Spreading the Water Wealth

Making Water Infrastructure Work for the Poor

An IRN Report

Welcome to International Rivers Network's first annual "Dams, Rivers and People" report. Each year we will focus on a key issue affecting the world's rivers and the people who depend upon them. We will also summarize key dam-related developments in the previous year and predict where the hotspots will be for the coming year. This year's theme is water infrastructure and poverty.

CONTENTS

Introduction and Key Messages 1

Spreading the Water Wealth: Making Water Infrastructure Work for the Poor 2

The Big Potential of Small Farms 14

Water Innovators: Low Tech, Low Cost, High Reward Solutions 19

Dams, Rivers and People in 2005: The Year in Review 20

River Hotspots for 2006 22

Fast Facts on Water and Poverty 24

Ackowledgments . . . . . Inside Back Cover

Printed in the United States of America

ISBN: 978-0-9718858-3-7

Cite as "Spreading the Water Wealth: Making Water Infrastructure Work for the Poor," IRN Dams, Rivers and People Report 2006, International Rivers Network, Berkeley, CA.

Published March 2006 by International Rivers Network
1847 Berkeley Way, Berkeley, California 94703 USA

Edited and produced by Lori Pottinger
Designed by Jeanette Madden
Printed by Hunza Press
Printed on 100% recycled paper.

Cover Photo: *Nepali girl drinks from an NGO-installed tap. Photo by Alex Zahnd.*

INTRODUCTION AND KEY MESSAGES

Photo: Alex Zahnd

Meeting the basic water, food and energy needs of the world's poorest people, and generating the economic growth needed to lift them out of poverty, can only happen if investments in water infrastructure are redirected to affordable, decentralized and environmentally sustainable technologies. Yet this approach is being largely ignored by international financial institutions and governments, and the large-dam lobby is now aggressively supporting a resurgence of investment in water mega-projects. This report argues that the needs of the poor must be put front and center in water infrastructure strategies, and rebuts the main arguments for the mega-project approach. The report's three key messages can be summarized as follows:

1. The widespread implementation of small-scale infrastructure for delivering water and energy services is a prerequisite to achieving the Millennium Development Goals (MDGs).

Affordable technologies that can raise the yields of small farmers are essential for increasing food production, poverty alleviation, and economic growth in the poorest countries. Small farmers, most of who live on rain-fed lands, make up the great majority of the world's extremely poor people. Raising their yields requires water management strategies such as rainwater harvesting, affordable drip irrigation and pump technologies, and farming techniques that reduce water needs while increasing yields.

Large water infrastructure can only serve geographically limited areas for reasons including cost, water availability, and topography. Small-scale technologies, by contrast, can be applied anywhere across the world's croplands.

Reaching the MDGs by bringing 100 million small farming families out of extreme poverty through low-cost water technologies would cost approximately $20 billion over ten years – less than a tenth of developing countries' investment in large dams from 1990-2000. The estimated economic benefit is $300-600 billion.

Low-cost community-based technologies are essential to meeting the MDG of halving the number of people without access to safe water and basic sanitation. Using small-scale technologies to meet this Goal would provide estimated benefits of $400-500 billion at a cost of $80-100 billion.

2. Poverty in developing countries is not due to low levels of water storage capacity in large reservoirs, nor to under-exploitation of their potential for large hydropower.

The World Bank has repeatedly argued in recent years that countries are poor because they have low levels of capacity to store water in large reservoirs. Yet per capita large reservoir storage capacity is by no means a reliable predictor of poverty. Zambia and Zimbabwe both have a greater per capita large reservoir capacity than the United States. Ghana has a per capita large reservoir capacity three times higher than Australia.

The ability to store water for when it is most needed is vital. And climate change is making the ability to store water even more important. However, water stored in small reservoirs, in groundwater, and in wetlands generally provides much greater economic benefits – and benefits that are much more likely to reach the poorest – than that in large reservoirs.

