FEATURE SECTION

Rural Technologies

As we celebrate India's remarkable economic growth of recent years and the rise of the IT and manufacturing sectors, we need to consider some sobering statistics: fully one quarter of the world's poor – almost 300 million – live in India. The IT sector accounts for almost 4 percent of GDP, but employs only a million people. About 65 percent of India's population depends on agriculture for its livelihood. In 2001, about 720 million people of India lived in 600,000 villages and 40 percent lived a significant distance from a road. And about 150 million of our countrymen live in slums.

Technology is hardly a panacea for all of India's ills. But it can help dramatically reduce the prevalence and severity of many developmental problems. It can help improve the quality of life, especially for the poor and disadvantaged, by permitting more and better services, transforming economic activity and reducing inequalities based on factors like geography and history. The appropriate technology may be something as elementary as a strategically placed hole in the ground to harvest rainwater or it may be a sophisticated satellite-based system for tracking infectious diseases. What we need are solutions that are affordable, sustainable and acceptable to the people who end up using them. So the matter of high tech or low tech is immaterial, as long as it is the right tech.

In discussions about technologies for the rural sector, some of the questions often raised are:

- How do we encourage development of technologies and technology-based solutions appropriate for the rural sector?
- How do we promote positive change through adoption of innovations and make beneficiaries partners in the process?
- How do we encourage grass roots innovation?
- How do we translate innovations into viable products and take them to market?
- How do we support rural employment and bring equitable growth through the application of technology?

There are a number of organizations in India, both private and public, that do R&D for the rural sector. This includes the IITs. A range of applications are being developed that include energy (for lighting, cooking, transportation, and agriculture), water (for domestic consumption and cultivation), agriculture (better seeds, practices, and equipment), manufacturing (small scale, agro-based, etc.), sanitation, health, transportation, communication, environmental conservation, and rural employment.

This feature section has articles on some of these topics. Some explore the issues, while others present R&D from the IITs.

PiTech Editorial Team

Technologies for Rural India

__Palagummi Sainath__ was born in Andhra Pradesh and is a grandson of former President V.V. Giri. His preoccupation with social problems began when he was a student in college. He launched his career as a journalist at the United News of India in 1980. In the last decade he has spent about 280 days each year living in the villages of India and reporting firsthand on agrarian crises arising from policies related to globalization and privatization.

Through his work on India's social problems, described in his best selling book Everybody Loves a Good Drought, *Sainath has helped focus public attention on the condition of India's rural poor. He has earned a journalistic name by receiving numerous national and international awards for his reporting, and Nobel Laureate Amartya Sen has described him as, "one of the world's greatest experts on famine and hunger." He is currently rural affairs editor of The Hindu, a leading newspaper based in Chennai, India. Recently our PiTech editorial team interviewed P. Sainath to get his views on technology-based initiatives to address problems faced in rural India.*

How did you become interested in the debate on food, hunger, and rural development?

That's a long story. It's not that I woke up one day and suddenly decided I was interested. I was born into a family that was closely involved in the freedom struggle and it was perfectly natural for me to be interested in these issues. Around 1991-92, when India changed its policies, I was appalled at how these policies were affecting the rural areas. When the media started focusing on the top five percent – the 'beautiful people' as I call them – I decided to focus on the bottom five percent. It ended up being the bottom 40 percent.

During 1993 to 2004 I was a freelancer, visiting the poorest districts of India and reporting on rural poverty for The Times of India. In 2004 The Hindu offered me a position to do exactly what I had been doing, but on their platform.

In your book, *Everybody Loves a Good Drought*, you have made a distinction between treating problems related to poverty as *processes* and treating them as *events*. Can you explain the distinction?

It's very easy for the media to cover an event. It is much more difficult to cover a process. Covering a process requires hard work, it requires research, it requires patience, and it requires an editor who will give you enough time. The Indian media are very strong on covering events.

For instance, I'm sure you have read a lot more about the farm suicides in Vidharba in the past two months. It even made the front page of The New York Times. But the actual news is several years old and the suicides have been going on for years. Why did it receive media attention only now? The reason is that because of the desperate situation in Vidharba, we forced the Prime Minister to visit the farmers. At that time, it suddenly became an *event* and got wide press coverage. The suicides are part of a *process*, but the media does not cover processes.

The main peg of the coverage in Vidharba was the Prime Minister's visit. This sort of coverage has limited value, because when the event ceases to be an event, the news fades and the problems of the people in that area are quickly forgotten.

Poverty is a process, not an event. It is not a natural calamity. It is created by our use and control of resources – the manner in which we use them as a society and the manner in which we deny access to them for millions of people. All this is part of policy and process, and not an event. They are embedded in the structure of our society.

Exploring this process is much more challenging than covering a Prime Minister's visit. It requires a lot more skill in bringing out the underlying realities of a process because there is far more drama in a process than in an event.

What technology-based initiatives can help address problems in rural India?

I have to confess that I am a terrible gizmo freak in my own life, but I do want to emphasize that technology does not always imply high technology.

The day we invent a leak proof tap will be revolutionary for rural India. I'm serious. Today billions of liters of water, which is by far the most crucial resource, are being wasted. In the current situation in India's countryside, technology has got to be useful to people. It's not just a question of being more efficient. That is a narrow viewpoint.

I would propose four criteria for designing technology: (1) How is it useful for the society in which you are introducing it? (2) How does it improve productivity? (3) Does it enhance or undermine employment? (4) The fourth criterion deals with the democratization of technology control and the decision making process. That is, technology must be in the control of and answerable to the people who should have a say in whether or not they need a particular technology.

It is difficult but not impossible to design technology based on these criteria. The easy and lazy way is to use intensive technology that yields 'incredible' results in the narrow framework of the technology itself. But if the technology displaces employment on a vast scale, then it affects the socio-economic fabric of the community in which it is deployed.

Technology-based initiatives must preserve employment, enhance productivity, demonstrate their usefulness, and be in control of and answerable to people – what I have referred to as the democratization of technology.

Can you give us an example of such a technology?

Certainly. There are many examples but I will talk about just one. The 'Jugaad' is the funniest looking "automobile" on the planet. It is manufactured from discarded parts of tractors, cars, and in one case, aircraft tires. It runs on a 5 horse power diesel engine and it costs under Rs. 10,000 (US $225).

But it adequately serves the purpose for which it was built. It takes produce from the farm to the market. It drops children to school. It transports old people around the village. The fare is about Rs. 2 (5 cents) and can vary depending on the region and the distance involved. It's

Although it appears comical, the 'jugaad' is an excellent technology innovation for rural transportation.

a local transport system for farmers. It was conceived to meet a transportation need.

However, the 'jugaad' has been banned in Haryana because automobile companies protested to the government. Madhya Pradesh also banned it, but the ban was ignored after many people complained. The lobbying for the bans was spearheaded by auto makers on the pretext of safety. That is a difficult argument to understand because the 'jugaad' travels at 5 miles per hour.

In one sense, the 'jugaad' has something that no luxury automobile can claim – EVERY 'jugaad' is custom made because there is no individual inventor! Moreover, because it is made from waste materials, it is good for the environment.

Technology must be accessible and controllable. When technology becomes too big, and is not subject to democratic and social controls, it leads to a lot of corruption.

One of the greatest technology needs of urban India is non-polluting public transport that can create millions of jobs. Cities like Bangalore are breaking down today because of the amount of pollution. In rural India, the democratization of technology is important.

Technology comes up in society to meet a need. We do not need to import it in all cases.

What technologies should India focus on to address real problems of real people?

Water and energy are going to be the giant explosive issues for Indian society in the near future. We are going to run out of energy. We cannot function in the manner we have been all these years. Some questions we must address with respect to water are: (1) How do we reduce wastage of water? (2) How do we increase public access to it?

There are political issues that technology cannot solve. For example, questions such as "Who owns water?", "Who owns ground water?", and "Who owns fresh water?", are all political questions that technology cannot answer.

But if we have a decent political position, technology can enhance that and make it real. How do we deliver water to the smallest handlers? Technology can play an important role in seeing that water is not wasted, in seeing that water is preserved, in seeing that water is efficiently transported and distributed.

The water crisis is going to be the crisis of the century. Wars are being fought over water. Major disputes arise from water-related issues – an example is the dispute between Karnataka and Tamilnadu in southern India over the Cauvery River. Water is going to be a major issue even at the village and household levels. That is where technology can be of great help. We have to think and envision technologies that will be responsive to the social needs of communities. We have to make the processes just and efficient, in that order. That is where technology can be a true enabler.

I'll give you an example of where technology can solve a real problem. One practice that is taking place along India's coastlines is that large-scale trawler fleets are wiping out small fishermen. The trawlers deplete the narrow coastal waters of fish, forcing the fishermen to go into deeper water in their catamarans, causing the number of deaths to increase. Fish is the cheapest source of protein and most marine life is concentrated close to the coast, because that's where the nutrients are.

Technology can place a tool in the hands of traditional fishermen to take advantage of this fact.

We can equip the small fishermen's boats with a telephone "dubba" (box) that is used in the Public Call Office (PCO) telephone booths. These PCO dubbas are very sturdy in the sense that they can take a beating from the weather, but still function reliably. We can install a box on each boat that serves multiple functions. The first is an SOS function. The second is coast-to-boat and boat-to-coast communications. The third is a GPS with shoal-tracking software that would save enormous time and labor. Such a PCO-like dubba will not level the playing field, but it will make it a little less worse.

The M. S. Swaminathan Research Foundation has collaborated with fishing institutes and created a database for fishermen in Pondicherry. Information and data are in the control of the community, which obtains information about the location of shoals from the fishing institutes. The challenge is to develop a shoal-tracking system that gets this information from the shore to the boat, but I think that it is fairly modest technology and easily doable today.

How can IITs and IITians help in the development of rural technologies that serve the purpose of the people?

IITians are taken very seriously and you should begin by laying out some principles and a framework for the development of rural technologies:

(1) Whom does the technology help?
(2) How does it help?
(3) Does the technology enhance or undermine employment and livelihood of people?

For each technology that is proposed, IITians can evaluate it by doing a study on its productivity gains and its health benefits or side-effects. The middle classes in India today are completely sold on techno-fixes to problems. For rural India, however, we need technological solutions that address the underlying causes of problems. The costs of everything we do are not just economic – there are related social, environmental, and health costs also that need to be factored. IITians can help with technologies in the areas of water, energy (to get out from the reliance on fossil fuels), mass transportation, and health. You have the credibility and collective expertise, and it will be difficult for the government to ignore any advice that you give them. ■

Ideal Tractor for Small Farms

Different stages of agricultural development, from primitive mechanization to automation, have taken place in India during the last four to five decades. The application of machine to agricultural production has been one of the outstanding developments in Indian agriculture. The use of suitable agricultural machines helps in timely operation and is particularly advantageous when it minimizes peak labor demand that occurs over a relatively short period of time during each crop season. Many field operations must be performed within the critical period to obtain maximum returns.

Today, the tractor has become one of the most important power sources in agriculture. The total farm power availability has increased from 0.295 kiloWatt/hectare (kW/ha) in 1971-72 to 1.231 kW/ha. A majority of farms are small land holdings and farmers need to have a small tractor. Although power tillers have provided a solution of sorts, they are not very popular because the farmer has to walk behind the machine during operation. Moreover, while the cost of the power tiller is high at Rs. 1.30 lakhs, the farmer does not get the status of a tractor owner.

