter the threat to sustainable development is provided by the city called Kita-Keyushu, which used to be covered by smog and surrounded by heavily contaminated water around 1960. With intensive efforts now, both air and water quality have dramatically improved in the city.

Prof. Murasawa accentuated that IR3S (Integrated Research System for Sustainability Science) aims to develop visions and policies for repairing and rebuilding the global, social, and human systems and linkages among them. He also mentioned about the need for trans-disciplinary approach for attacking issues of sustainability—a sort of an interdisciplinary partnership between linking natural sciences, social sciences, and humanities. Emphasizing the need for partnership, he brought out that his institute itself (IR3S) is a kind of a consortium of leading Japanese universities, with the University of Tokyo as the hub of network management. The University itself participates in a number of international partnerships such as the International Alliance of Research Universities, and much before it established IR3S, the university played an active role in founding the Alliance for Global Sustainability. The University of Tokyo expresses full commitment in taking a lead role in promoting global sustainability through various partnerships.

Highlighting the industry-academia partnership for technology development, Ms Annapurna Vancheswaran elaborated on the initiatives instituted by TERI in this direction. She presented a paper titled 'Technology Development in the Corporate Sector', on behalf of Mr Michael P Schulhof, Chairman, Global Technology Investments LLC, New York, that he prepared for the summit.

Ms Vancheswaran said that TERI-BCSD India (TERI-Business Council For Sustainable Development, India) – instituted in 2002 in partnership with the WBCSD (World Business Council for Sustainable Development),

Geneva – is an extremely important initiative on part of TERI in establishing association with the industry. Companies from almost all the sectors, from automobile to paper and pulp to cement and so on, are its members, with the oil and gas industry having a prominent presence in it.

TERI–BCSD India offers a variety of services to its members: programmes on designing and implementation of CSR (corporate social responsibility), CSR reporting and documentation, outreach, and so on. However, in addition, it is also looking at rural India, to touch the lives of the most needy and forging ways for the corporate sector to appropriately involve itself in such endeavours. One such programme initiated is INSTEP (Integrated New and Sustainable Technology for Elimination of Poverty). It basically uses integrated approach to delivering packages of energy-technology-based solutions to meet the myriad needs of the community, which usually the corporate sector is unable to take account of.

Another key focus is the SSI (small-scale industry) in India. There have been direct impacts of TERI's technology interventions on the SSI; as a result of which, there has been an energy saving of 15 000 tonnes of oil equivalent and cumulative reduction in CO<sub>2</sub> emissions of over 5000 tonnes. The interventions have also touched the lives of 8000 workers in about 500 locations all over the country.

Mr Schulhof highlighted how supports from the corporate sector can lead to development of new products and sustainable growth, and offer solutions for the world's toughest problems. The technology advanced by TERI – the Microbial Enhanced Oil Recovery or MEOR – uses genetically enhanced micro-organisms or microbes to change conditions in an oil well to increase oil production. He mentioned in his paper that collective capabilities and expertise of TERI and the Global Technology Investments make Glory Oil uniquely positioned to be the world's leading petroleum biotechnology company, with the ability to create jobs in India and the United States.

It was once again emphasized that such examples of partnerships are very heartening but certain challenges still remain. There is need for the academia to deepen and intensify cooperation. Business needs to increase business-based R&D investment. And, there is need to intensify research cooperation between universities and research institutes.



# Concluding session and the way forward



## Panelists

- **Dr R K Pachauri**, Director-General, TERI, India
- **Prof. Akio Morishima**, Chair of Board of Directors, Institute for Global Environmental Strategies, Japan
- **Prof. Yoichi Kaya**, Director General, Research Institute of Innovative Technology for the Earth, Japan
- **Mr Kazumasa Kusaka**, Special Advisor to Ministry of Economy, Trade, and Industry, Japan

**T**he WSDF (World Sustainable Development Forum) envisages being a conduit to identify, analyse, and disseminate policy interventions to enhance human well-being in the present, and create conditions for a sustainable future. In wake of the rising footprints of human activities, the challenge of sustainable development has become even more daunting than ever before. In this context, forums like WSDF provide a platform for knowledge accumulation and policy discourse for a sustainable future. The RSDS (Regional Sustainable Development Summit), with the theme 'science and technology for sustainable development' marks the very first step in the direction of the forum's long-term objectives. The great enthusiasm and interest on part of the summit participants reinforced the tremendous scope of such meetings in the future and their likely impact on the policy environment.

The concluding session of the summit featured a presentation by Mr Kazu Kusaka on promoting clean technology in Japan. His presentation provided a brief overview of Japan's energy and environment policy along with examples of policies and measures

undertaken to reduce carbon dioxide emissions and to influence energy demand and supply structure in Japan. He highlighted the 3Es encompassing the basic principles of Japan's energy policy. These include: security of energy supply, harmony with environment, and economic efficiency. He also mentioned that as a result of mainly the energy conservation technologies and introduction of efficient equipment along with the changes in industrial and socio-economic structure, in the reference case, the energy demand in Japan would take a downturn in fiscal 2021. Along with this, energy supply structure is also expected to gradually change by 2030. Innovative technologies and energy efficiency improvement are the key to sustainable development. The Government of Japan emphasizes on energy-related research and development with a view to reduce emissions not only domestically but also globally. In accordance with this concept, several clean technologies have been promoted and efficiency programmes undertaken. One example of such a programme is the 'Top Runner Programme' that was introduced in 1998 as energy conservation standards for home/office appliances and fuel efficiency standards for automotives. International cooperation is a must to achieve goals of sustainability. In this regard, he mentioned about India and China being the important regional partners. To conclude, it is essential for three components of sustainability namely, environment, energy, and economy, to be in harmony to achieve higher goal at a minimum cost to other objectives.

Dr R K Pachauri invited suggestions from the panel and the participants for mapping future steps for such regional events. A number of valuable propositions were put forward during the discussion.

It was pointed out by Prof. Yoichi Kaya that, for initiatives such as the WSDF to have an impact on practical grounds, the propaganda of each participant outside this forum would be of immense help in promoting sustainability. He also suggested bringing out documents along the lines of the Club of Rome that was brought out 30 years ago on limits to growth. It was profound in its influence. Thus working on these lines would be yet another way to have an impact.

Sustainable development is a broad concept involving a range of issues such as energy, climate change, poverty alleviation, water, food, health, and forests. The kind of partnerships that have been discussed at

this summit raise the question: what kind of issues of sustainable development could be carried out with such partnerships? And, it occurs that the best common ground is energy and climate change issues, a point mentioned by Prof. Akio Morishima. He also proposed that the forum needed to maintain an Asian focus in order to reach some concrete results.

There was a general consensus on the scope feeding into the G-8 dialogue on climate change in view of the G-8 Summit to be held in Japan in 2008. Participants were also keen to expand the partaking in any such meetings in the future, notably, to include China and other Asian players along with the more prominent presence of policy-makers. It was expressed that it is extremely important to have participation from China, given the likely impact the country is going to have on the future energy and environmental scene of the world. If it is expected for such summits and meetings to have a concrete impact or to contribute to the G-8 dialogue on climate change, it is vital to be more specific and work towards making concrete proposals.

The plethora of suggestions and comments made at the summit clearly brings out the keen interest and the genuine desire on part of the international community to work towards the cause of sustainable development. This provides encouragement to organize such events in future, consciously incorporating the lessons learnt and accordingly filling gaps.





# Toyota Shirakawa-Go Eco-Institute, Japan



## INTRODUCTION

Shirakawa-Go is situated in the northernmost part of Gifu Prefecture on the border with Toyama Prefecture and said to have once been home to members of the Heike clan after they had fled the capital at Kyoto. It is a village of steep-roofed thatched houses built in the traditional Japanese gassho architectural style, and has been declared a world heritage site. Starting from the lowland to the entrance of the Hakusan Super Rindo, the road passes between low mountain ridges and emerges from a tunnel onto a narrow plain. The Toyota Shirakawa-Go Eco-Institute is spread out at the foot of the holy mountain of Hakusan.