While countries generally get richer as they increase their use of modern energy, the trend goes the other way for dependency on hydroelectricity. Of the world's 40 richest countries, only one is more than 90% hydro-dependent; of the world's 40 poorest, 15 are more than 90% hydro-dependent. Numerous hydro-dependent countries have suffered drought-induced blackouts and energy rationing in recent years. Energy security means these countries should diversify power generation away from hydropower, rather than deepening their dependency. Changes in rainfall patterns due to global warming make this especially critical.

Meeting the MDGs also requires reducing the economic and health costs of energy use among the poorest. Increasing access to modern cooking fuels and expanding the use of improved cookstoves are one energy priority. Another is for a massive expansion of electricity into rural areas. It is cheapest and quickest to electrify these areas with decentralized and sustainable systems such as geothermal, small hydro, modern biomass turbines, cogeneration and wind power. Cost-effective mechanical energy for crop processing and other purposes can be provided directly by small wind or water turbines, or through biofuels or diesel motors. The decentralized nature of these technologies means that they reduce the need to build expensive transmission lines. They also create many more jobs than conventional centralized power systems.

Providing access to electricity for all urban dwellers is first and foremost a question of requiring utilities to extend connections to the areas where poor people live. Because poor people cannot afford to use much electricity, the increased demand from investments in connecting slum areas to grids will not create a huge demand for extra supply.

3. A resurgence of major "multipurpose" hydropower and water diversion projects will have unacceptable environmental and social impacts and will divert funds away from investments that would significantly reduce poverty.

The World Bank and the big-dam industry are trying to resuscitate 1950s-style multipurpose water and energy mega-projects. Yet these schemes have repeatedly failed to produce their supposed benefits. Multipurpose projects frequently cost more than estimated in feasibility studies, produce less electricity, irrigate less land, displace more people, cause more environmental damage and exacerbate rather than reduce flood damage.

Large multipurpose projects tend to be the most environmentally and socially disruptive water infrastructure projects. They flood the largest areas, displace the most people and cause the most damage to downstream ecosystems and communities. ■

Spreading the Water Wealth

Making Water Infrastructure Work for the Poor

by Patrick McCully
Executive Director, International Rivers Network

"The 'easy and cheap' options for mobilizing water resources for human needs have mostly been exploited," the World Bank declared in 2002.[1] If the World Bank were right, this would be a depressing message indeed. Thankfully, the Bank is wrong. There are many technologically easy and relatively cheap options for water and energy provision that can help lift hundreds of millions of people out of poverty, end widespread hunger, and reduce the daily workload of women and children. The difficulty lies not in the lack of appropriate technologies, but in generating the political will and institutional capacities to implement these options, and in blocking the lobbying efforts of those whose interests lie in maintaining the status quo.

Want of clean water, decent sanitation, and adequate food and energy strips people of their dignity and their most basic rights. Inequitable access to water, especially for growing crops, is a major factor in global poverty, and a death sentence for millions each year. Ending this unacceptable situation will require a radically new approach to investing in water infrastructure.

"Modern" water management for most of the twentieth century has meant huge, capital-intensive river-engineering projects that sought to transform entire regions through the generation of hydropower for industries and diversion of water to irrigate commercial farms. While these projects provide around a sixth of the world's output of both food and electricity,[2] this "big is beautiful" form of water management has been intensively criticized in recent years for its technical and economic failures, for benefiting the well-off at the expense of the poor, and for its massively negative impacts on ecosystems.

It is now widely recognized that meeting the basic water, food and energy needs of the world's poorest people, and generating the economic growth needed to lift them out of poverty, can only happen if investments are redirected to affordable, decentralized and environmentally sustainable technologies. Yet this approach is being largely ignored by international financial institutions and governments, at the same time the World Bank-led large-dam lobby is aggressively supporting a resurgence in the building of water mega-projects.