The Agricultural & Food Engineering Department at IIT Kharagpur has designed and developed a small and versatile tractor that costs no more than Rs.1 lakh. The tractor is able to cover an area of about 4-5 ha per day and consumes 0.8 litres of diesel per hour. ■

K.P. Pandey, V.K. Tewari,
H. Raheman
IIT-KGP

Transforming Rural India with Telecommunications

In the mid-1980s, it took seven years to get a home telephone connection in urban India. The telephone was considered a luxury and beyond the reach of lower middle-income and middle-income Indians. The introduction of Subscriber Trunk Dialing–Public Call Offices (STD–PCOs) in the late 1980s marked the first telecom revolution in India. A few simple principles were used to overcome the fact that telephony was unaffordable to the majority of the country's population. The first was to aggregate the demand for telephony within a local geography; the second was to get an entrepreneur to provide the service; and the third was to ensure that nobody needed to walk more than 50 meters from their home to access a telephone.

STD–PCOs, run by entrepreneurs, began to appear on every street corner. They were kept open 16 hours a day, 365 days a year, and telephony soon became available to ordinary urban Indians. By the mid-1990s, there were a million such PCOs serving about 300 million people and contributing to 25 percent of total telecom revenues in the country.

These facts are relatively well known. What is less known is the extent to which this first telephony revolution spurred the growth of the economy. As PCOs were installed (even in remote parts of towns), taxi stands appeared near them, followed by auto-repair and other shops, which boosted local businesses. Women felt safer travelling to these areas for work, primarily because of access to a telephone. Despite these developments, the total number of telephones was still under 10 million in 1994, growing at the rate of about a million lines per year. Telecommunications in India was a monopoly of state-owned operators Bharat Sanchar Nigam Limited (BSNL) and Mahanagar Telephone Nigam Limited (MTNL).

Wireless Telephony

The National Telecom Policy 1994 (NTP–94) paved the way for private players in the telecom sector. It was also recognized that wireless would be the key to increasing telephone density in India. However, the mobile telephone industry, hyped to be the sunrise industry of the 21st century, had only one million subscribers in 1998. The promise of a large Indian market was nowhere to be seen and private telecom operators were crumbling financially.

The reasons for this are manifold and date back to 1994. Egged on by consultants and foreign partners, wireless operators had ignored ground realities and overly-hyped the potential of middle-income Indians and their purchasing power. Chasing this virtually non-existent middle-income group, operators bid for licenses at exorbitant rates. With the cost of mobile handsets at approximately Rs. 25,000 (US $550) and mobile tariffs at Rs. 16 per minute, the projected growth in the number of subscribers and the return on investment (ROI) did not materialize. The telecom industry was on the verge of bankruptcy in 1998. The basic economics were still not working out. The capital expenditure (CAPEX) for installing a telephone line was still about Rs. 40,000, and taking into account the 15 percent interest, 12 percent depreciation and yearly operational expenditure (OPEX) that amounted to about 12 percent of the CAPEX, one needed an Average Revenue per User (ARPU) of over Rs. 1,200 per month to simply break even. Even if a household were to spend 3 percent of its income on telecom, this was affordable to less than 5 percent of Indian households.

India has become the fastest growing telecoms market in the world, adding 5 million lines every month.

The tide turned for the telecom industry with the National Telecom Policy 1999 (NTP–99). The Government of India made a revolutionary move attempted by no other country in the world at the time. It waived the license fee obligation (committed to by operators through open bidding in 1994) and moved to a "revenue-sharing regime." The license fees paid by operators up to July 31, 1999, were considered as the entry fee. Since then, 15 percent (subsequently reduced further) of the gross revenues of operators were to be paid under the revenue-sharing model.

Since NTP–99, economies of scale have been achieved and the maturing of mobile technologies and standardization has helped rapidly reduce the cost of infrastructure. The CAPEX for infrastructure is now lower than Rs.10,000 per subscriber. The cost of mobile handsets has dropped drastically to less than Rs. 1,500. Due to increased competition and a reduced cost structure, mobile tariffs in India stand at 50 paise per minute, the lowest in the world. Telephony has become widely affordable. It is small wonder then that India has become the fastest growing telecom market in the world, adding 5 million lines a month. By 2015, it is predicted that India will be the second largest telecom market in the world. The second phase of the Indian telecom revolution is reaching its peak. Not coincidentally, there has been a huge concurrent growth in the Indian economy.

Yet, India's teledensity is only just over 10 percent. And the distribution of telephones within India is highly inequitable, with rural teledensity being only 1.5 per hundred, while urban teledensity was 20.7 per hundred in 2004. This is especially troubling since over 70 percent of India's population is rural. At the same time, Internet connectivity in India remains in the same situation as telephony did in the late 90s. India has barely two million broadband connections. To leverage the Internet fully, India needs to add at least 50 million such connections in the next five years and efforts are underway to make this possible.

The PCO booth is ubiquitous in India's towns and cities

Rural Scenario

India has over 630,000 villages, each with an average population of about 1,200. A distinctive feature of rural India is a rather high population density compared to other parts of the world. Most states in the country have a population density over 250 people per sq. km, and in some states the figure is as high as 700. A significant proportion of villages do not have a single reliable telephone connection today and less than one percent of villages have an Internet connection. Rural areas in India are also characterized by very low incomes, most households earning below Rs. 3,000 per month (which amounts to Rs. 600 per capita per month). Providing telephony and Internet to such populations on a commercial basis has always been a challenge.

Since telephony, and especially Internet connectivity, are known to be powerful tools of empowerment, by giving people in low-income areas access to a wide range of resources, the Internet hurdles several socio-economic and geographical barriers. It allows people to avail of better education and access information, thereby expanding their horizons unimaginably. People in remote areas feel a sense of inclusion as they begin to learn about the various opportunities that exist to enhance their lives in the spheres of health, education, career, entertainment, and so on.

Villagers engaged in various professions – artisans, farmers, local doctors – can consult experts remotely for specific advice in their respective fields. In the health arena, remote diagnostics is a significant technological advancement that can prove extremely useful where specialists and proper hospitals are absent. In education, academic institutions can offer certification courses at a distance, which is invaluable in areas where proper schools and colleges do not exist.

Technologies for Rural Connectivity

Over the past 15 years, the Department of Telecommunications and BSNL have made significant contributions toward connecting rural India by laying fiber to almost all taluka (county) headquarters and towns. Today, many private telecom operators (Reliance, Tata, and Bharati), and organizations such as Railtel, have laid fiber to connect towns. Nearly 85 percent of Indian villages are situated within a 15-20 km radius of these taluka towns and therefore a wireless system with a radius of coverage of about 20 km deployed in these towns is able to connect nearly all these villages. Today, wireless systems may cost about Rs. 10,000 per line, including towers and deployment, and can provide telecom and Internet connectivity within a 20 km radius. Broadband corDECT, designed by IIT Madras, is perhaps the best available today, providing a 256 kbps dedicated connection to each village even with limited spectrum. Wireless technologies that further reduce costs and increase bit-rate, are evolving every year and OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (Multiple Input Multiple Output antenna system) based technologies will improve rural connectivity even more in years to come. Most of rural India can indeed be connected with broadband.

While a 50 paise per minute tariff and an ARPU of Rs. 300 per month may be inexpensive in the urban context, it is still unaffordable in rural areas. A look at Indian rural income shows that the rural ARPU needs to be less than Rs. 100 per month and a tariff of no more than 25 paise per minute is required for telecom to boom. How does one provide such differential tariff for mobiles in urban and rural areas? The TeNeT (TElecommunications and Computer NETworking) group at IIT Madras and Midas communications have taken an initiative to develop a very low cost single channel micro-GSM base station using software radio concepts, with an IP back-haul provided on the broadband connection to a village. This can provide mobile telephony at a differential tariff for rural areas. Installed in a village with broadband Internet providing the back-haul, it enables a villager who is connected to such base stations to enjoy a lower tariff. These systems are likely to significantly boost rural connectivity.

About 15 percent of the villages in India are in areas where the presence of fiber is low. These tend to be the hilly, forested or desert areas where the population is sparse and average incomes are lower than in the plains. Laying fiber in such areas is both difficult and expensive. A Sparse Area Communication System (SACS), which combines satellite and terrestrial wireless systems, has been developed at IIT Madras along with the Indian Space Research Organization (ISRO) to connect villages in such areas. In this system, a satellite remote terminal with a 128 or 256 Kbps dedicated connection (both ways) is installed in an elevated area, such as on top of a hill. A terrestrial wireless system provides connectivity from this remote terminal to about 50 to 70 villages within a radius of 15 to 20 km. As the satellite remote terminal and recurring costs associated with the satellite segment are shared by 50 to 70 villages, the cost is not as high – total cost is estimated to be Rs. 35,000 per connection with recurring costs of about Rs. 1,500 per year per village.

Business Models for Rural Connectivity

Technology is just a beginning. An innovative business model is required to deliver Internet services to rural areas. Commercial delivery is essential since in the long run funded models drain financial resources and are neither scalable nor sustainable. An example of one such business model is that of n-Logue Communications Private Limited, which was incubated by the TeNeT group of IIT-M with a mission "to significantly enhance the quality of life of every rural Indian" by setting up a network of wirelessly connected Internet kiosks in villages throughout India.

n-Logue's business model involves Internet Kiosk Owners (KOs) in each village who are provided a multimedia PC, a UPS with battery, a digital camera, printer, and the wireless subscriber unit with related accessories. The total cost of this equipment and a marketing kit, local language software, training and an Internet connection for the first six months of operation is approximately Rs.50,000.

Once the kiosk is in operation, the KO accesses a host of services. These include computer education, adult literacy programs, agriculture-related services, health services and e-Government services. Many of these services make use of iSee, a low bandwidth videoconferencing software (developed by a company called OOPS in association with TeNeT group) that allows villagers to communicate with various experts remotely. Other online services include entertainment (games, music, and movies) and astrology. In addition, the KO offers any number of services that he or she develops independently, or with other partners, at the kiosk.

Information & Communication Technology (ICT) Services

Education is the highest revenue earning service in kiosks. Computer education is especially widely used. A major educational service is the Online Tutorial developed by the TeNeT

Group, which focuses on coaching students to pass their 10th and 12th grade examinations. Wherever this service has been launched, the impact on student performance has been extremely impressive, with high pass percentages and absolute scores on examinations. In 14 of 18 villages where it was used widely in the early months of 2006, 100 percent of the coached students passed the SSLC examinations. Spoken English is another service that is popular, among women in particular. Newer services that have been developed are in the areas of Computer Graphics, typing, etc., and also show promising early results.

Health services in these kiosks started in an unplanned manner with some villagers sending pictures of their eyes to an eye care center. It soon resulted in doctors seeing patients remotely via video and advising them. From eye doctors, it moved to veterinary doctors seeing small animals and then general practitioners seeing human patients. The service has been enhanced by development of a tele-medicine kit (by a company called Neurosynaptics incubated by TeNeT), which allows patients to transmit vital parameters such as blood pressure, pulse rate, temperature and ECG, online to doctors located remotely. It has been piloted in a few areas but has shown only limited results despite the fact that many villages do not have access to a well-qualified doctor or hospital facilities.

Conclusion

For a nation with 700 million rural people, rural use of the Internet for development is still very much in the rudimentary stages. While ideas exist and some experiments have produced significant results, the overall impact is negligible. All one can do at this stage is point out the potential. In order to utilize the tools of ICT to make changes that can scale a lot remains to be done. India's telecom revolution will remain incomplete until this happens. ■

Ashok Jhunjhunwala and Sangamitra Ramachander (IIT-M)

Entrepreneurial ingenuity - rural style

A survey of more than 150 rural Internet kiosk operators (KOs) over two years showed that a third have invested in additional computers for their kiosk. About 60 percent have added photocopiers, fax machines, scanners, CD writers, or lamination machines. Thus, in many cases the kiosk has become a 'business centre' for the village, providing access to multiple technologies. The proliferation of various kinds of ICT in rural areas is a definite step toward bridging the rural-urban technology divide.