The village of Shirakawa is one of Japan's most beautiful villages. The Institute in this village is Japan's finest nature school and a completely new and innovative endeavour. It is spread over 172 hectares (acquired in 1973).

The facilities are owned by Toyota and operated by: NPO 'Shirakawa-Go Nature Coexistence Forum'.

## OBJECTIVES

TOYOTA Shirakawa-Go Eco-Institute was established to fulfil the following three objectives.

- To provide a place for the youth of today, who will be tomorrow's leaders and to experience nature first hand
- To provide a 'spiritually healing environment' to the general public; a place where visitors can be directly in harmony with nature
- To protect and restore the natural environment of the surrounding areas



## COEXISTENCE PROJECTS

The Toyota Shirakawa-Go Eco-Institute is engaged in a number of unprecedented co-existence projects and is tackling difficult issues with relatively long-term views of 5 or 10 years. The various projects involve cutting-edge research and also considerable labour input. Few projects are listed below.

### Butterfly garden project

A variety of butterfly species inhabits the school grounds. Following a basic survey to help create an environment in which the endangered Gifu swallowtail butterfly can thrive, researchers are working to lay out a garden by planting plants that the butterfly feeds on and those from which it draws nectar.



### Project to revive beech woods

Within the grounds of the school, there is barren land. This is a project to turn this barren land back into beech woods like those that used to surround the village. For this purpose, a variety of tree species and shrubs will be planted, with the main emphasis on beech, to restore forest in snowy areas.

### Project to regenerate the silkworm-rearing industry

The Magari district that housed a thriving industry in silkworm rearing is habitat to the Japanese Oak silkworm (*Antheraea yamamai*), said to be the species from which the silk was derived. The attractive green cocoons produce a glossy thread of high quality. Wild silkworm rearing in the forest is one of the various insect-related projects that the Institute plans to undertake.

## SEASONAL PROJECTS

The nature school offers several different programmes adapted to each of the four seasons.

### Craft workshops

The Institute offers a variety of craft workshops, including a silk craft using silk and fallen leaves, and a leather craft where you can make a number of different animals.

### Guided bird watching walk

One activity that can be enjoyed through all seasons is bird watching. In particular, the area around the Okubo pond adjacent to the school grounds is a treasure trove of wild birds.

Japanese black bear, Japanese serow, flying squirrel, sable, hare, Japanese field mouse, and long-eared bat



(endangered species) are among the many species of mammals that have been confirmed to inhabit the school grounds. The Institute has put together a programme in which it approaches the habitat of each of these animals and explores their habits.

Apart from the above-mentioned projects there are various other interesting projects running in the Institute. The key ones are programmes on: learning about environmental technologies using fuel cell batteries, studying insects by using a microscope, hands-on nature programmes, rice planting at the Eco-Institute, mountain climbing, black bear observation programme, and so on.

## OTHER ACTIVITIES

In front of the school, a tunnel was excavated and 7 hectares of land was covered with excavated soil rock. This tunnel is the second largest in Japan.

Land was primarily concrete and comprised alkaline soil which made it impossible to plant and nurture trees. This land was covered with old thatched roof – called choa – that made it possible for plants to thrive on this land.

Planting trees is not enough. We need to understand the relationship between trees and CO<sub>2</sub> (carbon dioxide). This Institute works particularly in this field. CO<sub>2</sub> level has been increasing over the period. Its concentration in the atmosphere was 180 PPM (parts per million) 40 000 years ago that skyrocketed to 380 PPM after the Industrial Revolution. Trees help in



removing excess of CO<sub>2</sub> from the atmosphere. So the Institute emphasizes on planting as many trees as possible to sustain the present lifestyles.

In order to protect its rich natural environment, the Toyota Shirakawa-Go Eco-Institute was built according to a design policy of not realigning the landscape and leaving existing topographical features intact as far as possible. In landscaping activities, care is taken to preserve existing trees and paths. Buildings take their design motif from the steep thatched roofs of Shirakawa-Go and are structurally designed to cope with heavy snowfall. Meanwhile, buildings, furniture, and other elements make use of natural materials, chiefly wood, thus blending in with the beautiful landscapes that unfold on the surrounding slopes of Mount Hakusan. In this way, a space in tune with nature has been created.





# Energy technologies and sustainable development: India and China

## ***Background paper***

(Prepared by Dr Pradeep Kumar Dadhich, Ms Prima Madan, and Dr Ritu Mathur, TERI, New Delhi)

Presented by Dr R K Pachauri  
Director-General, TERI, New Delhi

## **THE ENERGY CHALLENGE**

**E**nergy is universally recognized as one of the most important input for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, the growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be reliant on energy demand. Accordingly, energy related issues are at the backdrop of any country's development agenda. Secure, reliable, and affordable energy resources are fundamental to economic stability and the development of all nations. Talking in terms of sustainable development, the threat of disruptive climate change, the erosion of energy security, and the rapidly growing energy needs of the developing world pose major challenges to energy decision-makers the world over. Future projections indicate that all economies, developing ones in particular, have to gear themselves to face this daunting challenge in order to proceed on a sustainable path of development. Modern knowledge in terms of new applications of science and technology, if developed and deployed astutely, would come to the rescue of the global community.



## WORLD TRENDS

Several studies have been undertaken to gauge energy demand of the world economy in the future. And all predict a continuous increase in the world's energy appetite.

As per IEA (International Energy Agency) estimates, if left to the current policies and systems, the world energy requirements will be almost 60% higher in 2030 than they are now and there will be repercussions in terms of availability of already depleting energy resources, geopolitical implications, and climate destabilizing carbon-dioxide emissions which would call into question the sustainability of the current energy system (IEA 2004).

The EIA (Energy Information Administration) 2006, in its reference case, projects that although there would be an increase in use of all energy sources through 2030, fossil fuels, in continuation of their trend in the past, are expected to meet 85% of the world's incremental energy needs (IEA 2005).

According to EIA 2006 estimates, world marketed energy consumption is likely to increase by an average of two per cent per year from 2003 to 2030 and the most rapid growth in energy demand is likely to be manifested in the nations outside the OECD (Organization for Economic Cooperation and Development) bracket. Table 1 provides the estimates for average energy growth rates for various regions from 2003 to 2030.

**Table 1** Projected energy demand growth rate from 2003 to 2030 (%)

Region	Average growth per year
Non-OECD Asia (including India and China)	3.7
Central and South America	2.8
Africa	2.6
Middle East	2.4
Non-OECD Europe and Eurasia	1.8

Source EIA (2006)

## INDIA AND CHINA: DOMINANCE IN THE GLOBAL ENERGY SCENARIO

Given the world energy consumption patterns, one cannot ignore the dominance of the two Asian giants, India and China, in the global energy scenario over the next 25 years, given their high growth prospects.

There has been a phenomenal increase in the energy consumed in the two countries since 1965 when China consumed 4.72% of the world energy and India a mere 1.37%. These figures increased to 8.43% for China and 2.38% for India, in 1990. In 2005, these figures stood at 14.75% for China and 3.67% for India (BP 2006).

The massive increase in the energy appetite of these nations has been mainly on account of the rapid increase in their rates of economic development. Presently, the Indian economy has been growing at over seven per cent per year, while China's economic growth is around nine per cent. Estimates indicate that if India and China maintain their current rates of economic growth for the next 10 to 20 years, both economies will double in size, and will surpass other economic powerhouses in the world, such as Japan, the US, and EU (IEA 2005).