While politicians and the media fret over terrorism and bird flu, each and every day dirty water and poor sanitation and hygiene kill some 6,000 children – a staggering death toll of 2.2 million children a year.

While politicians and the media fret over terrorism and bird flu, each and every day dirty water and poor sanitation and hygiene kill some 6,000 children – a staggering death toll of 2.2 million children a year.[3] Water mismanagement contributes toward food insecurity for the world's 800 million undernourished people and the poverty of the more than half of the world's people who survive on less than two dollars a day.[4]

Adding to the grim statistics of water and health are those diseases directly linked to the environmental changes caused by big water projects, most notably malaria and schistosomiasis (bilharzia). The economic and psychological hardship suffered by the tens of millions evicted to make way for reservoirs during the twentieth century is yet another of the human impacts of water management decision-making. Bad decisions on water investment also increase the destructiveness of floods.[5]

Dams and diversions have moderately or severely altered 60% of the flow in the world's major rivers. Water diversions for large irrigation schemes contributed to the destruction of half of the world's wetlands in the twentieth century. The physical and hydrological alterations caused by dams are the main reason why freshwater ecosystems tend to have a higher proportion of species threatened with extinction than any other major ecosystem type.

This global-scale destruction of river, wetland and lake ecosystems has also taken a huge human toll. As argued by the UN Millennium Ecosystem Assessment:

"The harmful effects of the degradation of ecosystem services … are being borne by the poor, are contributing to growing inequities and disparities across groups of people, and are sometimes the principal factor causing poverty and social conflict …The degradation of ecosystems is already a significant barrier to achieving the Millennium Development Goals … Rural poor people, a primary target of the MDGs, tend to the be the most directly reliant on ecosystem services and most vulnerable to changes in those services."[6]

The MDGs were agreed upon by all 189 members of the UN at the Millennium Summit in September 2000. The eight Goals aim to achieve drastic reductions in poverty, hunger, disease, illiteracy, environmental degradation, and discrimination against women. The

Women and girls do most of the water-fetching in the Zambezi River valley. Photo: Tiago Esmael

two MDGs most closely linked to water and energy management are those to "eradicate extreme poverty and hunger" and "ensure environmental sustainability." Indicators for reaching these two Goals include halving by 2015 the proportion of people whose income is less than a dollar a day and, over the same period, halving the proportion of people without sustainable access to safe drinking water and basic sanitation. Achieving the other MDGs, especially those on gender equality and health, is also inextricably linked with increasing access to water and energy.

The World Bank and the Big Dam Lobby

The World Bank is the single most influential institution in setting water infrastructure investment priorities in developing countries. Its influence comes not only from the billions of dollars it lends every year, but also because of its policy research, and the access of its staff to top-level politicians, government bureaucrats and corporate officials, and the media.

For the first five decades after its establishment in 1944, the Bank was at the vanguard of efforts to promote water mega-projects in developing countries. In the early 1990s, however, the Bank started to pull back from funding large dams and to emphasize the importance of better management of existing infrastructure. Other major international funders followed suit.

This drying up of funds hit the international dam industry hard. Yet the big-dams industry is now once more in an optimistic mood. Recent announcements for industry conferences (with World Bank participation and sponsorship) enthuse about a "growing excitement about development potential worldwide" (Waterpower XIV) and claim that the "inherent benefits" of hydropower are "now more fully recognized by planners, decision-makers and financiers worldwide" (Hydro 2006).

A large part of the reason for this optimism is the World Bank's renewed commitment to funding what it terms "high-reward/high-risk hydraulic infrastructure." This was first laid out in detail in the Bank's 2004 Water Resources Sector Strategy (WRSS) written by the institution's then Senior Water Advisor, John Briscoe. The strongly pro-dam message in this strategy paper has been repeated many times since then by Bank staff in speeches, media releases and policy papers, and is now frequently quoted by government officials, funders and dam industry lobbyists.