In agriculture, n-Logue partners with experts at the Tamil Nadu Agricultural College and Research Institute to provide advice on farming methods and solutions to crop and animal diseases, via videoconferencing. Through the kiosk, farmers can also access various agricultural portals to find weather information, crop prices, and improved farming techniques. Some kiosks may sell tractors and spare parts for farm equipment manufacturing companies, others may dispense online veterinary advice. Kiosk operators in some instances have partnered with industries that source raw materials from the villages and the kiosk is being used as a point to coordinate transport of the raw materials. KOs are also serving as agents for insurance companies who wish to enter rural areas, and online application forms for insurance are being introduced.

Future services could include facilities for soil testing at the kiosk, online farming 'schools,' an early warning system for disease outbreaks, and long-term predictions on crop prices, demand, and rainfall.

Kiosk Operators are also developing new services for their customers. One woman KO uses her digital camera, printer and lamination machine to produce ID cards for a local government agency on a contract basis. Besides providing services to the local village population, several KOs have trained themselves in certain skills such as basic data-entry and take on jobs either from local agencies (local governments, police stations, etc) or from urban clients. The Rural BPO team, a part of the TeNeT Group at IIT Madras, manages the outsourcing of IT-enabled services to rural areas by linking the kiosk network with urban clients.

E-Governance through kiosks provides access to government portals that contain online forms and applications for birth and death certificates. In the southern state of Karnataka, the kiosk network has partnered with the government's Bhoomi database, allowing access to land records. Videoconferencing sessions between village kiosks and local government officials are also organized. By providing a means to bypass government bureaucracy such services have a huge demand but have not seen commensurate results. Despite the hype, implementation of the services is inconsistent and depends completely on the individual Government officer.

An online tutorial has been developed to coach students for the 10th and 12th grade examinations. Wherever this service has been made available, the impact on student performance has been extremely impressive with high passing percentages. In 14 of 18 villages where it was used in 2006, all the coached students passed the SSLC examinations.

Low bandwidth video-conferencing is being used for a wide range of innovative purposes. In one case, timely detection and diagnosis of crop disease in Okra remotely by agricultural experts was able to save an entire harvest.

Overall, the most popular services in the kiosks today are Internet browsing and email, gaming, and computer education. Desktop publishing and photography also are popular.

WATER

managing a precious resource

Professor Asit K. Biswas, an Indian-born Canadian citizen and President of the Mexico City-based Third World Centre for Water Management, was awarded the 2006 Stockholm Water Prize. Since 1991, this award has been presented annually to an individual, institution, or organization for outstanding water-related activities. In selecting him, the Nominating Committee cited his "outstanding and multi-faceted contributions to global water resource issues, including research, education and awareness, water management, and human and international relations in both developed and developing countries."

Close on the heels of the Stockholm award, Prof. Biswas received the prestigious Aragon Environment Prize of Spain, and Man of the Year Award from Prime Minister Stephen Harper of Canada.

Professor Biswas received his B.Tech and M. Tech. degrees in Civil Engineering from IIT Kharagpur, and has published 68 books and over 600 scientific and technical papers. His work has been translated into 32 languages. As an advisor to 18 governments and most major international organizations, he crisscrosses the world continuously. PiTech recently caught up with Prof. Biswas to get his views on water management policies and technologies for India.

How did you get interested in a career in water management?

I have always been interested in water. My M.Tech. was on hydropower and dams, and Ph.D was in water resources management from the University of Strathclyde, Glasgow. My whole career has been based on water-related issues. Technically and scientifically, water management is a complex and fascinating process, which is likely to become increasingly more complex in the future.

Is there a water crisis in India? Is the crisis because of lack of water or inadequate water management policies?

Globally, we are NOT facing a crisis because of actual physical scarcities of water. However, we are facing a crisis because of poor management practices of the past. While these practices are improving, they are doing so only gradually and incrementally. What we urgently need are radical changes in our water management practices and processes to successfully meet the challenges of the future. We already have enough knowledge and technology to improve our management practices dramatically. However, because of social and political reasons, in-built inertia and opposition to changes, we have managed to improve water management practices only marginally so far.

India is no exception to this overall global trend. For example, one hears about water scarcities in Indian mega-cities like Delhi, Chennai, and Mumbai. These scarcities are primarily man-made because of past and present mismanagement. Given political will and proper management practices, these so-called water problems can be resolved cost effectively within 2-3 years.

Asit Biswas receiving the prestigious Aragon Environment Prize from President Iglesias and Environment Minister Narbona of Spain, on World Environment Day, June 5, 2006

What are the major water management challenges facing India at present?

The main water problem facing India is how best to manage the country's available water resources efficiently and equitably so that its economic development continues, along with poverty alleviation and environmental conservation. This can be done, but we have not done it very successfully in the past. All over India, we are using inefficient water management processes and practices. Business-as-usual simply is no longer an option for the future of the country.

Are there technology based initiatives currently in place aimed at addressing these problems?

Technology is improving radically in many water-related areas. This will certainly help. For example, because of biotechnological advances, we are likely to have new varieties of drought- and pest-resistant crops during the post-2015 period which are likely to ensure we can produce more usable food in the same area of land and using similar, or even less, quantum of water. We also expect major biotechnological breakthroughs in the foreseeable future in terms of good water quality management. Similarly, we have seen dramatic improvements in desalination costs because of technological advances and improved management practices. Within the past five years, the cost of desalination of sea water has come down from about \$1.50 per m^3 to less than \$0.50. Since more than half of the world's population lives within 100 km of a coast, water for human, industrial and commercial consumption is not a major issue for many of these areas for the first time in human history because of technological advances.

Currently there is a great deal of interest in rainwater harvesting. What are your views on it?

Humankind has always harvested rainwater for survival. Take the case of India. Much of the annual rainfall in most parts of the country occurs in less than 100 hours, which are not necessarily consecutive. The question then is how to collect and store this immense and intense rainfall so that the stored water can be used for the rest of the year. A variety of solutions are available for harvesting rainwater. This may range from construction of dams (large, medium or small), use of tanks, and groundwater recharge. The main issue is how best to conserve rainwater so that it can satisfy human needs reliably and efficiently over the year and in between years.

A large country like India is very heterogeneous in nature because of climatic, economic, social, political, and environmental conditions. In addition, management and technical capacities often vary from one location to another, as do institutional and legal frameworks. Accordingly, there is simply no one single solution that could be equally appropriate for the country as a whole. Solutions that may work in Assam may not work in Rajasthan, and vice versa. In the field of rainwater management, one size does not fit all. Nor is there any room for dogmatic debates and solutions. For example, in one specific location, small could be beautiful, but it could be ugly in another context. Similarly, big could be magnificent but it could be a disaster. Every thing depends on the context in which it is applied. Solutions have to be carefully found for specific locations and boundary conditions. Depending on the context, a large dam may be the best option for harvesting rainwater, or groundwater recharge, or use of tanks, or some combination of these alternatives. For the future welfare of the country, there is no room for dogmatic debates and universal solutions.

How can the water problems of rural India be resolved?

Rural water problems can be solved if we change our mindsets. Provision of clean water and collection, treatment, and disposal of wastewater costs money. People have to realize that they have to pay, either directly or through taxes, for the privilege of having clean water in their houses and also for the disposal of wastewater. In India, proper rural and urban water supply and sanitation services are often non-existent and, when they exist, they are highly subsidized. Current approaches will NOT provide universal access to water services

The Stockholm Water Prize for 2006 was awarded to Asit Biswas

The main water problem facing India is how best to manage the country's available water resources efficiently and equitably so that its economic development continues, along with poverty alleviation and environmental conservation.

in the country, nor will they improve water conservation within one generation. For sustainable and reliable rural water provisioning, we need to consider water pricing, public-private partnerships, participation of stakeholders and education of the general public on water conservation and personal hygiene. We need to take a holistic approach and search for reliable, long-term and equitable solutions for the rural areas.

Can India learn some lessons from other developed and developing countries to improve its water management practices?

The first lesson of technology and knowledge transfer between countries has to be that these are often not directly transferable. We must carefully analyze how other countries have solved, or are solving, the types of water problems India is currently facing. The next step will be to see to what extent these solutions can be applied (perhaps after significant modifications) to meet the specific conditions of the appropriate Indian locations.

In the area of urban water management, the best practice in the world is now in Singapore. Can these practices be transferred directly to India? I doubt it. For example, political interference and corruption is rampant in most Indian water supply corporations, which simply do not exist in Singapore. These two factors alone (there are other factors as well) will mean that the Singaporean solutions can only be tried after considerable "Indianisation." There is a lot of research that needs to be done before the Singaporean solutions can be attempted in India, or in other developing countries. Unfortunately, not a single institution in India is now conducting this type of applied research. Thus, India can learn many lessons from other countries, but these solutions can be applied only after considerable forethought and advance preparation.

You are currently serving as the President of the Third World Centre for Water Management in Mexico. Could you tell us about this Centre and its activities?

Dr. Cecilia Tortajada and I were the prime movers for the establishment of the Third World Centre for Water Management in Mexico. It is a knowledge-based think tank, specializing in generation, synthesis, application and dissemination of knowledge. The Centre is totally independent, and does not subscribe to any dogmatic or predetermined solution. It always starts with the analysis of a specific problem in a specific location, with its specific boundary conditions. A feasible and implementable solution can only be found within the very specific context of a specific problem. In the real world, one size does not fit all, and the prevalent current approach of the international institutions' "solution-in-search-of-a-problem" generally does not work.

Countries like India have paid a very high price because in the past it has accepted solutions recommended by international experts and institutions who had only very limited knowledge of the climatic, physical, social, cultural, economic, environmental, and institutional conditions of the country within which any solution had to be implemented. Without such knowledge, the potential for successful application of any solution is very limited.

Unlike all other international institutions, our Centre is unique since it does not try to solve water problems of countries like India, Egypt, or Turkey with experts based in Mexico. Once we decide to work on a specific issue in a specific location, we identify the best institution and the best experts the country has on that specific issue. We provide the financial support and only the expertise that is not available in that country to solve the problem. We develop the solutions together with the national experts and also in close collaboration with the policy-makers of the national institutions who have to implement the solution.

This model has proved to be highly efficient in terms of finding implementable and cost-effective solutions. Equally, the process has helped in building the management and technical capacities of developing countries.

Our Centre does not accept any funding unless the results of our work can be made readily available. The results of our work are always published as books by major international publishers, and in technical and scientific journals. Details of the modalities of the working of our Centre, and our current publications can be found at *www.thirdworldcentre.org*. The work of our Centre has now been translated into 12 languages.

While your ideas are laudable, a lot of political support may be necessary to implement them. Do you think India can succeed and what will this entail?

There is no question that if one is working in policy areas, one must have close access to policy-makers so that solutions are developed in close consultation with them. The probability of any policy being accepted, let alone implemented, without the support of high-level policy-makers is almost close to zero. Thus, political support is a pre-requisite for acceptance and implementation of any water policy.