The concomitant energy needs would be humongous, and according to the IEA, the total primary energy requirement (including biomass) for India would be around 1000 MTOE (million tonnes of oil equivalent) by 2030, accounting for about six per cent of the global energy requirement. TERI estimates indicate that these figures would be much higher, according to which, in India, total commercial energy consumption is projected to increase 7.5 times till 2031/32 under the BAU (business-as-usual) scenario (eight per cent GDP [gross domestic product] growth, and fuels and technology development as per current trends and as envisaged in government programmes) (TERI 2006a). IEA estimates depict that China will be responsible for approximately 13.67% of world energy consumption in 2030. This implies that India and China alone will account for approximately 20% of world energy consumption in 2030.

## IMPLICATIONS OF RISING ENERGY NEEDS

These rising energy needs in the future would have implications in terms of the availability of energy resources, environmental impacts, and geopolitics of energy.

There are growing concerns of energy security the world over, more so as it is expected that dependence on fossil fuels will continue in the future. Major oil and gas importers, including most OECD countries, China, and India, are anticipated to become even more dependent on imports from distant, often politically unstable parts of the world. The rising oil demands (mainly due to the growing needs of the transport sector) will have to be met by a small group of countries with large reserves, primarily the Middle East members of OPEC (Organization of the Petroleum Exporting Countries) and Russia. With such an increase in the dependency on external energy sources, the future of security cooperation in general and major power relationships in particular will be influenced by the degree of energy cooperation or the lack of it.

The environmental impacts of mounting energy needs have occupied the minds of the energy policy-makers the most. It is being emphasized that unless current policies change, global energy-related carbon dioxide emissions will continue to grow in the future. In the EIA 2006 reference case, world carbon dioxide emissions increase from 25 028 MMT (million metric tonnes) in 2003 to 43 676 MMT in 2030. Table 2 provides world carbon dioxide emissions by region from 2003 to 2030.

Looking at India and China specifically, Table 2 depicts that of the total emissions projected for the year 2030, India and China together would contribute around 30% of the world emissions, with China alone contributing 25% of the total emissions in 2030. This is mainly because of the high reliance of these countries on coal as a source of energy, which will continue its dominance in the energy profile of these nations. For example, in India, recent estimates indicate that coal will continue to fuel 45% to 50% of India's energy requirements till 2030 (TERI 2006a).

From the core aspect of the economic development process emerges the climate change problem. Among the most important anthropogenic causes for climate change is energy use and the related GHG (greenhouse gas) emissions. Human-induced climate change as a result of these emissions has resulted in large-scale perturbations in the earth's atmosphere (IPCC WG I, TAR 2001). However, the changes are not uniform all around the world and are likely to vary from region to region. Countries with limited economic resources, low levels of technology, poor infrastructure, unstable or weak institutions, and inequitable

**Table 2** World carbon dioxide emissions by region, 2003–2030 (MMT)

Region	<i>History</i>	<i>Projections</i>		<i>Per cent change 2003–2030</i>
	2003	2015	2030	
OECD	13 150	15 020	17 496	1.1
North America	6 797	7 997	9 735	1.3
Europe	4 264	4 632	5 123	0.7
Asia	2 090	2 390	2 638	0.9
Japan	1 206	1 228	1 219	0
Non-OECD	11 878	18 643	26 180	3
Europe and Eurasia	2 725	3 444	4 352	1.7
Asia	6 072	10 753	15 984	3.6
India	1 023	1 592	2 205	2.9
China	3 541	7 000	10 716	4.2
Middle East	1 182	1 647	2 177	2.3
Africa	893	1 363	1 733	2.5
Central and South America	1 006	1 436	1 933	2.4
Total World	25 028	33 663	43 676	2.1

Sources EIA (2006)

empowerment and access to resources are predicted to have lower capacities to adapt to climate change (IPCC WG II 2001). The impact of climate change, therefore, is likely to fall disproportionately on developing countries and their poor, exacerbating inequities in health status and access to adequate food, clean water, and other resources.

The above trends from various sources clearly depict that the world is not on a course for a sustainable energy future. The energy challenges posed to the world energy situation in the last 30 years are as much a challenge today, as before. These challenges include the following.

- Oil supply disruptions leading to oil price fluctuations the world over.
- Increasing awareness of the environmental impacts of fossil fuels now demand a decarbonization of what was expected to be a fossil fuel future, which involves looking for alternative sources of energy.

- For the past six years, the abnormally high oil prices have made world economies ever more vulnerable to oil than before.

If the future is in line with the present trends, as illustrated by the IEA 2005 reference scenario, carbon dioxide emissions and energy demand will continue to grow rapidly over the next 25 years. This is after taking account of energy efficiency gains and technological progress that can be expected under the existing policies.

Therefore, technology leapfrogging and policy interventions are the key to ensure a sustainable energy future. Today, there are unique opportunities for new applications of science and technology that could meet this growing demand for energy more intelligently and, at the same time, lower the carbon dioxide emissions by efficient use of energy. However, looking at the world today, there is a significant gap between OECD countries and developing countries in technology development and deployment. The primary reason for this is that technology research, development, and deployment are very capital-intensive. In addition, the scientific base of OECD countries is quite high compared to that of the countries like China and India. There is, therefore, a need to highlight the barriers to the spread of energy-efficient technologies for sustainable development and the role of tailored public policy, varying from society to society, towards adoption of these technologies. This would call for partnerships between the developing and developed world to bridge the technological gap and ensure economic development in the most effective manner.

Also, the developing world can learn lessons from countries like Japan, which have emerged not only as powerhouses of development and application of new technologies, but have achieved all this in a sustainable way.

## IMPLICATIONS OF DEVELOPMENT GOALS OF INDIA AND CHINA

It can hardly be overemphasized that the development plans of the two fastest growing economies of the world, India and China, will have an impact on the global scenario for energy and environment in the future, and there will be significant positive global impact if these Asian countries are able to forge a sustainable development path.

With regard to India, the Tenth Five Year Plan (2002–07) of the Indian government has envisaged a target of eight per cent growth for the economy for India to eradicate poverty and meet its basic economic and human development goals. Box 1 provides a brief overview of India's development goals as emphasized in the Tenth Plan document, Planning Commission 2001. It is but natural that such levels of economic growth and social sector development targets would call for increased energy

### Box 1 India: Tenth Plan development goals

- A Target of eight per cent GDP growth for the period 2002–07
- In addition to raising the GDP of the country, an equal emphasis has been laid on enhancement of human well-being. Accordingly, the following specific and monitorable targets for few indicators of human development were identified in the Tenth Plan document:
  - reduction of poverty ratio by five percentage points by 2007 and by 15 percentage points by 2012;
  - providing gainful high-quality employment to the labour force over the Tenth Plan period;
  - all children in school by 2003 and all children to complete five years of schooling by 2007;
  - reduction of gender gaps in literacy and wage rates by at least 50% by 2007.
  - reduction in the decadal rate of population growth between 2001 and 2011 to 16.2%;
  - increase in literacy rate to 75% within the plan period;
  - reduction of Infant mortality rate to 45 per 1000 live births by 2007 and to 28 by 2012;
  - reduction of maternal mortality ratio to 2 per 1000 live births by 2007 and to 1 by 2012;
  - increase in forest and tree cover to 25% by 2007 and 33% by 2012;
  - all villages to have sustained access to potable drinking water within the plan period; and
  - cleaning of major polluted rivers by 2007 and other notified stretches by 2012.

**Source** Planning Commission (2001)

usage directly or indirectly in order to address the requirements for enhanced social infrastructure, and production and consumption abilities in order to attain economic, social, and environmental objectives intrinsic to the concept of sustained human development.

Energy services contribute both to economic and social development. Energy facilitates economic development by underpinning economic activity, enhancing productivity, and providing access to global markets and trade; modern energy services contribute to social development by enabling the fulfilment of basic human needs of nutrition, warmth, and lighting, in addition to education and public health.