The key messages stressed in the WRSS and subsequently by Bank staff are that:

- The "easy and cheap" options for mobilizing water for human needs have mostly been exploited and that water sector investment must focus on large-scale infrastructure.

- Economic disparities between developed and developing countries are a direct consequence of a water "infrastructure gap," with the wealthier countries having much more water storage per capita and having exploited a far higher percentage of their hydropower potential.
- Major multipurpose hydropower and water diversion projects of the type favored especially in developing countries and the Western United States between the 1950s and 1980s can be built in an "environmentally and socially sustainable manner" and will lead to pro-poor outcomes.[7]

The Reality: The Easy and Cheap Options are Underexploited

There is no chance of reaching the Millennium Development Goal of halving the number of people in extreme poverty by 2015 without a major redirecting of water infrastructure investments away from centralized mega-projects and toward low-cost, decentralized and community-based schemes. The claim that water investments must be refocused on high-risk projects because the low-risk/high-reward "easy and cheap" options have mostly been exploited inverts reality – it is the high-risk projects that are over-exploited and are producing diminishing returns.

The great majority of the world's extremely poor inhabitants are small farmers in Sub-Saharan Africa and South Asia. While the number of urban poor is rising rapidly, roughly three-quarters of the world's poorest people still live in rural areas.[8] Most of these people live on arid lands and are dependent upon rain-fed farming for their livelihoods. The UN Millennium Project describes the smallholder farm as the "global epicenter of extreme poverty."[9]

Raising the incomes of small farmers is thus key to reaching the MDGs. Doing so will require increasing their yields, which as the Millennium Project points out would also:

- Enable farmers to feed their families.
- Provide low-cost food for the rest of the economy.
- Support growth in businesses supplying inputs to farmers and in food processing, with benefits cascading through the broader economy.

The Millennium Project states that such a strategy "could be made environmentally sustainable through thoughtful investments at the farm and village level, in soil health, water harvesting, improved seed varieties, feeder roads from farms to trunk roads, electrification, improved water sources, sanitation, and modern cooking fuels to replace fuelwood."[10]

While most agricultural investments in developing countries have gone into major irrigation projects, 60-70% of the world's food is still produced from the 80% of crop land that is rain-fed.[11] The importance of rainwater for agriculture has traditionally been overlooked by hydraulic engineers and water managers who have seen their job as mainly one of capturing and redirecting water from rivers, lakes and aquifers. Yet, as Malin Falkenmark of the Stockholm International Water Institute and Johan Rockström of the Stockholm Environment Institute have pointed out, this visible "blue water" flow represents only around one-third of the total precipitation over the earth's landmass. The rest is in what the emerging discipline of ecohydrology terms "green water" – the invisible water cycling through soils and vegetation and, in the form of vapor, the atmosphere.[12]

Rainwater harvesting has improved crop yields for this Indian family. Photo: Patrick McCully

Falkenmark and Rockström argue that there is relatively little "surplus" blue water left to use in expanding conventional irrigation. In the semi-arid savanna areas where the majority of extremely poor people live, most rivers are now "closed" – that is, there is no more scope for increasing dry-season diversions without causing serious ecological harm. Falkenmark and Rockström estimate that providing a decent diet to everyone in the world by 2050 will require an additional amount of water for agriculture greater than current total "blue water" irrigation withdrawals. And they estimate that expansion of "blue water" can only account for around a sixth of the needed water. The rest of the water must come from "green water" – that is, from increasing the productivity of rain-fed farming.