Fortunately, during my career over the past four decades, I have been fortunate enough to work closely with 18 governments at ministerial and secretarial levels, six Heads of the United Nations Agencies, and a president of the World Bank. The problems I have worked on in the past, and our Centre is working on at present, are identified jointly by the responsible policy-makers and us. We keep in touch regularly with the policy-makers with our work and its progress. This close collaboration means that policy-makers are always aware of our thinking from the very moment we start our work and until the end. We consult them frequently, and thus the solutions we recommend do not come as a surprise to them. In fact, they often make major inputs in the solution of the problems and formulation of policies. Accordingly, we consider interactions with the policy-makers an important and essential component of our work. For example, in July, I met with the Prime Minister and Water Minister of India and two Chief Ministers of provinces. These were all one-on-one meetings. Such regular meetings with senior policy-makers are essential components of our work.

Can you tell us briefly the results of your latest meetings with the Prime Minister and Water Minister of India?

Our discussions covered many issues and they were wide ranging. One of the areas we discussed is how best we can build up technical and managerial capacities of the existing water professionals in India. Many, if not all, water problems of India are because of poor management practices. In order to solve and manage seemingly technical problems, we need a new breed of water professionals who not only have expertise in technical areas, but also are knowledgeable on the social, economic, legal, environmental and institutional issues within which the technical solutions are to be applied. Most water projects in India are now not progressing because of inter-state water disputes, which touches not only technical considerations (which can be called 'hard' solutions) but also social, economic, legal and environmental issues ('soft' solutions). We thus need a new breed of technocrats who are knowledgeable in both hard and soft sciences.

I have proposed to the Indian Prime Minister and Water Minister, at separate meetings, that we consider an IIT, where we can develop a new water program to meet the future water needs and challenges of the country. The reactions of the Prime Minister and the Water Minister were not only enthusiastic but also to the point. They both felt that India's water problems are immense, and one single IIT cannot produce enough new breed of technocrats who can make a serious dent in the country's water problems. The program should encompass more educational institutions. Hence, my current idea is to formulate a multi-institutional program, in which leading international and Indian water experts can participate.

Following these discussions, I met with Director Dube, Dean Chakraborty and Prof. Das Gupta (Head of Civil Engineering) of IIT Kharagpur, my alma mater. We had a very constructive and productive discussion in Kolkata. We plan to start with a new water program at Kharagpur first, which could then be promptly followed at other institutions. I shall also be meeting with the Water Minister, Prof. Saifudding Soz, in late August in Stockholm to develop the program further. Prof. Soz is unquestionably the best and most competent water minister India has had for a considerable time. I am thus looking forward to working with Minister Soz and IIT Kharagpur, to develop a new type of country-specific water program for India, which currently simply does not exist anywhere in the country or the world. It will not be easy, but it is certainly doable. I am now discussing with some major donors to fund the external costs of formulating and implementing such a program. The initial donor responses are quite positive. If any IIT alumni would like to be associated with this new water program in the country, we welcome their advice and collaboration. They can contact me at *akbiswas@thirdworldcentre.org*. ■

*Rural water problems can be solved if we change our mindsets. Current approaches will **not** provide universal access to water services in the country, nor will they improve water conservation within one generation.*

India Water Portal

Arghyam is a public charitable trust established in 2001 in India with a personal endowment from Rohini Nilekani. Our mission is "Enough water, safe water ... always and for all." Arghyam supports focused programs in the water sector that enhance equity in access to water for all citizens. It emphasizes sustainability - environmental, financial, social and technical - as the key desirable outcomes in all projects we support. It works with diverse partners across the country, including NGOs, research institutions and government agencies, giving special attention to people's participation, capacity building and opportunities for leverage and scale. Current project areas include drinking water and sanitation, integrated domestic water management, rainwater harvesting, groundwater management, and water quality.

The India Water Portal is an initiative of Arghyam to leverage and extend the work of its project partners. It is an open, inclusive, web-based platform for sharing water management knowledge amongst a network of practitioners. Arghyam takes the rich experience of grass-roots experts, packages and adds value to it through technology, and then disseminates it to a larger audience.

Knowledge asymmetry among stakeholders of the water sector is a critical factor hampering the sustainable management of water resources. By sharing best practices, advocating sustainable approaches, bringing transparency of public data/info, and spreading awareness, the portal seeks to address this asymmetry. Arghyam is actively pursuing alternative outreach methods like print media, radio, and workshops to reach those on the ground who need it most.

Portal Features

The portal is a collaborative space for sharing tools and practices on water management and related subjects like sanitation, agriculture, and wastewater management. It has the following characteristics:

1. It is modeled after a proven practice, and so can impact issues and solutions on the ground,
2. There is a well-defined group of users who can benefit from it, and
3. It functions according to a clearly defined process.

Some of the important portal tools are:

1. ***E-Learning Courses on Water Management Practices***: these are being developed by domain experts in three areas: Watershed Development by Samaj Pragati Sahyog, Groundwater Management by ACWADAM, and Flouride Mitigation by BIRD-K. These partners provide content which draws heavily from the work that they have been doing for years in training and mentoring other organizations. With a technology partner, Trina, Arghyam has designed multimedia courses for training using audio, animation and 3-D simulation.

Courses on CDs will be used at training workshops, at NGO centers, and in kiosks to achieve scale in capacity-building. It has been observed that lack of capacity and awareness often lead many large-scale water projects across the country to malfunction.

The portal will also have a body of information like slideshows, case-studies, policies, and research material on these and other topics like rainwater harvesting, sanitation, and wastewater management.

2. ***Organization Locator***: Arghyam is compiling a large directory of grass-roots organizations, government bodies, and institutions working in the water sector from many diverse sources. Many social work consultants visit and collect information from organizations in the Cauvery Basin. Working with its partner, eGovernments Foundation, Arghyam is presenting this directory through a powerful GIS-based mapping application that will let users easily zoom down to the taluk level, identify and search for organizations on any water-related topic like rainwater harvesting and sanitation.

Whether it is the government trying to find NGO partners for a large drinking water program, a donor agency, or a practitioner seeking advice for setting up eco-sanitation systems, a map-based locator will meet a huge need.

3. ***Public Private People Partnership (PPPP)***: Arghyam is partnering with the Government and a network of NGO partners on a project called *Suvarna Jala* to help improve the quality of the program. *Suvarna Jala* aims to setup rainwater harvesting systems in 23,000 rural schools across Karnataka. The network gathers field data, trains school staff and monitors the status of the program. The portal is used as a vehicle to share accurate, up-to-date information on the project with all stake-holders, including state and district level administrations, NGOs, school bodies, and Gram Panchayats.

During the course of the project, Arghyam will present survey data on GIS maps with charts on status, issues, successes, and quality of the project so that stakeholders can immediately share information. This transparency lends high credibility to the program and also results in prompt feedback and corrective action as necessary on issues.

4. ***River-Basin Mapping***: It is now commonly recognized that river-basin planning based on natural watershed boundaries leads to optimum solutions in water resource management. As a pilot for the Cauvery Basin, a diverse range of data is being presented on features such as agriculture, water quality, rural water availability, and industrial waste through easy-to-understand GIS maps that provide a holistic view of water resources in the basin.

This will be of use to researchers, planners, administrators, NGOs and students who are interested in large-scale water management.

The portal will also have tools like discussion groups, event calendar, search, and daily live news to connect up the virtual network of practitioners. The portal is scheduled for launch in January 2007.

Arghyam believes that the India Water Portal has the potential to catalyze change on a large scale. It is keen to involve many more partners to expand the knowledge base and reach in the water sector and would like to hear from interested parties. ■

The Impact of AGRICULTURAL TECHNOLOGIES

Indian agriculture faces unique challenges, but technological innovations are affecting the key metrics of agricultural productivity in significant ways.

Agricultural patterns in India

About 56 percent of India's landmass is arable. That compares to 20 percent for the U.S. The principal crops grown in India are food grains, oilseeds, sugarcane, commercial crops (also known as cash crops), and fibers. These account for over 85 percent of the national agricultural output.

In the June-October months, the southeast monsoon traverses the subcontinent, progressively bringing rain to the land. Over the eons, agricultural practices in the region have evolved to match the pattern of the monsoons. In a good year, it allows three, or even four, separate yields of crops in the same fields. The Kharif (autumn) crops are raised during the monsoons, paddy being the perfect example. These crops require a lot of water, from the time they are sowed to when they are harvested. West Bengal state in eastern India leads the nation in paddy production, having a predictable and heavy rainfall schedule.

Rabi crops, like wheat, do not require as much water and so are raised in the months outside the monsoon season. Punjab, in the northwest, is known as the granary of India and a wheat producing powerhouse. Off-season, or 'in between,' season crops such as sugar cane also are quite popular in parts of India such as Uttar Pradesh and Maharashtra. Black soil, spread through the Deccan Plateau that constitutes much of central India, is ideal for sugar cane cultivation.

While the system described above works well in years with good monsoons, it fails in off years. In 2004, for example, the lackluster performance of the monsoons left much of India's farming community reeling. This had a domino effect on the entire economy, and lowered the GDP of the country significantly, even though the technology sector was witnessing a boom of historic proportions.

Agriculture in India has been slow to adopt modern technologies. This can be attributed to a variety of factors, rampant poverty being one of them. Coupled with a high degree of dependence on natural elements, it is evident that the biggest challenge faced by innovators aiming to transform Indian agriculture is to raise bottom line productivity at reasonable cost.

Impact of agricultural technologies

In order to enhance productivity meaningfully, the agriculture sector has to manage three key metrics:

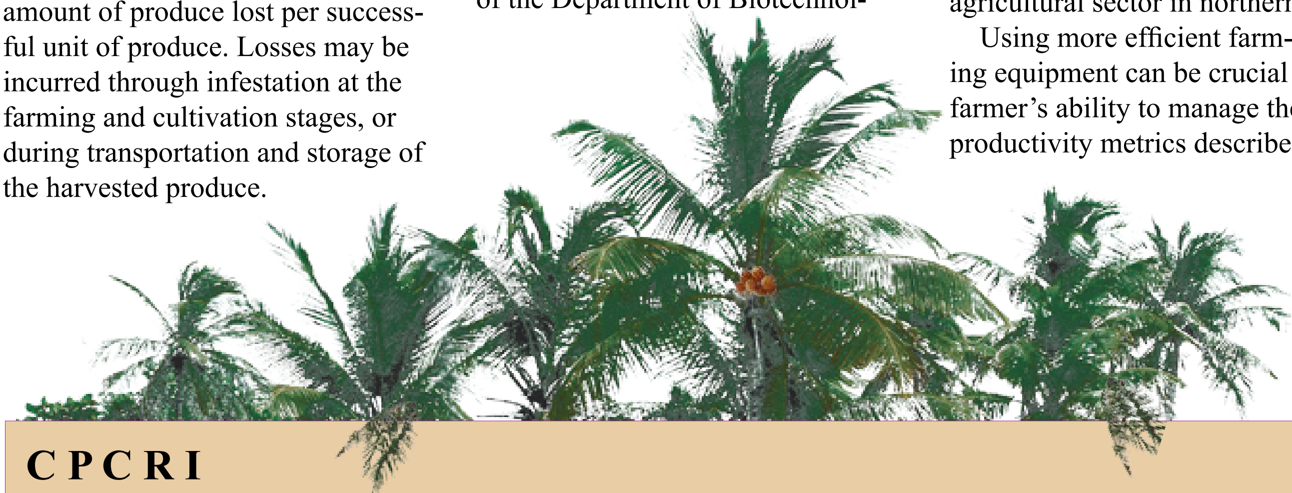
- Yield rate (Y): Yield rate is defined as the amount (weight) of produce a unit of cultivated land is capable of producing. This metric depends primarily on two factors: genetics of the seeds being sown, and the fertility of the land itself (which may be enhanced through irrigation and appropriate use of fertilizers).
- Loss rate (L): This is defined as the amount of produce lost per successful unit of produce. Losses may be incurred through infestation at the farming and cultivation stages, or during transportation and storage of the harvested produce.
- Cost of farming (C): Cost captures various investment elements within it, such as cost of the equipment being leased or bought, variable cost for procuring the seeds and other raw materials, and costs associated with storage and transportation.