The energy challenge is thus of fundamental importance to India's developmental imperatives. And that the attainment of India's economic and social development goals will have significant energy implications has been acknowledged by the India Vision 2020 (Box 2) document as well (Planning Commission 2002).

Although India's energy intensity has halved since the 1970s, there is still ample room for improvement. Also, an integrated approach to policy and implementation has been missing. In recognition of this lacuna in the energy sector, the Planning Commission has recently drafted the Integrated Energy Policy Report that is guided by the objectives of meeting energy demands in a technically efficient, economically viable, and environmentally sustainable manner.

Similarly with China, its economy is on a fast track with growth projected to quadruple in the first two decades in this century. China, like India, has large population pressure. It is expected that India's population will increase to over 1.3 billion by 2020 (Planning Commission 2002). For China, even with the continuation of its family planning policy over the long term, the population is estimated to increase from 1.26 billion in 2000 to 1.475 billion in 2020. More than half of the population, or 52%, is expected to live in or near cities by 2020, compared to 36% in 2004 (Zeihong 2004). Similarly, in India, there are increasing pressures due to urbanization and industrialization of the economy, leading to mounting energy needs in both the nations. Accordingly, there are concerns in both the economies on how best manage and sustain growth.

In China as well, there are rising concerns for the energy conservation measures. However, since 1980, in the Chinese economy, some

## Box 2 Ensuring sustainable energy: India vision 2020

- India Vision 2020 comprehends that economic growth is driven by energy that powers the nation's industries, vehicles, homes, and offices. It emphasizes the following.
- 'Business-as-usual' will result in a spiralling cost for imported fuels and a surge in emission of environmental pollutants.
- Total coal demand will nearly double, and both oil and gas demand will triple.
- Expanding domestic production capacity will require substantial investments, while increasing dependence on imported forms of energy will increase vulnerability to fluctuations in global energy prices. Surging demand will also place increased burden on the physical and social environment.
- For future growth to be both rapid and sustainable, the energy source needs to be as resource-efficient and environmentally benign as possible.
- Enhanced adoption by the public and private sector, of best practices and environment-friendly technologies, more efficient use of energy, promoting private sector investment, and greater efforts to protect the environment will be required to cope effectively with the nation's growing energy appetite.
- Greater reliance on renewable energy sources offers enormous economic, social, and environmental benefits.
- Concerted effort to implement a more visionary approach to alternative energy generation could significantly reduce India's dependence on imported fuels while also reducing the strain on the environment.
- Biomass power production, ethanol motor fuel, and jatropha fuel oil can generate millions of rural employment opportunities and contribute to higher rural incomes, at the same time reducing the outflow of foreign exchange.

**Source** Planning Commission (2002)

achievements in energy conservation have been attained, owing to efforts by central and local governments, industrial sectors, and energy end users. Studies indicate that energy-saving measures during the period resulted in a reduction of 773 MTOE, and contributed to

environmental protection by cutting roughly 20 MT (million tons) of sulphur dioxide emissions, 263 MT of cinders, 13 million tons of ash and dust, and 440 MT of carbon emissions (Zeihong Wei 2004).

However, despite certain steps taken in the two countries for meeting their respective energy needs, their dominance in the world energy scenario in the future as a result of the ambitious economic and social targets, cannot be ignored. It is technology development and deployment that would assume importance in these countries. The following section summarizes the results of studies undertaken for India and China, bringing out the role of technologies in meeting the energy challenges in the two nations.

## TECHNOLOGY VISION: STUDIES ON INDIA AND CHINA

### INDIA

In order to have an integrated energy approach and to meet the policy goals of economic efficiency, energy security, energy access, and environment, the Principal Scientific Advisor's Office to the Government of India awarded the study *A National Energy Map for India – Technology Vision 2030* to TERI in March 2004 that was completed in July 2006. The key focus of this study was to examine the role that the various technological options could play under alternative scenarios of economic growth and development, resource availabilities, and technological progress. The study adopted a bottom-up energy sector model (MARKAL [Market Allocation]) to examine the pathways for optimal energy supply and use under various scenarios.

The study has provided certain useful insights of the Indian energy sector as the future unfolds. This will enable the policy-makers to better prepare for the future in terms of economic, technological, and environmental implications both in terms of the Indian economy and the world at large.

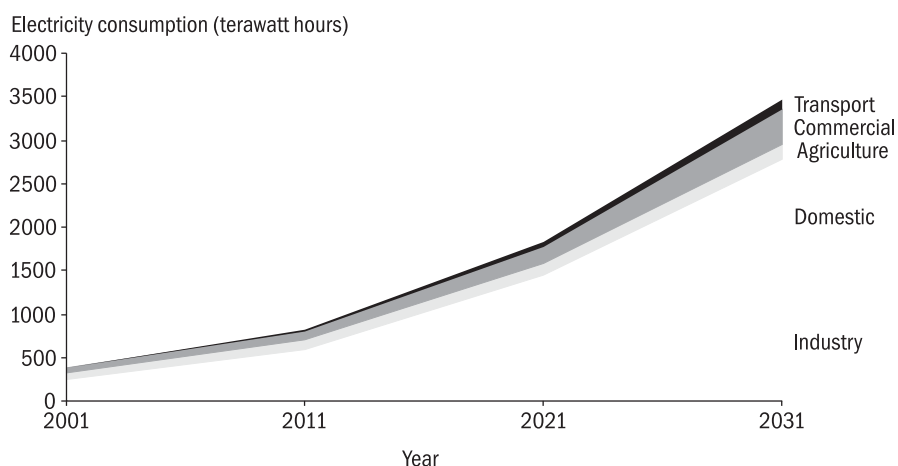
The study indicates that the total commercial energy in India increases by 7.5 times (6.9% growth rate) over the 30-year period from 2001 to 2031 in the BAU scenarios.<sup>1</sup> Coal remains the dominant fuel in commercial energy consumption in India.

<sup>1</sup> BAU scenario implies an eight per cent GDP growth; fuels and technology developments as per current trends and as envisaged in government programmes.

India has massive electricity needs at present. The Ministry of Power estimates indicate that the peak demand in India totalled 95 583 MW (megawatt) during April and July 2006. There are also huge shortages of power in the entire country, the energy deficit being 8.7% and peak demand deficit being 12.8% during April and July 2006 (Ministry of Power 2006).

The study also indicates that the electricity consumption in India in the BAU increases rapidly in the industry and residential sectors and by 2031, these two sectors account for nearly 80% of the total electricity consumption. The total electricity consumption increases in the domestic sector by 12.6 times from the year 2001 to 2031. Figure 1 provides the sectoral electricity consumption in the BAU.