Partly because the lion's share of investment in agricultural infrastructure and research has gone to large-scale irrigation, rain-fed yields in semi-arid areas currently tend to be very low, especially in sub-Saharan Africa. Fortunately, a combination of better soil and water management could significantly increase yields in savanna lands. According to Falkenmark and Rockström, "there are numerous examples of affordable, socially and environmentally appropriate water management strategies that can double and even triple yield levels in rain-fed savanna farming systems."[13]

The key to understanding water needs for farmers on the savannas that cover two-fifths of the world's land surface is that drylands are often not as dry as is thought. The problem is much less the quantity of annual rainfall, but the variability and unpredictability of rainfall. Savanna farmers do not need a year-round supply of water from an irrigation canal; they need methods to trap rain when it falls on their farms, to recharge and pump groundwater when it is needed, to increase the ability of soil to hold moisture, and to increase the efficiency of the small-scale irrigation methods they use (small farmers on "rain-fed" farms may actually use artificial watering techniques although these are usually not classified as irrigation by agricultural researchers due to the latter's bias toward large-scale schemes).

Rainwater harvesting involves trapping rainwater behind small dams built across seasonally flooded gullies or depressions, or catching it on surfaces such as roofs and storing it in tanks or jars. In many areas, the most important purpose of rainwater harvesting structures is not to make water available in ponds or storage tanks, but to allow water to percolate down into the ground. The water storage provided by rainwater harvesting, whether in artificial tanks or as groundwater, provides crucial "supplemental irrigation" during dry periods. It also provides easily accessible water for domestic uses, greatly easing the work burden of women and children. Rainwater harvesting structures can usually be built and managed by farmers and households themselves at a fraction of the cost per family or hectare supplied of large water projects (see box, page 11).[14]

Rainwater harvesting is particularly beneficial when coupled with affordable technologies such as simple drip irrigation kits, which can drastically reduce the quantity of water needed to irrigate crops, and human-powered treadle pumps for lifting groundwater. (For more on the incredible benefits of these technologies see article on pp. 14). Researchers from the International Water Management Institute (IWMI) cite studies claiming three- to fourfold yield increases for farmers in Burkina Faso, Kenya and Sudan using drip irrigation and hand-watering made possible by rainwater harvesting.[15]

A Rice Revolution

Boosting water productivity – achieving more "crop per drop" – is essential for feeding the world's growing population while protecting freshwater ecosystems and stopping aquifers from being sucked dry. A set of principles and methods called the System of Rice Intensification (SRI) holds the promise of a dramatic improvement in water productivity of rice, and potentially other water-intensive crops. SRI can typically increase rice yields by 50-100% compared to conventional techniques, while requiring only 50-75% as much water, no chemical fertilizers or pesticides, and only 10-15% as much seed. Himanshu Thakker of the South Asia Network on Dams, Rivers and People describes SRI as "one of the most remarkable developments in agriculture in recent times."[16]

Traditional rice growing can use twice as much water as the SRI method. Photo: Lori Pottinger

SRI was developed by a French Jesuit priest in Madagascar in the early 1980s and refined over the following years. In 1997, Norman Uphoff from the International Institute for Food, Agriculture and Development (CIIFAD) at Cornell University in New York started to popularize the SRI principles internationally. As of early 2006, SRI was being practiced in at least 32 countries. Although some field trials have been disappointing, the overall experience has been overwhelmingly positive.[17]

The key differences between SRI and conventional rice farming are that seedlings are transplanted at a much younger age, they are planted farther apart, and their soil is kept moist and well-drained, not flooded. These seemingly simple changes led to a huge improvement in root growth, the main reason for the stunning yield increases. On the poor soils of Madagascar, SRI can increase average yields from just two tons per hectare to eight tons per hectare.[18]

Norman Uphoff states: "SRI has had the disadvantage of sounding 'too good to be true.' This is the main reason why it was not taken seriously by agricultural scientists for many years, though this is now changing."[19] SRI has spread rapidly via the internet, by word-of-mouth, and through the initiative of individual farmers, local officials and environmentalists. In 2003, there was only one farmer using SRI in the Morang District of Nepal. Two years later, thanks to the efforts of a district extension officer, Rajendra Uprety, the number has increased to more than 1,400. Word is spreading of their good results and Mr. Uprety now gets telephone calls from farmers all around the country asking for information on SRI. In 2005, Morang District farmer Dan Bahadur Rajbansi told the BBC, "I tried sowing the seed on about 1,200 square meters of land. The results were marred by the drought. But they've still been impressive. We used to get barely 3,000 kilos of rice per hectare. Now we get about 6,000."[20]