Innovations in agricultural practices in India over the last 55 years fall into the following broad categories: better quality of seed, deeper understanding of crop infestation, more efficient farming equipment, and cost-effective agricultural practices.

Indigenous and international research in the fields of genetics and biotechnology has had immense impact on the quality of seeds being used in our farms today. A case in point is the Bioinformatics Center within the Central Plantation Crops Research Institute (CPCRI, see Inset). Established under the auspices of the Department of Biotechnology of the Government of India, this unit specializes in research on the biotechnological aspects of coconuts, cocoa, and arecanuts. Along with providing up-to-date information in the field of biotechnology to plantation crops research workers, it has been instrumental in developing molecular markers to fingerprint coconut gene sequences.

The center has applied molecular biotechnology techniques to study root wilt diseases in coconuts. It has also been able to create new disease resistant varieties of coconut using in vitro multiplication technologies. The real power of such cutting edge research comes from the close partnership that the center forms with local communities. Through seminars and workshops, this institute has been a powerful force in meaningfully impacting the bottom line of the agricultural sector in northern Kerala.

Using more efficient farming equipment can be crucial to a farmer's ability to manage the key productivity metrics described above.



CPCRI

The Central Plantation Crops Research Institute was established in 1970 and is headquartered in the sleepy town of Kasargod in northern Kerala. In addition to developing appropriate production, protection, and processing technologies for coconut, arecanut, and cocoa through basic and applied research, it acts as a national repository for genetic resources for these crops.

Other objectives of the institute are to standardize agro-techniques for various agro-climatic regions, develop appropriate farming/cropping systems compatible with the main crops and climatic conditions, and to study their effect on soil fertility. The institute works closely with local communities to transfer technologies to farmers with the cooperation of developmental departments.

Today, CPCRI has the world's largest coconut germplasm collection, comprising 313 accessions including 132 exotic (from 22 countries) and 181 indigenous accessions. This includes a recent collection of exotic accessions from Indian Ocean Islands using embryo culture technique for the first time in the world. In addition to genetic research, the scientists at CPCRI have created proficient hybrids involving crosses between tall and dwarf varieties of coconuts, which have since been released for commercial cultivation. Farmers of Kerala, Tamilnadu, Andhra Pradesh, Karnataka, and Goa use these seedlings.

The institute also houses a Bioinformatics Center that provides up-to-date information in the field of biotechnology to plantation crops research workers. The Center develops bibliographic databases, gene data banks and molecular data banks related to plantation crops.

Paddy, a principal Kharif crop, is water-intensive

Various scientific and technological institutes that are spread across India conduct research on these topics. A shining example in this regard is the Center for Technology Alternatives for Rural Areas (CTARA), affiliated with IIT Bombay.

The right technologies can make life easier for farmers while keeping solutions practical and cost-effective. The financing mechanisms available to key stakeholders in agriculture are also of significance. In India, cultivation is a traditional activity and the vast majority of farmers fall at or below the poverty line. One of the biggest bottlenecks they face is the inability to maintain a cash flow sufficient to sustain continued investment in their endeavors. A couple of years of failed monsoons could break the back of many farmers. It is here that microfinance institutions can make a difference. Since farmers cannot afford traditionally high interest rates on larger loans, entities such as SKS microfinance and the Grameen Bank encourage stakeholders to proactively manage their loan requirements through smaller loan chunks at reasonable rates, on an as needed basis (read about SKS Microfinance by in this issue).

Agricultural innovations of tomorrow

It is increasingly possible to map the genomes of entire species rapidly. With increases in computing power, we will be able to run through millions of DNA sequences of combinations of desirable characteristics in crops. Molecular breeding techniques can produce the perfect crop for any climate (which itself will be more easily predictable) to generate 'supercrops' that are able to withstand the elements and give bountiful yields. The possibilities are endless.

Genetics and biotechnology have played a key role in furthering India's Green Revolution. Institutes such as the Indian Council for Agricultural Research are committed to advancing the innovation agenda into the future. Continued interest and investment from the government will be required to ensure success. As the world gets more connected, the time it takes to apply an innovative new technology developed in the U.S. to an agricultural problem in India will collapse dramatically. The challenge for the key stakeholders in the agricultural world will be to use these new tools to generate massive efficiencies and optimize the key metrics of yield, loss, and costs. ■

Hithesh Raghavan, IIT-B Alumnus

CTARA

The Centre for Technology Alternatives for Rural Areas was created in 1985 at IIT Bombay. It is involved in the design and development of technologies such as farm machinery, food processing, low cost housing, renewable energy, water management, and rural industry. Examples include:

- Solar fruit and vegetables dryer: Drying fruits and vegetables in the sun is easy and inexpensive. Heat from the sun is captured by a diagonal perforated metal sheet through a plastic cover and conveyed to the food dryer. Air holes in front and back permit air circulation necessary for efficient drying. The equipment is quite effective even under partial sunlight.
- Power tiller: A 10 horsepower power tiller has been developed at CTARA for agriculture and transportation. Resembling a small tractor, it is suitable for use in small to mid-sized farms. Different implements can be attached at the rear end of the power tiller. In a farm, the power tiller can be used for opening up the ground or breaking big clods of soil. When a lawn mower is attached, it can even cut grass. With a trolley attachment, it can be used for transportation. The engine of the power tiller can be used for running irrigation pumps, electric generators, threshers, etc.
- Rain water harvesting technologies: Annual rainfall in the Konkan region of India is about 4,000 liters. However, water runs away on the slopes and very little water is left for use. There is often severe water scarcity in the summer season. In this rainwater harvesting structure, six houses are constructed around the sides of a hexagonal water tank. Water falling on the roof is collected and conveyed into the centrally located water tank. The capacity of the water tank is 1.2 lakh liters. On the basis of per capita consumption of 25 lit/day, water stored in the tank would be sufficient for six families for up to four months during the summer season.

Two examples of innovations coming out of CTARA are:

- Briquettes that substitute for firewood are made from dried leaves, dung, saw dust, etc. The mixture, prepared by adding sufficient water, is placed in the mold of the briquette machine and is compressed by a hand lever. The machine can make 25-30 briquettes an hour. The density of briquettes made in the hand briquette machine is around 500 – 600 Kg/m^3.
- CTARA has undertaken studies of water resources of some regional stream basins. Rainfall filtration, runoff, and variations in water table conditions, discharges and water quality data have helped in water resource conservation and utilization studies.

Bamboo's promise

Bamboo accounts for a significant part of India's forest cover, especially in the northeast. It is a versatile plant with enormous economic potential for that region of the country. Research and development could yield better solutions for agro-based industries that exploit this valuable and renewable resource.

Bamboo is a grass of the family *Poaceae*. There are more than 1,200 species of bamboo in the world. It is considered the fastest growing woody plant, growing a third faster than the fastest growing tree. Some bamboo species have been reported to increase in height by 3-4 feet in a single day.

Bamboo is a versatile and renewable resource. It provides economic and ecological benefits to millions around the world, with applications as varied as food, fuel, housing and construction, furniture, fabric, paper, and medicine. Some species may be used for soil stabilization, urban wastewater treatment, reduction of nitrates contamination, and soil and water conservation. In fact, bamboo has more than a thousand documented uses. In many cases, it can susbstitute for less environmentally-friendly materials such as plastics and metals, without compromising functionality.

The bamboo tree has a short growth cycle, and can be harvested in 3-5 years, unlike hardwoods, which typically require 15-20 years. It requires no replanting and can be harvested time and again from the same plant.

The worldwide market for bamboo is about US $10 Billion and growing. China is a pioneer in bamboo products, and they contribute significantly to China's economy.

The domestic bamboo economy is estimated at more than Rs.2,000 crores (US $445 million), but market potential is estimated at more than double that figure. Bamboo is an ideal raw material for scalable exploitation - it can form the basis for rural cottage industries just as well as it can for large-scale manufacturing.

India has the second largest resources of bamboo in the world, next only to China. It has about 10 million hectares of bamboo forests, which yield 3.2 million tons of exploitable bamboo annually. However, India's yields are much lower than China's because of poor harvesting methods.

Five percent of India's annual bamboo harvest goes to the crafts sector, 40 percent to the paper industry, 40 percent to housing and construction, and 15 percent to other uses.

India's northeast is especially rich in bamboo forests. For example, about 30 percent of Mizoram is covered by wild bamboo, with makes it a valuable resource for the state.

More research and development are needed to exploit bamboo's enormous potential in India - in areas such as bamboo-related GIS, plant genetics, cultivation and harvesting methods, post-harvest treatment, and product development. ■

Utilitarian Bamboo Furniture

Most rural schools and health centers are poorly equipped for lack of funds. Among basic amenities, they often lack furniture. Cane and bamboo offer tremendous scope as raw material for making furniture with local materials and skills.

The northeastern states have an abundance of cane and bamboo varieties. The Department of Design at IIT Guwahati has undertaken a project to use cane and bamboo in the design and production of a new range of utilitarian furniture that meets basic needs in rural schools and primary health centers. Its objective is to orient local craftsmen working in cane and bamboo to produce functional and utilitarian items of furniture using simple hand tools. The project emphasizes economic viability and ecological sustainability.

The goals of the project are to develop innovative functional objects, develop process rationalization, train craft persons in new techniques, and create new business opportunities.

A team, comprising members of the Design department faculty, surveyed schools and primary health centers in rural locations around Guwahati. The work practices of craftsmen were documented. Locally available cane and bamboo were assessed for their suitability as furniture material. A new range of ergonomic and functional furniture was designed, prototyped, tested and refined. The end product was a complete range of bamboo furniture for schools and hospitals. The project has received support from the office of the Development Commissioner (Handicrafts), Ministry of Textiles and the Khadi and Village Industries Commission.

Bamboo manufacturing is a potential source of employment and wealth creation in rural areas. The range of applications includes housing, grain storage barrels, agricultural implements, animal carts, furniture items, hand tools, household containers, ladders, and temporary structures.

Although bamboo offers high employment potential in the craft sector, much of the bamboo crop is presently used by the paper industry at subsidized rates. And, unfortunately, indiscriminate exploitation of bamboo forests is leading to serious ecological damage. ■

Ravi Mokashi-Punekar, Department of Design, IIT-G

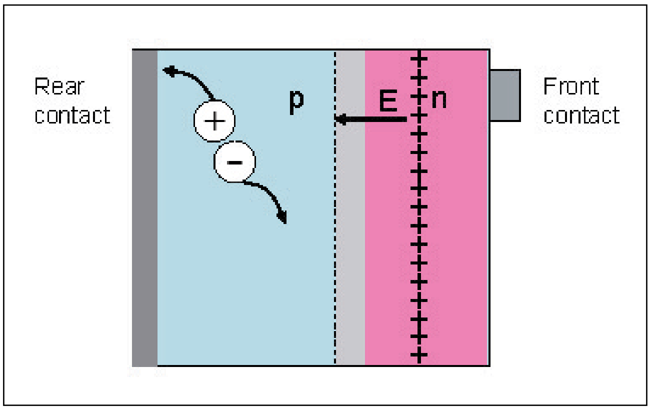
Bamboo manufacturing could generate jobs in India's northeast, as well as in other areas where bamboo is abundant. IIT Guwahati's Design department develops applications of this versatile material.