**Figure 1** Sectoral electricity consumption in the BAU scenario



Source: TERI (2006a)

In order to emphasize the role of technologies in pursuing a sustainable energy pathway, the above study constructed various policy scenarios as indicated in Box 3. The hybrid scenario is a combination of the BAU, high-efficiency, aggressive renewable energy, and high nuclear-capacity scenarios. It describes the energy future of the Indian economy

**Box 3** Scenarios

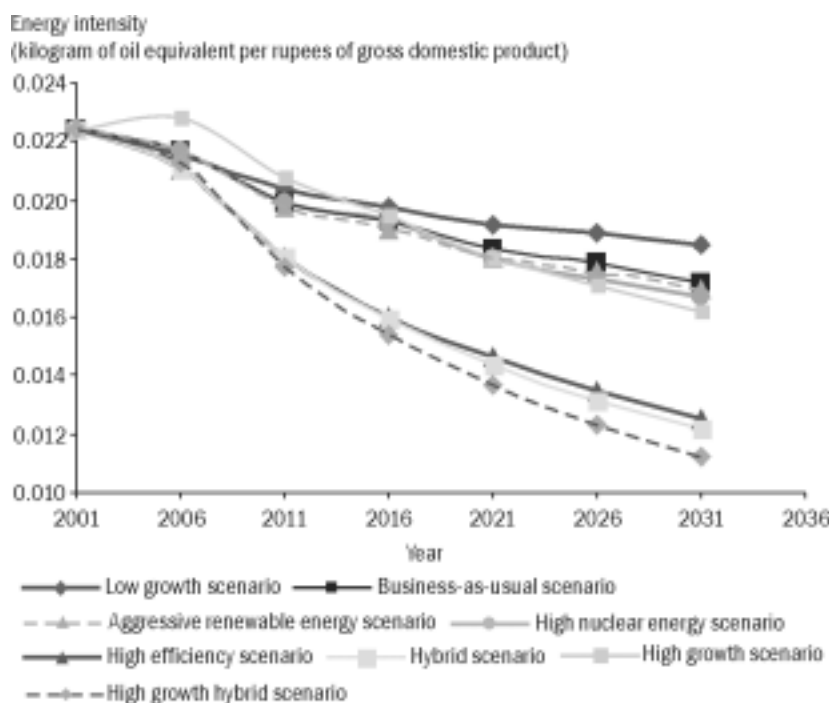
- LG (low growth) represents a low GDP growth rate of 6.7%.
- HG (high growth) represents a high GDP growth rate of 10%.
- EFF (high efficiency) represents the scenario of energy-efficiency measures spanning across all sectors.
- REN (aggressive renewable energy) scenario represents a high penetration of renewable energy.
- NUC (high nuclear capacity) scenario includes nuclear-based power generation.
- HYB (hybrid) scenario is a combination of the BAU, high-efficiency, aggressive renewable energy and high nuclear capacity scenarios.
- HHYB (high-growth-cum-hybrid) scenario represents a high growth rate of 10% in addition to the hybrid scenario.

Source TERI (2006a)

by incorporating the entire range of energy-efficiency measures in the end-use sectors, the complete deployment of clean coal technologies, aggressive penetration of nuclear-based power generation technologies, and an aggressive push towards renewable energy sources.

On comparing the HYB (hybrid) to the BAU scenario, the commercial energy consumption in the year 2031 is lower by 29.2% in the HYB scenario. The coal consumption reduces by 35% in the HYB scenario. The import dependency of the nation is the lowest in the HYB scenario. Technology interventions on both the supply and end-use side played a crucial role in achieving this low consumption in energy. However, it is also evident from the model results that only supply-side interventions, in terms of nuclear and renewable alternatives, cannot bring substantial reduction in the energy consumption. It is efforts at both the supply and demand side depicted by the HYB scenario that bring about a sizeable reduction.

Figure 2 depicts energy intensity across various policy scenarios for India as described in Box 3. Energy intensity in the BAU exhibits a reduction from 0.022 kgoe/Rs of GDP in 2001 to 0.017 kgoe/Rs of GDP in

**Figure 2** Sectoral electricity consumption in the BAU scenario

Source TERI (2006a)

2031 (a decrease of 23%), indicating that the economy is already progressing along an energy-efficient path even with the current government plans and policies. However, the BAU scenario takes a conservative view with respect to the technology deployment by the way of limited penetration of clean-coal technologies, H-frame combined cycle gas turbine, the timing of penetration of efficient power-generation technologies, a low degree of penetration of nuclear and renewables, etc. In the HYB scenario the energy intensity is observed to decline to 0.012 kgoe/Rs of GDP in 2031 indicating the scope for further reduction in energy intensity in the economy.

For assessing the impact of energy-efficiency measures and technologies, it would be prudent to compare the carbon dioxide emission intensity of GDP in BAU and HYB scenarios. Table 3 indicates carbon dioxide emission-intensity of GDP.

**Table 3** Carbon dioxide emission intensity (kg CO<sub>2</sub>/Rs of GDP) for BAU and HYB scenarios

Scenario	2001	2011	2021	2031
BAU	0.072	0.063	0.058	0.059
HYB	0.072	0.056	0.043	0.039

Source TERI (2006a)

Comparing the two scenarios, it is evident that the carbon dioxide emission intensity in the year 2031 is 34% lower in the HYB scenario than that in the BAU. This again reinforces the fact that there exists considerable scope for reducing the carbon dioxide emission intensity subject to the removal of technical, financial, and geopolitical barriers.

Also, it may be emphasized that carbon dioxide emissions can be reduced significantly in the HYB scenario with faster deployment of clean coal technologies, efficient H-frame combined cycle gas turbine, higher share of renewables and nuclear options for power generation as well as reduction in specific electricity consumption in various end-use devices.

### The transport sector impact

The transport sector has a crucial role in shaping a nation's economic development. And India is no exception. The GDP (measured at 1993/94 prices) accruing from the transport sector activities in India (comprising transport by railways, road, air, and coastal transportation) has increased at an average annual rate of 6.42% for the time-period 1990 to 2003 doubling from Rs 353 560 million in 1990–91 to Rs 793 740 million in 2003–04 (MoSPI 2005).

Moreover, the transport sector is one of the largest energy-consuming sectors in the country and also an emitter of GHGs due to its excessive reliance on fossil fuels. Therefore, energy-efficiency measures in this sector are likely to have a major impact on the economy as a whole.

Therefore to examine the various options available in the transport sector, the TERI 2006a study developed an alternative set of scenarios for the transport sector in India. Box 4 briefly describes these scenarios.

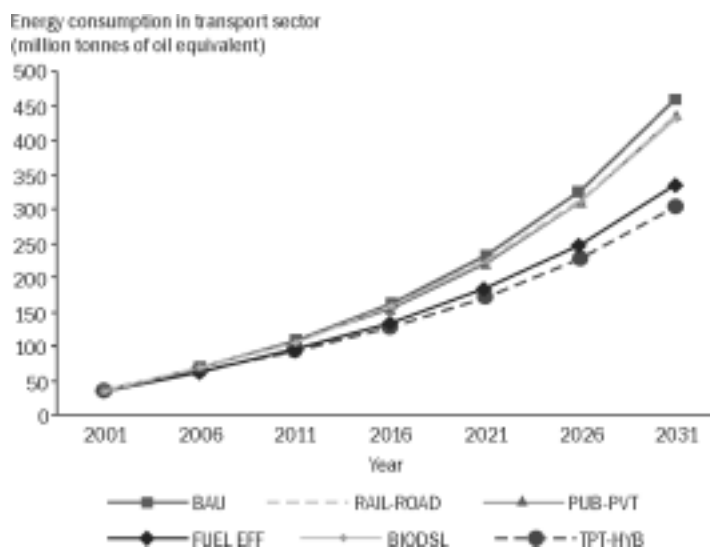
#### Box 4 Transport sector scenarios

- BAU characterized by continuation of past trends.
- RAIL-ROAD characterized by increased share of rail *vis-à-vis* road in passenger and freight transport demand.
- PUB PVT characterized by enhanced share of public transport *vis-à-vis* personalized modes of transport.
- FUEL EFF characterizes fuel efficiency improvements.
- BIODSL characterizes penetration of bio-diesel.
- TPT-HYBRID is a combination of RAIL-ROAD, PUB-PVT, FUEL-EFF, BIODSL.