Innovations in alternative energy technologies

A big challenge in sustaining India's growth, especially in the rural areas, is ensuring a reliable supply of energy to fuel industries, households and vehicles. Recent advances in nanotechnology and materials science could yield more efficient and cleaner sources of energy with great portent for rural India.

Solar Photovoltaics

The sun is one of our best sources of energy. Solar cells or photovoltaic devices convert light to electrical energy. They consist of a semiconductor layer that can create electron-hole pairs after absorbing light and another layer that can transport the generated electrons to complete an external circuit. While the concept has been around for several decades, photovoltaic devices have low energy-conversion efficiency (less than 10 percent) and the materials that constitute them can be quite expensive. This has been a key issue limiting the widespread use of solar energy conversion devices. Some key research being pursued today investigates the use of inexpensive materials such as organic dye molecules to fabricate solar cells. Researchers are also exploring nanoscale methods to mix the electron-hole generating layers with the current collectors to efficiently transfer the carriers prior to recombination within the semiconductor. Nanoscale approaches could boost the efficiency of solar cells and dramatically open up opportunities for their widespread application. For a country like India that receives a large amount of sunlight throughout the year, the opportunities are boundless. Especially, combining inexpensive materials with nanoscale approaches such as self-assembly can lead to breakthrough opportunities for solar technologies.



Schematic of a solar cell comprising a p-n junction and two metal contacts. The carriers generated in the semiconductor layer are transferred to the external circuit through the contact.

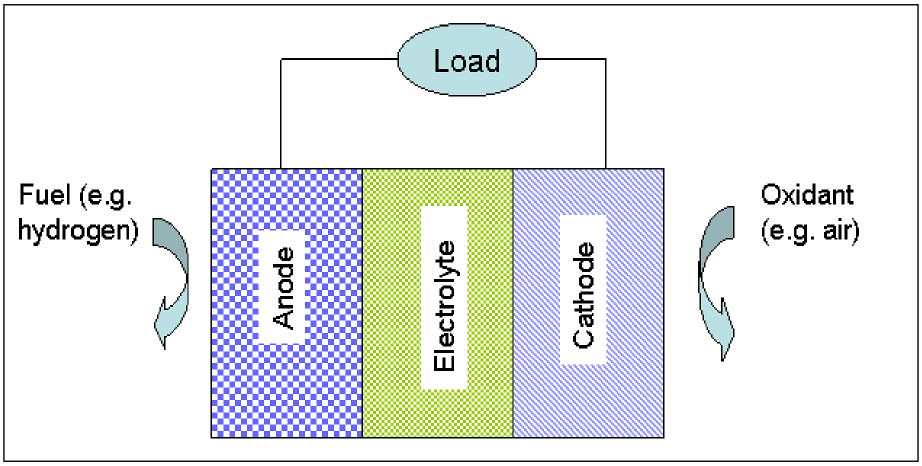
Fuel cells

Fuel cells convert chemical energy into electrical energy. Unlike their solar counterparts, fuel cells are rather efficient. In fact, efficiencies can be 60 percent or higher if the waste heat is used for other purposes. While there are several classes of fuel cells depending on the type of fuels used and the operating temperatures, let us consider the solid oxide fuel cell (SOFC) as an example. SOFCs use an oxygen-ion conducting membrane to create electrical current from an electrochemical reaction:

$$H_2 + O^{2-} = H_2O + 2e^- \text{ (at anode)}$$

$$\tfrac{1}{2}O_2 + 2e^- = O^{2-} \text{ (at cathode)}$$

One of the important areas of research in fuel cells is reducing operating temperature of oxide fuel cells from 1,000°C down to a few hundred degrees, which can open up possibilities of fuel cells as viable sources of energy for transportation. The beauty of fuel cells is that they are environmentally friendly and can potentially lead to a carbon-neutral technology. A fascinating area of research presently underway is the exploration of nanoscale ion-conducting materials that have dramatically enhanced conductivity due to the presence of large amount of surfaces and interfaces in the membranes. Nanoscale approaches include use of membranes that are only a few tens of a nanometer thick and also nanostructuring the electrodes that can subsequently improve the kinetics of electrochemical reactions occurring at the electrode-electrolyte interfaces. Such innovative tailoring of materials at the nanoscale can lead to dramatic improvements in performance of oxide fuel cells at lower temperatures that can be utilized in transportation applications. In addition to oxide fuel cells, low temperature proton-conducting fuel cells incorporating polymer membranes are suitable for transportation applications. However, one of the main limitations is the need for pure hydrogen as a source of fuel. While we lack the infrastructure for storing and transporting hydrogen in mobile applications, this could change in the future.



Schematic of a fuel cell device. The fuel cell converts chemical energy into electrical energy through electrochemical reactions at either electrode. The electrolyte is a membrane that is selectively permeable to ions and not electrons.

Outlook

'Nano' has pervaded several disciplines of engineering and pure sciences in the last decade. While a lot of initial emphasis has been on exploring nanotechnology to build better devices and possibly reduce form factor, energy and environment are clearly of great importance in future. Utilizing key aspects of nanoscale science and nanomaterials can lead to breakthroughs in energy technologies which, in turn, can directly improve the quality of human life. ■

Shriram Ramanathan, Harvard University, IIT-M alumnus

Powering Rural Homes

At the time of Independence (1947) India's total power generation capacity was a mere 1,300 mega watts (MW). In 2006, it is 125,000 MW. Yet, there are power shortages in all the cities and the situation is far worse in the villages. According to the Central Electricity Authority, only 85 percent of villages have been electrified.

The Government of India has the goal of providing power to all by 2012. Since this cannot be accomplished with conventional energy sources alone, we will need to tap non-conventional, renewable forms that are sustainable and pollution-free. And decentralized and hybrid energy systems (distributed/dispersed generation) will be required to meet the growing energy demands of rural areas.

The main challenge today is to upgrade the existing methods of renewable energy generation and to promote the development, demonstration, scaling up and commercialization of newer technologies. The Centre for Rural Development and Technology (CRDT) at IIT Delhi is engaged in this effort, and its products include the Mangal turbine for small hydro power generation, an improved chulha (stove), and wind energy systems for widespread rural use.

In the rural sector, the main thrust areas are biomass briquetting, biomass-based co-generation and other biomass related technologies. In solar photovoltaics, large size solar cells/modules based on crystalline silicon thin films need to be developed. The efficiency of solar cells needs to be improved to 15 percent to be commercially viable. Another priority is the development of high efficiency inverters. Power from urban and industrial wastes yielded 23 MW in 2005, but offers more potential. There are already 35 million improved chulhas, but more could be distributed.

In rural India, several places are yet to be connected to the electricity grid. In the absence of electricity, hurricane lanterns, which burn kerosene, are popular light sources in Indian villages. They are typically used 2-3 hours after dusk. They produce polluting gases and consume fuel that has to be brought from long distances, often with difficulty. The need for an alternative to the hurricane lantern led to the design of the solar lantern, at the Centre for Energy Studies (CES) at IIT Delhi.

The solar lantern consists of a lamp, a battery and electronics placed in a housing, along with an external photovoltaic (PV) module. The lead-acid, maintenance-free battery is charged during daylight hours by electricity generated by the PV module. This battery operates the lamp through a high efficiency inverter and control electronics, which also control the charging and discharging of the battery. The class D quasi-sinusoidal waveform inverter operates a compact fluorescent lamp (CFL) of 5 Watts or 7 Watts. ■

D. P. Kothari, IIT-D

IIT-K Centre for Environmental Sciences and Engineering

A Centre for Environmental Sciences and Engineering is being established at IIT Kanpur with Rs. 110 million (about $2.4 million) pledged by Mr. Arun Shourie, Rajya Sabha member from Uttar Pradesh, from his MP Local Area Development Scheme (MPLADS) funds. The center will bring together experts from various disciplines to find solutions to specific environmental problems and to develop new technologies.

Issues that demand immediate attention include emissions by industries and power plants, depletion of ground and surface water, thinning of the ozone layer, and health risks associated with modern technologies.

The center is expected to achieve self-sufficiency within a few years by attracting funds from industry and other sponsors, as well as by licensing patents for technologies developed through its R&D. A leading industrial house of India has already shown interest in collaborating in the area of water and environment pollution. Participation of industry from the early stages of problem formulation will ensure that the work carried out at the center is relevant to industry and society.

In the meantime, a consortium of four universities from the United States has submitted a proposal to launch an Environment Health Science and Technology initiative at IIT Kanpur. This initiative will combine current technology platforms with well designed epidemiological approaches to obtain critically important information for the prevention, early detection and treatment of diseases in Asian populations. Prominent IITK alumni will be associated with the center, including Prof. U. Lall , Chairman of the Department of Earth and Environmental Engineering, Columbia University, and Prof. V. P. Aneja, Department of Marine, Earth and Atmospheric Science at North Carolina State University.

The building will house 10 laboratories and other facilities for different disciplines of environmental science and engineering. The building has been designed to be both functional and energy efficient. Several green features have been incorporated in the design. These include efficient lighting, incorporation of earth air tunnel with a cooling system to reduce air conditioning load, reduction in water demand due to efficient fixtures, and use of photovoltaic panels for meeting part of the energy requirements. Moreover, the negative impact of construction and development on the environment will be minimized. ■

Arun Shourie examines a model of the proposed Centre

Rural R&D at IIT Delhi

IIT Delhi's Centre for Rural Development and Technology has been developing appropriate technologies for more than 25 years

It is well recognized that economic growth, while necessary, is not sufficient for achieving sustainable development. In India, the benefits of growth are marginal for large segments of society, the majority of who reside in rural areas or urban slums. In an era of globalization, it has been a challenge to protect the welfare of small farmers, artisans, and small-scale entrepreneurs.

The focus of current government policy is providing urban infrastructure to rural areas. Its implementation requires appropriate science and technology, along with sound management principles, to be integrated with traditional skills and knowledge.

As early as 1979-80, IIT Delhi established a Centre for Rural Development & Technology (CRDT) to provide science and technology support and to coordinate activities related to rural development.

Basic Approach

CRDT cooperates with other departments and centers at IIT Delhi, other technical institutions, voluntary agencies and government organizations. Working directly with rural populations, it has undertaken to:

- educate faculty and students about sustainable development and human values;
- conduct R&D and pilot scale evaluation of technologies appropriate for rural areas;
- create an information repository on technologies suitable for sustainable rural development;
- transfer technologies through formal and non-formal channels; and
- help shape technology policies of the government.

These activities are carried out by designing and offering relevant courses, carrying out research to address rural needs, and conducting seminars and workshops to impart training, both at the academic and field levels.

Major Emphases

Rural Energy Solutions: The use of animal dung and other biowastes for generating biogas has vast potential, but the technology needs improvement to improve its viability. Systems for gasification of biomass, generation of liquid fuels such as biodiesel, and mini and micro hydel turbines have been successfully tested.

Water Treatment and Waste Management: The Centre has experimented with membrane technologies such as nano-filtration and reverse osmosis for removal of fluorides and other dissolved salts from drinking water. Chemical processes have been developed for removing contaminants, such as silica coated ferric hydroxide for removing arsenic. Other success areas include domestic rainwater harvesting, water quality monitoring and waste water recycling by phytoremediation and bioremediation, solid waste management by rapid composting, vermicomposting using local earthworms, and efficient microbial strains.

Organic Cultivation of Food Crops, Storage and Quality Control: Intensive agriculture using chemical pesticides and fertilizers has led to decreasing returns and environmental problems. So the Centre is keen to develop alternatives. In addition to composting different biowastes for agriculture, work has been undertaken on biodynamic technologies with the right choice of indigenous seeds. Formulations from plants such as Vitex negundo and others are used for pest control. Developing a facility that tests foods for pesticide residues (important for certification of organic products) is one area of interest. The biopesticidal value of endomycorrhizal fungi, along with additives (botanicals & bioinoculants), against nematodes (Meloidogynae incognita) and termites has been tested.

Sustainable Biomass Production: A number of agro-forestry and agri-horticulture models have been developed and implemented, promoting medicinal and aromatic plants, timber, fodder, and fruit bearing plants. Rural women have been organized into self-help groups, which were then given training in vermicomposting and vermiculture, mushroom cultivation, sericulture, nursery raising, backyard nutrition, and use of biofertilizers.

Natural and Herbal Products: Work has been done on the extraction of vettiver, sandalwood, Himalayan cedar wood, turmeric, jasmine, ginger, ajwain, lemon grass, and neem. The work includes production of jasmine absolute from jasmine concrete, Texol from Taxus bacalta and Azadirachtin from neem. Technologies for a super critical fluid extraction plant and for the processing of Hop flower and other biomass are ready for transfer to industry. A depulper for the easy processing of neem seeds has been developed. A bio-pesticide also has been developed from lemon grass oil for soil-based fungicides.

Rural Industrialization: CRDT is working on technologies related to leather, pottery, carpet weaving, soap, small industry equipment, chemicals, biofertilizers, and agro-based industries. New hand tools, improved looms for carpet weaving, and new machines count among its accomplishments. A GIS (Geographical Information System) and database for handicrafts have been made for marketing support.

MGIRI: A major initiative undertaken by the center in collaboration with faculty drawn from other departments and centers has been in setting up MGIRI (Mahatma Gandhi Institute of Rural Industrialization) at Wardha. This major turnkey project completed early this year has resulted in the creation of a nodal institute that will coordinate the process of providing comprehensive science, technology, and management inputs to the Khadi and Village Industries sector. As part of this project, more than 30 technology downsizing, development, and dissemination projects have been executed in association with NGOs in different parts of the country.

HUDCO: Another major initiative taken by the center, in collaboration with HUDCO (Housing and Urban Development Corporation), is to promote rural industrialization with a focus on bamboo products. It is being done by upgrading artisan skills and developing improved processes, technology, and machinery through scientific, technological, and design inputs. The core strategy is to strengthen and upgrade the skills of artisans, entrepreneurs and trainers to achieve the widest possible dissemination of bamboo-based technologies and skills needed for managing, marketing and adding value to a hitherto under-utilized resource. IIT Delhi and HUDCO have collaborated to set up the National Resource Facility on Bamboo Technology (NRFBT).

Technology Transfer and Outreach: Taking technologies from development to implementation and adoption is most crucial. CRDT has created a micromodel as a unit for interfacing between the labs at IITD and people. The unit provides facilities for pilot scale research and training of trainers from voluntary agencies, thus allowing for participatory assessment, incubation, and demonstration of rural technology. Field centers have also been established in different village clusters for extension.

Impact and Future

At least 200 UG/PG students take courses at the center every semester. Over 30 research scholars are involved in Ph.D. programs related to rural development. Faculty publish in national and international journals and organize seminars and workshops. The center continues to add to its laboratory facilities in different areas of science and engineering. For example, labs for supercritical fluid extraction, food quality safety, and applied microbiology were added recently.

Rural transformation requires a holistic approach, where technology is appropriately designed and integrated for specific local conditions. This calls for multidisciplinary inputs. And efforts have to be backed by policies which keep in view the unique requirements of India. ■

A biogas plant at IIT Delhi's Centre for Rural Development & Technology

With half a billion livestock, India has a large potential supply of raw material for biogas production

BIOGAS Possibilities

A technology for producing compressed natural gas (CNG) from biogas has been developed and tested at the Centre for Rural Development & Technology in IIT Delhi. The novel Bio-CNG technology utilizes the principle of carbon dioxide absorption in water. It yields 95 percent pure methane from raw biogas that can be a substitute for CNG/diesel/petrol.

India can potentially generate 6.38×10^{10} m^3 of biogas from 980 million tons of cattle dung produced annually, with a total heat value of 1.3×10^{12} MJ (mega joules). In addition, 350 million tons of compost are produced annually, a process that also yields biogas. Present applications of biogas are limited to cooking, lighting, and engine operation in dual fuel mode. The removal of carbon dioxide present in biogas and further compression (usually methane) into cylinders makes it easily usable for transport applications as a substitute for CNG/diesel/petrol, in cars, buses, three-wheelers, tractors, pick-up vans, etc., and for stationary applications at various remote locations. Since CNG technology has already been tested in these applications, Bio-CNG (enriched biogas) which is nearly the same as CNG, can also be used in all these applications.

Biogas from organic biomass waste could supplement gaseous fossil fuels, while the solid byproducts could reduce chemical fertilizer consumption. When produced through anaerobic digestion, biogas contains 55-65 percent methane (CH_4), 35-45 percent carbon dioxide (CO_2), and trace amounts of hydrogen sulphide (H_2S), water vapor, and other minor gases. The presence of CO_2 in biogas makes it a low-heating value gaseous fuel. The IIT-Delhi process involves removal of carbon dioxide from biogas. Furthermore, enriched biogas (+95 percent CH_4) is filled into CNG cylinders at 20 MPa pressure using a high pressure gas compressor as used for CNG in an automotive car (Maruti-800) and in a stationary engine. Performance studies have shown that enriched biogas gives similar performance and is comparable to CNG fuel in terms of easy and quick starting, and smooth running of the engine without any associated problems.

There are thousands of *gaushalas* (places where old and sick cow herds are kept on charity) and dairies in the country that have plenty of dung and can produce large quantities of biogas. There are also a large number of food processing units, sewage treatment plants, distilleries, and other industries producing lots of organic waste water that have the potential for biogas generation. Thus the technology benefits employment and income generation, besides providing environmentally friendly fuel.

The CRDT biogas enrichment and compression technology unit can be made commercially viable with an investment of about US $40,000. The payback period is roughly 2-3 years depending on the cost of cow dung and the selling price of Bio-CNG and compost. Overall, the Biogas Enrichment and Compression System could be profitable for rural areas. It is recommended that rural entrepreneurship be developed based on this system for effective utilization of local resources and production of alternate bio fuels in a decentralized manner.

V. K. Vijay, Centre for Rural Development and Technology, IIT-D

IIT Roorkee Pushes Rural Innovations

Information Technology for Remote Villages

IIT Roorkee has conducted a successful exercise in bringing the benefits of information technology to rural Uttaranchal. The project, entitled 'Pro-Poor IT Initiatives in Uttaranchal,' is funded by UNDP. Over the past three years, faculty from four departments at IIT Roorkee worked closely with the Government of Uttaranchal, the IT industry, and people at the grass-roots level to bring information and government services to the doorsteps of rural residents. A sustainable model has been developed and implemented in the villages of Nainital district.

A team of IITR faculty studied six village clusters, representing varied topographies, literacy levels, vocations, and socio-economic conditions. Their findings helped in the design of a citizen-centric and exhaustive bilingual (English and Hindi) portal that provides appropriate information and IT-enabled services.

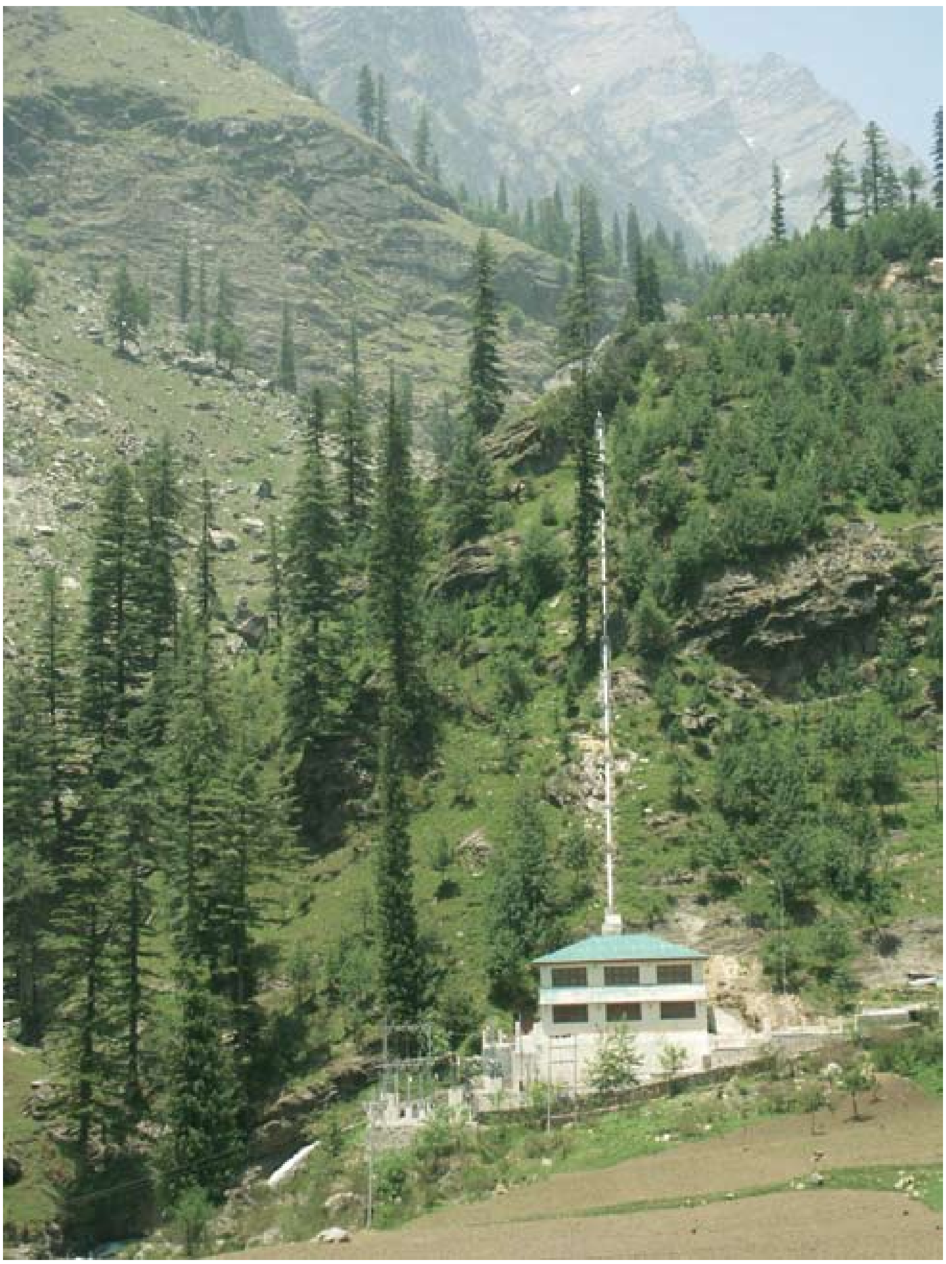
More than 30 information kiosks, called *Soochna Kutir* (literally meaning information huts), have been established and are run by unemployed, local IT–educated youth with technical support and training from IIT Roorkee. VSATs (very small aperture terminals, used for satellite-based data communication) were installed to provide last-mile connectivity because most of the kiosks are in remote areas with no other means of connectivity. A roving *Soochna Kutir*, equipped with VSAT, computer, and diesel generator, also moves from place to place providing the same services to the remaining areas.