Source TERI (2006a)

In the BAU scenario, the total energy consumption in the transportation sector would increase 14 times, with an average annual growth rate of 9.1% during 2001 and 2031. However, as shown in

**Figure 3 Comparison of energy consumption in transport sector across scenarios**



Source TERI (2006a)

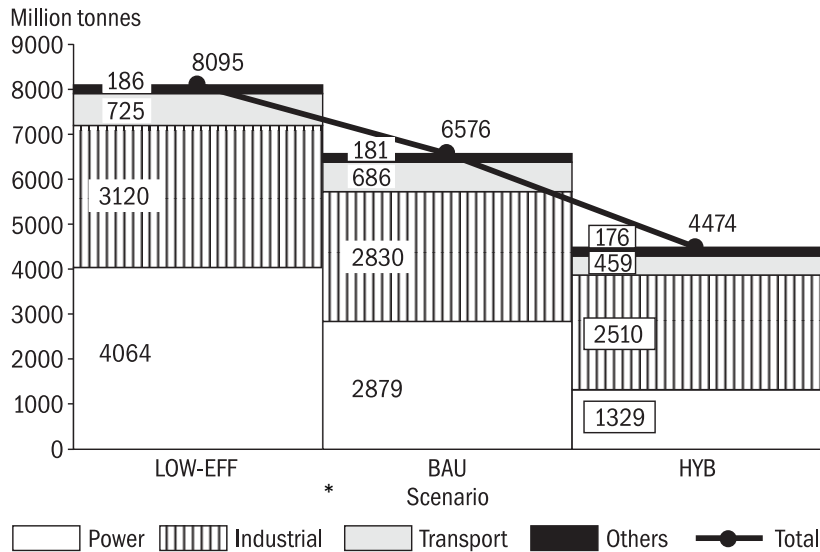
Figure 3 energy consumption can reduce by about 35% in 2031 in the transport hybrid scenario *vis-à-vis* the BAU scenario.

It is evident from the above discussion that there is ample scope for India to proceed on an energy-efficient path by reduction in energy consumption, improved energy intensity, along with reduction in emissions. However, this is possible only if there is efficient development and deployment of technologies across each of the sectors, especially in the power industry and transport sectors. These, in turn, call for the need to identify the barriers to the uptake of efficient and sustainable technology options and thereafter direct policies towards their removal.

### Crucial technological interventions

In case of India, the model results indicate that power, industry, and transport sectors will account for more than 95% of the total carbon dioxide emissions in both BAU and HYB scenarios, as is evident in Figure 4.

**Figure 4 Carbon dioxide emission in 2031, by sector**



\*LOW-EFF scenario assumes a pessimistic/conservative view for the Indian economy with regard to the adoption of energy-efficient technologies in the various energy-consuming sectors.

Source TERI (2006b)

Moreover, the power, industrial, and transport sectors also present the maximum potential for reduction in carbon dioxide emissions. The carbon dioxide emissions are 54%, 11%, and 33% lower in HYB compared to the BAU scenario. This, therefore, makes it essential to identify technologies that would actually help in the process emissions reduction from these sectors.

## POWER SECTOR

Coal-based generation is the dominant source of power generation in India. There is immense scope for improving the energy efficiency and reducing the environmental impacts from the power sector. On the generation side, the potential energy-efficiency measures (GHG mitigation options) are as follows.

- Clean coal technologies such as PFBC (pressurized fluidized-bed combustion), supercritical steam cycle, ultra-supercritical steam cycle, and IGCC.
- Deployment of H-frame gas turbine-based combined cycle plants for gas-based generation.
- Enhanced capacity of nuclear, hydro, and renewables-based power generation.
- Renovation and modernization of old power plants leading to improvements in efficiency.

Also, the model results for the power sector indicate that if all the power generating technologies were allowed to compete for new capacity additions, the preferred choice of technologies in the order of economic merit would be (1) large hydro; (2) refinery residue based IGCC; (3) imported coal-based IGCC; (4) high efficiency CCGT (H-frame gas turbine); (5) indigenous coal based IGCC; (6) normal CCGT; (7) ultra super critical boiler; (8) super critical boiler. Table 4 indicates the potential for deployment of power generation options, by technology, for the years 2021 and 2031 across the BAU and HYB scenarios.

On the demand side, various DSM (demand-side management) measures leading to efficiency improvements in end-use applications of power by industry, commercial sector such as commercial buildings,

**Table 4** Technology deployment in the Indian power sector (including decentralized) in the years 2021 and 2031 in BAU and HYB scenarios (in GW)

Technology	2021		2031	
	BAU	HYB	BAU	HYB
Coal sub-critical	170	88	456	131
Coal-efficient	5	0	10	1
Coal IGCC	0	32	0	160
Gas	118	89	137	91
Gas-efficient	0	10	0	53
Diesel	7	7	8	8
Hydro (large and small)	116	118	158	160
Nuclear	21	40	21	70
Renewables	4	12	4	26
Total	441	395	795	700

IGCC - integrated gasification combined cycle

Source TERI (2006a)

lighting systems, and residential sector are expected to reduce carbon dioxide emissions to a great extent. The BEE (Bureau of Energy Efficiency) has projected that there exists a scope of reduction in electricity consumption to the extent of 20% to 30%.

## INDUSTRY SECTOR

A detailed analysis of the industrial energy-use pattern reveals that around 60%–70% of the total energy consumption in the industrial sector is accounted for by seven sectors (1) cement (2) pulp and paper (3) fertilizer (4) iron and steel (5) textiles (6) aluminium and (7) chemicals and petrochemicals (TERI 2006b). Thus, the adoption of various energy-efficient technologies in the various industrial sub-sectors could lead to a significant reduction in GHG emissions.

In case of the cement industry, for example, a shift towards blended cements (by mixing ash or slag inclinker) can significantly reduce the energy requirements for cement production. The share of blended cement production in India is increasing; it has increased from 28% in 1993/94 to 44% in 2000/01. Due to such energy-efficiency measures, there has been a reduction in energy consumed in this sector. For example, the heat requirement in clinker production has reduced from 1300 to 1600 in the 1950s through to the 1960s, to 665–800 kcal/kg in 2003 (TERI 2006a).

In addition, with the increasing use of energy-efficient equipments in different sections (raw material preparation, grinding mill, kiln, etc.) of the cement mill, specific energy consumption in Indian cement sector is around 665 kcal/kg of clinker, which is comparable to the world best of 640 kcal/kg clinker (TERI 2006a).

In the iron and steel industry, four different steel manufacturing technologies existing in the country are (1) BF-BOF (blast furnace-basic oxygen furnace), (2) Scrap-EAF (scrap-electric arc furnace), (3) DRI-EAF (direct reduction iron-EAF, and (4) COREX.

Iron and steel plants using COREX technology and coal and gas based DRI plants also constitute mitigation technology options for the iron and steel industry.

The Integrated BF-BOF in the country have shown a reduction in energy consumption of around 22% from 1990/91 to 2003/04 but it is still high as compared to the US and Japan, indicating further scope of undertaking energy efficiency measures for reduction in specific energy consumption requirements (TERI 2006a).

There still exists considerable scope for GHG mitigation (energy-savings) in different intermediate processes (coke-making, blast-furnace, integrated casting, integrated hot-rolling, integrated cold-rolling and finishing, etc.) of steel making. Similarly, in steel plants using EAF, there exists considerable potential for carbon dioxide emissions reduction.

As for the paper and pulp industry, the specific energy consumption for paper production is very high in India as compared to the international standards. Since this industry has remained protected from international competition it has lagged behind in technological advancement. There is ample scope for energy efficiency in this industry.

The carbon dioxide emissions can be reduced through various energy-efficiency measures such as cogeneration, blow heat recovery, high solid concentration of black liquor and use of the continuous digester process, etc.

## TRANSPORT SECTOR

Being the largest consumer of fossil fuels, the transport sector in India offers tremendous scope for reduction in carbon dioxide emissions through various energy-efficiency measures. The GHG emissions from the transport sector can be reduced by policies and measures aimed at reducing energy intensity through improvements in fuel efficiency of existing motorized transport modes over time, penetration of alternative fuel-efficient technologies, and accelerated electrification of railways substituting diesel by electricity, switch towards alternative cleaner fuels such as CNG (compressed natural gas), use of biofuels such as bio-diesel, changes in modes of transport through increase in rail movement *vis-à-vis* road through increases share of railways in both passenger and freight movement, and promotion of public transport in urban areas.