Recently, eight information centers were set up in the block development offices of Nainital district. Since there are no internet service providers in these remote areas, a gateway to the internet is provided at the portal. This has brought the vast information and knowledge available on the internet to remote villages, and connected them to the whole world through e-mail. Soon, voice over internet will provide low-cost voice communication facilities in every part of the district.

The set-up developed in Nainital district is now being replicated in other districts of Uttaranchal. The benefit of this IT initiative will ultimately reach the entire state population of 8.5 million population, nearly 75 percent of who reside in villages.

Village Electrification

IIT Roorkee is providing comprehensive support for the development of small hydro power in the hills and plains areas, including development of decentralized energy systems



Small hydel systems have great potential in hilly areas

An improved water mill of IIT Roorkee design

for remote areas. The Institute has provided expertise for setting up more than 50 small hydro schemes in Jammu & Kashmir, Himachal Pradesh, Uttaranchal, West Bengal, Sikkim, Arunachal Pradesh, Bihar and Jharkhand. These power stations are meeting the electricity demand of rural populations living in isolated pockets.

The introduction of electrical power brings a surge in economic activity. In the villages of Chamoli and Bageshwar districts, the 10 small hydropower stations have installed capacity ranging from 50 kW to 200 kW. A number of businesses have sprung up, including a biomass briquette unit, grinding mill, wool carding, electrical and electronics repair, lift irrigation, cable television, computer literacy center, grinder/pulverizer for ritha processing, GSM-PCO unit, fabrication/welding unit, fruit processing unit and carpentry.

IIT Roorkee has formulated state-level master plans for electrification of remote villages using small hydropower and other renewable energy sources in Uttaranchal and Chhattisgarh. Similar plans are being drawn up for UP, MP, Assam, Nagaland, and Meghalaya.

Water Mills Initiative for Hill Villages

In the hills, water mills have great potential for generation of mechanical power from water streams, mainly for grinding purposes. About 200,000 water mill sites exist in the Himalayan and sub-Himalayan regions. The traditional water mills in these locations have extremely low output, due to low efficiencies, and do not provide enough economic support for mill owners.

IIT Roorkee has developed highly efficient, cost effective, and light weight water mill devices that are also easy to fabricate and install. Over 250 of these devices are in operation in J&K, Himachal Pradesh, Uttaranchal and Arunachal Pradesh. The devices feature (a) an improved vertical-shaft water mill that gives a mechanical output up to 3 kW, and (b) a multipurpose horizontal-shaft open cross-flow turbine that gives an electrical output up to 10 kW using a generator.

Many small scale manufacturers and entrepreneurs have been given designs and testing facilities at nominal cost. About 100 para-technicians in rural areas have been trained to install, operate and maintain the new water mills and turbines. Most rural villages of Uttaranchal and Himachal Pradesh are adopting them.

Improving Rural Roads

About 600 million Indians live in nearly 600,000 villages scattered all over the country. Access roads bring rural populations into the mainstream. About 40 percent of habitations in the country are still not connected by all-weather roads. As a poverty reduction strategy, the *Pradhan Mantri Gram Sadak Yojna* (Prime Minister's Rural Road Programme) was launched as a 100 percent centrally-funded program for the development of rural roads in India. Rural connectivity is expected to have wide and deep impact on agricultural employment, rural social services, and the overall economy.

With a grant from the Government's Department of Science & Technology, IIT Roorkee has undertaken a research project to develop optimal design and maintenance solutions. It involves extensive field studies of traffic flow, geometric details, pavement composition, subgrade characterization, distress monitoring, and alternative pavement compositions. ■

Rural Electrification

Using Solar Photovoltaics

Solar powered 2-lamp LED system

A photovoltaic street light

Grameen Suriya Bijlee Foundation (GSBF, www.suryabijlee.com), founded by an IIT Kharagpur alumnus and a provider of affordable solar energy lighting systems, markets a solar LED home lighting system and a solar LED street lighting system of its design.

The home lighting version, which costs US $50, is a two lamp LED system that uses a 5 watt solar panel, a sealed lead acid rechargeable battery, and two LED lamps with 33 LEDs in each lamp. The street lighting system uses 72 LEDs with a 20 watt panel and costs US $200.

Currently there are more than 2,000 solar lighting systems provided by GSBF in different states of India. The market size in India for the home lighting system is estimated at US $10 billion, while the market for the street lighting system is about US $1.2 billion. Other potential solar powered applications include electric fans and television sets. GSBF also intends to leverage solar panels used for lighting to power water filtration technologies to provide each household with potable water.

Initially, the lighting systems were given free to end-users by raising finance through charitable donations from NRIs, high net-worth individuals in India, and public and private companies. However, this meant that end-users didn't have an investment from ownership and so felt no responsibility to prolong the life of the system through maintenance. A new financing model was therefore developed that uses micro-finance. GSBF works with a local non-governmental organization (NGO) or self-help group (SHG). The end-user pays Rs. 100 per month and pays off the system in 24 to 36 months depending on the interest rate.

Challenges

The biggest obstacle is the scarcity of solar panels. Most solar panels manufactured in the world are ending up in Europe or Japan. India itself is exporting 90 percent of its panels to Europe and Japan at almost US $4 per watt. Germany has one of the best incentives for implement-

DISTRIBUTION OF HOUSEHOLDS IN INDIA BY SOURCES OF LIGHTING

Source of lighting	Total	%	Rural	%	Urban	%
Total	191,963,935	100.0	138,271,559	100.0	53,692,376	100.0
Electricity	107,209,054	55.8	60,180,685	43.5	47,028,369	87.6
Kerosene	83,127,739	43.3	76,896,701	55.6	6,231,038	11.6
Solar energy	522,561	0.3	394,425	0.3	128,136	0.2
Other oil	184,424	0.1	146,165	0.1	38,259	0.1
Any other	305,308	0.2	227,210	0.2	78,098	0.1
No lighting	614,849	0.3	426,373	0.3	188,476	0.4

Source: Census of India 2001

There is significant market potential for solar photovoltaics in India ing solar systems for both residential and commercial purposes. Even the United States is exporting 60 percent of its solar panels to Europe due to the high demand and long-term contracts. The cost of silicon feedstock mostly used in crystalline silicon panels (90 percent of the market) has gone up from US $25 five years ago to almost US $200 in the current spot market. Five years ago, 10 percent of silicon feedstock went into solar panels and now it is almost 50 percent.

So a new approach is to use alternative solar panel technologies. Thin films are the new wave solution and could bring down panel prices to approximately US $1.50 per watt. However, India needs panels at less than US $1 per watt to make the technology mainstream.

India should place a priority on investing in new solar panel technology such as thin films and dominate the area of solar systems integration. A group of Indian nationals, NRIs, and IIT alumni businessmen, could invest in a renewable energy consortium which would focus on different areas of renewable energy. ■

Kamkoty Krishnamoorthy, IIT-KGP Alumnus

Dipbahan – An Eco-Friendly Tricycle Rickshaw

Although the tricycle rickshaw is perceived as a slow, low grade, low-tech product, it is great for getting about within residential localities and within a few kilometers from main roads served by other public transportation such as buses and local trains. It is pollution free, places little load on the roads, and provides employment for many.

A new tricycle rickshaw design from IIT Guwahati, named Dipbahan, is lightweight, sporty, and stable, with a low center of gravity, and high maneuverability. It provides easy access for passengers to get in and out, has ample legroom and ergonomic seating, and protects passenger and driver from the elements of nature. It has an aerodynamic design, a space frame structure enveloping the driver, and a reinforced platform for supporting the structure. A mudguard shields occupants from direct impact with other vehicles and there is room for storing luggage. And, unlike the traditional rickshaw, Dipbahan addresses the comfort of the driver, as well as the passenger.

The tricycle rickshaw has evolved over the decades and its structure is more or less similar all across the country. However, the poor product quality and finish can be attributed to the manufacturing process and choice of materials such as iron, wood, and aluminum. Dipbahan uses jute based composites and is designed and produced in the Department of Design under a project sponsored by the Indian Jute Industries Research Association (IJIRA).The advantage of jute is that it is an environmental friendly, bio-degradable, and sustainable material. It consumes less energy during production and gives a very good composite with polyester resins. Specific advantages of jute composites in Dipbahan are its ease of manufacturing, cost effectiveness, durability, and comfort. ■

Rural Research Priorities

The Nimbkar Agricultural Research Institute (NARI), a non-profit organization in rural Maharashtra, does research and extension work in agriculture, renewable energy, and animal husbandry. It promotes sustainable rural development using science and technology. Some of its work and priorities are described here.

Sixty percent of rural India has no electricity. In the absence of electric bulbs, the inefficient hurricane kerosene lantern is often the primary source of lighting in rural areas.

NARI has been developing a very efficient lantern called Noorie, which produces about 1,350 lumens (lm) of light, equivalent to a 100 W electric bulb. A stumbling block to improving its efficiency is the thermo-luminescent (T/L) mantle. Currently, T/L mantles have an efficacy of 2-3 lm/W (lumens per watt), whereas a 100 W light bulb has efficacy of 10-13 lm/W and a compact fluorescent lamp (CFL), about 50-70 lm/W. If, through R&D, we can match the T/L mantle efficiency of a light bulb, then liquid fuel lighting could be better than electricity-based methods for decentralized rural lighting. R&D is also needed to fabricate mantles out of sturdier materials like carbon composites and ceramic, thermo-luminescent materials.

Ultimately, for decentralized light based on chemical fuels we should emulate the bioluminescence mechanism of the firefly, where visible light is produced very efficiently and at room temperatures. With grid electricity still a distant dream for most rural areas, efficient liquid fuel lighting needs to be encouraged.

Improved lamp designs could bring light to many more rural homes.

Cooking Energy

Only liquid and gaseous fuels produced renewably can provide clean cooking energy. Two fuels fall into this category: liquid fuels like ethanol and biodiesel, and gaseous fuel like biogas.

Ethanol is an excellent fuel for cooking. NARI has developed a stove which runs on 50 percent ethanol-water mixture. This mixture is very safe and the stove, which has a maximum thermal capacity of 2.5-3 kW, has flame control so that it works just like an LPG stove. Large-scale testing in the field has been very positive and almost all the rural women compare it very favorably with an LPG stove. However, current excise laws would need to be modified so that ethanol can be used as a rural household fuel.

Biodiesel is another fuel which can be grown locally. The Government of India has recently embarked on a major program to promote biodiesel as an automobile fuel. R&D is still required to improve biodiesel yield and for its use in cooking stoves.

A clean, gaseous fuel that can be produced from existing biomass is biogas. Biogas has been used extensively in rural India. However, it is produced very inefficiently in fixed and floating dome systems and requires lots of cow dung and other nitrogenous material. Biogas production is not suitable for a household with fewer than 3-4 cattle. Besides, there are problems of gas production during winter and from improper mixing of mixed inputs like biomass, human waste, and cow dung. Biogas - a mixture of methane and carbon dioxide - cannot be liquefied and requires very high pressure (> 100 atmospheres) to compress it so that it can be used over extended periods.

R&D is necessary in two areas. One is in the development of extremely efficient biogas reactors so that the production/unit of biomass inputs could be maximized. The second is the development of appropriate storage materials which can store biogas at medium pressures. Optimization of biogas production from a reactor requires sophisticated electronic controls and bio-chemical engineering. A small utility can afford to do it, whereas it might be too costly for a household. Tinkering with existing biogas reactors will not solve the problem. Sophisticated science and technology has to be brought to bear on the problem for optimizing biogas production in rural areas. ■

From a talk on 'Nation Building, IITians, and Happiness,' given at IIT Bombay by Anil Rajvanshi, Director, NARI

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