### Barriers to the mitigation options

In addition to identifying the prospective energy-efficient measures for the three sectors, it is also essential to highlight the possible barriers to the implementation of emission mitigation options, in the three most crucial sectors of the Indian economy.

## POWER SECTOR

The barriers in the implementation of GHG mitigation options in the power sector include the following.

- High upfront capital cost per megawatt.
- The lack of experience and technical know-how in advanced power generation technologies like ultra supercritical steam cycle, IGCC, etc.

- Hesitation in the adoption of advanced power generation technologies such as IGCC plants that have not been demonstrated on a commercial scale for Indian coal due to high-ash content.
- Non-availability of funds with the state electricity boards for renovation and modernization of state power plants.
- The high costs of power generation and variations in resource availability poses a hindrance in the adoption of renewable energy technologies.

## INDUSTRY SECTOR

- Institutional barriers in some industrial sectors like paper and pulp, textile, and fertilizer, hinder energy-efficiency efforts.
- Lack of adequate capital and low credit worthiness of small-scale enterprises hinder their ability to invest in energy-efficient technologies due to their high upfront costs. Also, there is lack of expertise and technical know-how on their part.

## TRANSPORT SECTOR

- Energy-efficiency measures require huge investments in the creation of new infrastructure.
- Efforts to reduce GHG emissions by the way of introduction of MRTS (Mass-rapid transit system) is fraught with difficulties resulting from diverting resources from other priority budgetary allocations.
- The use of MRTS is limited as they do not offer the benefit of door-to-door connectivity.
- The choice of the modes of travel are driven more by changing lifestyles and preferences of individuals. Thus, it is difficult to induce the inter-modal shifts in such a case.

## CHINA

Larson, Zongxin, DeLaquil, *et al.* (2003) using the MARKAL energy-system modelling tool, assessed the future-energy technology strategies for China. The aim of the study was to explore the prospects for China to continue its social and economic development while ensuring national energy-supply security and promoting environmental sustainability. Gainful insights into different energy development choices were accomplished by exploring scenarios for the evolution of the energy system from 1995 to 2050.

The study on the whole reveals that a BAU strategy relying, simply on coal combustion technologies would not be able to meet all environmental and energy security goals in China. What will be needed is an advanced technology strategy emphasizing (1) coal gasification technologies co-producing electricity and clean liquid and gaseous energy carriers (poly-generation), with below-ground storage of some captured carbon dioxide; (2) expanded use of renewable energy sources (especially wind and modern biomass); and (3) end-use efficiency, which would enable China to proceed on a path of social and economic development and at the same time ensure a sustainable energy future.

### Results

The two scenarios developed in the China study included the base technology scenarios and the advanced technology scenarios. The model runs with base set of energy conversion technologies intended to represent an energy profile of China with a continuation of current trends in energy-supply technologies with little incentive for the development and introduction of technologies that would provide 'leapfrog' improvements to the energy system in the country.

In order to consider technology leapfrogging opportunities for the country, the alternative scenario included advanced set of energy conversion technologies. Tables 5 and 6 summarize the key differences between the base and advanced set of technologies.

The model chooses the advanced technologies to minimize the total system cost subject to constraints of environment or energy import. In

**Table 5 Coal and renewable conversion technologies in the base and advanced scenarios**

Base scenario for China	Advanced scenario for China*
<b>Coal-derived electricity</b>	
<ul style="list-style-type: none"> <li>▪ Steam thermal plants with capacity 100, 200, or 300 MW (with and without emissions control)</li> <li>▪ PCC, 500 MW</li> <li>▪ AFBC, PFBC, and ultra-supercritical steam</li> <li>▪ Cogeneration of power and district heat (using traditional or advanced steam plants)</li> <li>▪ PCC cogeneration of power and industrial heat</li> </ul>	<ul style="list-style-type: none"> <li>▪ Integrated coal GCC</li> <li>▪ IGCC with CO<sub>2</sub> capture and sequestration.</li> <li>▪ Integrated gasifier/solid-oxide fuel cell with CO<sub>2</sub> capture and sequestration</li> <li>▪ 'Polygeneration' co-production of power and dimethyl ether (with and without CO<sub>2</sub> capture), hydrogen (with and without CO<sub>2</sub> capture), or methanol IGCC cogeneration of power and industrial heat</li> </ul>
<b>Coal-derived heat</b>	
<ul style="list-style-type: none"> <li>▪ Boilers (conventional or advanced)</li> <li>▪ Cogeneration (as above)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Cogeneration and polygeneration (as above)</li> </ul>
<b>Coal-derived solids, gases, and liquids (without co-production of electricity)</b>	
<b>Washed coal</b>	
<ul style="list-style-type: none"> <li>▪ Coke, with co-production of town gas</li> <li>▪ Town gas by traditional gasification, with coke co-production</li> </ul>	<ul style="list-style-type: none"> <li>▪ Towngas by modern oxygen-blown gasification</li> <li>▪ Fischer-Tropsch liquids (with and without CO<sub>2</sub> capture), methanol, dimethyl ether</li> <li>▪ Hydrogen (conventional technology)</li> <li>▪ Hydrogen, augmented by H<sub>2</sub> from coal-bed methane obtained by injection of CO<sub>2</sub> captured during H<sub>2</sub> production</li> </ul>
<b>Renewable electricity</b>	
<b>Biomass combustion (steam cycle)</b>	
<ul style="list-style-type: none"> <li>▪ Village-scale biomass gasifier/IC engine cogeneration</li> <li>▪ Small-scale wind farms</li> <li>▪ Residential solar PV systems</li> <li>▪ Hydroelectric plants (smaller or larger than 25MW)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Village-scale biomass gasifier microturbine cogeneration</li> <li>▪ Village-scale biomass gasifier solid-oxide fuel cell-microturbine hybrid electricity generation</li> <li>▪ Large, remote wind farms with long-distance transmission</li> <li>▪ Central solar PV systems</li> <li>▪ Co-production of electricity with Fischer-Tropsch liquids or with dimethyl ether</li> </ul>
<b>Renewable gases and liquids (without co-production of electricity)</b>	
<b>Village-scale anaerobic digesters</b>	
<ul style="list-style-type: none"> <li>▪ Village-scale producer gas</li> </ul>	<ul style="list-style-type: none"> <li>▪ Ethanol from lignocellulosic biomass</li> </ul>

\* In the advanced-technology scenarios, all technologies (including those listed under base) are included in the model.

MW – megawatt; PCC – pulverized coal combustion; GCC – gasifier combined cycle; IGCC – integrated coal gasification combined cycle; GCC – gas turbine combined cycle; AFBC – advanced fluid bed combustion; PFBC – pressurized fluidized bed combustion; PV – photovoltaic; IC – internal combustion; H<sub>2</sub> – hydrogen; CO<sub>2</sub> – carbon dioxide

addition, the choice of technology is made under a variety of conditions. For example, many of the radically new technologies will not necessarily be introduced into the Chinese economy without focussed government policies and support for technology research, development, demonstration, and commercialization.

It is indicated by the model results that China's economy improves its overall efficiency in all of the scenarios at a relatively aggressive rate. This is indicated by the rate of decline in primary energy intensity (primary energy use per dollar of GDP). Between 1995 and 2050, the primary energy intensity falls from 58 MJ/\$ (mega joule) to about 8 MJ/\$, which is an average of about 3.5% per year.

The results also indicate that total carbon dioxide emissions in 2050 are 2.3 GtC (giga tonnes carbon) in the base scenario and 0.9 GtC in the advanced scenario, with cumulative emission over the full analysis period totalling 99 and 66 GtC, respectively. Primarily a combination of more efficient transportation technologies, greater contributions from renewable energy sources, and the sequestering of 20 GtC between 2010 and 2050 achieve the low carbon emissions level in the advanced scenario. Annual carbon sequestration in 2010 amounts to 9 MtC (million tonnes carbon) as a by-product.

**Table 6** Key technology differences between base and advanced scenarios

Base-technology scenarios	Advanced-technology scenarios
<p><b>Efficient technologies at point of energy end-use</b></p> <ul style="list-style-type: none"> <li>▪ Coal used primarily by existing or advanced combustion technologies</li> <li>▪ Existing and improved gasoline engine vehicles</li> <li>▪ Currently commercial renewable energy technologies</li> <li>▪ No options available for carbon sequestration</li> </ul>	<ul style="list-style-type: none"> <li>▪ Super-efficient industrial process options added</li> <li>▪ Coal options extended to include gasification-based technologies for production of electricity and clean gaseous and liquid fuels</li> <li>▪ Vehicle include hybrid-electrics and fuel cells</li> <li>▪ Advanced renewable energy technologies become available, for example large-scale wind farms</li> <li>▪ Carbon sequestration options available with and without enhanced resource recovery</li> </ul>

## The Japanese experience: some lessons

Japan provides an excellent example of an economy that has not only embarked on the path of development in an extremely successful way but has done so in a very sustainable manner. It has achieved this by developing and adopting technologies most needed and suited to its economy, and by efficient deployment of these technologies. Developing countries like India and China can learn from the Japanese experience and also adopt technologies, though tailored to their own domestic economies, by pursuing mutually beneficial agreements with Japan and among themselves.

### Some lessons: Japan

Efforts of Japan for the development and deployment of PV (photovoltaic) and clean coal technologies, especially the adoption of ultra-super critical boiler, exemplify how sustainable energy options can be pursued by an economy to suit their own domestic economy. Japan is also currently implementing the IGCC (due to be commissioned by 2010).

For example, taking the PV energy, Japanese PV production – which presently accounts for 49% of the world total – had benefited from a variety of government incentive programmes. The 70 000 roofs programme established in 1994, initially covered 50% of PV installation costs. As the cost of solar cells fell with increased production, however, the subsidy was reduced to about 10%. By 2002, the number of residential systems installed in Japan had reached 144 000.

Other useful government incentives included a budget allocation of 20.5 billion yen (\$186 million) in 2003 – for research and development, demonstration programmes, and market incentives – and net-metering (feeding excess energy back into the power grid). Within nine years, from 1994 to 2003, these programmes helped Japan position itself as the world leader in both the production and installation of solar cells. The table below indicates the stepwise incentives taken by Japan to successfully establish solar energy.

#### Incentives for solar energy in Japan

- |             |  |
|-------------|--|
| <b>1992</b> | <b><i>New sunshine programme:</i></b> Established to introduce renewable energy throughout the country. Targets were set and a net metering law enacted. |
| <b>1994</b> | <b><i>70 000 roofs programme:</i></b> Initially, 50% of PV installation costs were subsidized and the annual budget (for R&D and market incentives) was  |

*Continued...*

### Some lessons: Japan (*continued...*)

\$18.3 million. In 2003, the subsidy was reduced to 15% and the budget allocation increased to \$186 million.

**2003** *Renewable power portfolio standard*: Requires that renewable energy be provided at a constant percentage of the electric power supply. This legislation aims for renewable energy to be 3.2% of the total by 2010.

With regard to clean coal technologies the growth in generation capacity in OECD Asia/Pacific region is projected to be 303 GW with 45 GW (gigawatt) of coal-fired capacity and 43 GW of that installed in Japan. The factors that shaped the adoption of clean coal technologies especially in Japan include deregulation/competition driving capacity decisions, along with national goals of diversification of fuel mix to increase the security of energy supply, and return on investment, environmental, politics and capital cost. Certain policies and measures that could enable and overcome the barriers to adoption of clean coal technologies include government financial incentives, market competition between technologies, and better methods of disseminating information.

The following methods for improving steam turbines have typically been used at Japan's conventional thermal power plants.

- increase their unit capacity;
- increase the temperatures and pressures of their steam conditions; and
- improve the turbines' internal efficiency.

Raising steam conditions at a turbine's inlet has been the most effective factor for boosting plant efficiency. In recent years, improved steam conditions have been applied extensively to utility plants in Japan burning pulverized coal. In particular, boosting steam temperatures at turbine inlets has produced significant improvements in plant efficiency.

**Source** Waldau (2003); <<http://www.iea.org/>>, last accessed on 20 September 2006; <<http://www.nedo.go.jp/english/index.html>>, last accessed on 18 September 2006

## CONCLUDING REMARKS

The present paper has expounded that world energy needs would continue to increase if current patterns of economic growth, technology diffusion, and policy frameworks continue. In particular, India and China will have a major role to play in influencing the future energy profile of

the world. Both these economies still have relatively large populations faced with 'unmet demands' which implies that with improvements in lifestyles and access to resources per capita energy needs would further increase. Unfortunately, technological uptake is also relatively more difficult in developing countries such as India and China, due to resource constraints and other barriers. Apart from threats to the local environment, most energy use is associated with global implications with regard to the environment. Therefore, it is emphasized that efforts need to be targeted towards mobilizing technological leapfrogging in these countries and facilitating the uptake of options that ensure that energy is used efficiently and in an environmentally benign manner.

In India, the scope for technological change seems to be more relevant and crucial in the power generation sector and in the transport and residential sectors from the demand side. The country has no option but to go all out towards making efforts to exploit the maximum possible potential of hydro, nuclear, and renewable base power whilst simultaneously adopting clean coal technologies such as IGCC (using imported coal) and ultra super critical boiler. In the transport sector, again, it is imperative for the government to focus on enhancing the share of rail-based passenger and freight movement, share of public transportation, and efficient transportation modes. Policies directed towards efficient appliances and lighting system also have a crucial role to play in providing energy efficiently in the residential and commercial sector.

On similar lines as India, in China as well, it is the end-use efficiency improvements that would provide least-costly option for meeting energy service demands and thus should be pursued regardless of what energy-supply strategy is adopted. Again, coal use must shift from combustion technologies to gasification-based technologies keeping in mind the environmental concerns. China, as in India, needs to exploit the full potential of renewable energy sources; wind energy is seen as a foreseeable contributor to electricity supply. Modern biomass technologies using agricultural residues, such as village-scale producer gas systems and larger-scale systems co-producing electricity could play an essential role in helping to meet energy needs of rural populations.

Thus, it would be prudent to conclude from the analysis of the paper, that technological solutions will be an important part of strategies and

actions for attaining a sustainable path of development world over, and particularly for the two emerging giants—India and China. It is also apparent from the case of two countries that capacity to absorb technology that would be of value in the future would also differ from society to society, requiring unprecedented partnerships that could help, alter, and correct the current inequitable pattern of technology deployment.

The Regional Sustainable Development Summit in Japan will thus be a policy forum on science and technology for sustainable development in context with the need to bridge the divide between developed countries in Europe (Britain) and developing countries in Asia, particularly China and India.

China and India, with prospects of sustained economic growth and development, and increasing roles as global economic powers, have great potential for partnerships for the upgrading technology. Links flourish in a huge number of areas, from environment to education, development to science and technology, between China, India, and several developed countries, which could be used to the benefit of the world at large.



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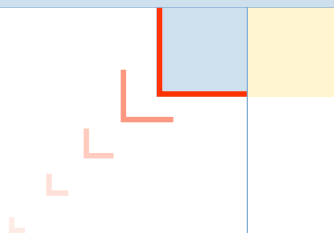
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