Mr. Uprety has persuaded Nepal's Ministry of Agriculture to promote SRI nationally. Last year, agricultural ministries in India, China and Cambodia (where as many as 50,000 farmers used SRI last year) started promoting SRI. More and more independent evaluations are confirming the remarkable results initially reported from Madagascar. Unfortunately, the World Bank and Asian Development Bank have failed to act on the opportunities that SRI presents, despite its massive potential for poverty reduction and its many environmental benefits.[21]

A common argument used by the backers of high-risk megaprojects is that while small-scale technologies can provide benefits on a small scale in marginal areas, interventions on a scale large enough to significantly increase food production and boost economic growth can only come from large water-storage infrastructure. In reality, the dam lobby has its arguments reversed – large water infrastructure is limited in the areas it can expand to for reasons including cost, "blue water" availability, and topography. Large dam-and-canal irrigation schemes are generally suit-

Arid Rajasthan state has been the center of India's growing rainwater harvesting movement. These women gather water at a basin built with the help of the NGO Tarun Bharat Sangh (see box, page 8). Photo: Patrick McCully

able only for broad alluvial plains alongside major rivers. In Africa and Asia there are few appropriate sites left on which to expand irrigation mega-projects.[22]

In contrast, small-scale technologies can be applied across the world's croplands. Improving yields for the world's 525 million small farms would have significant economic impacts at the national and global levels. Michael Lipton, of the Poverty Research Unit at the University of Sussex, argues that higher productivity on small farms is key to large-scale poverty reduction efforts and states that "there are virtually no examples of mass dollar poverty reduction since 1700 that did not start with sharp rises in employment and self-employment income due to higher productivity in small family farms."[23]

Paul Polak of International Development Enterprises believes that reaching the MDGs by bringing 100 million small farming families in Africa and Asia out of extreme poverty between 2005 and 2015 through low-cost water technologies would cost a total of some $20 billion (see page 14). This is less than a tenth of the investment on large dams in developing countries between 1990 and 2000.[24] Frank Rijsberman of IWMI calculates the total economic benefit of lifting these 100 million families out of poverty as $300-600 billion.[25] Polak's numbers indicate that every billion dollars invested in a mega-dam could have lifted five million farming families out of poverty via treadle pumps, drip irrigation and rainwater harvesting.

Prioritizing low-cost community-based technologies is essential to meeting the MDG of halving the number of people without access to safe water and basic sanitation. Rijsberman quotes World Heath Organization estimates that meeting the water and sanitation MDG would provide benefits on the order of $400-500 billion at a cost of $80-100 billion. This calculation is based on the value of health improvements. The economic return would be even greater were other benefits included, such as reducing the many hours that women and children in developing countries spend collecting water.

The technologies included in the above estimates are mostly public standpipes for water supply and, for sanitation, pit latrines in rural areas and low-cost sewerage in urban areas. Pit latrines have up-front costs of US$30-60 per capita. Initial investment in low cost sewerage in dense urban areas costs US$30-140 per capita. "Conventional" technologies cost more than seven times as much, although they are potentially superior in terms of the quality of service delivery (assuming that no problems are caused by them being more complex and expensive to maintain).[26]

Deconstructing the Water Storage "Infrastructure Gap"

The World Bank's WRSS introduced the argument that poor countries are poor and rich countries are rich because of their different stocks of water storage infrastructure. This theory of development is now widely used in World Bank presentations and documents and has been cited by many dam lobbyists and water sector analysts.[27]

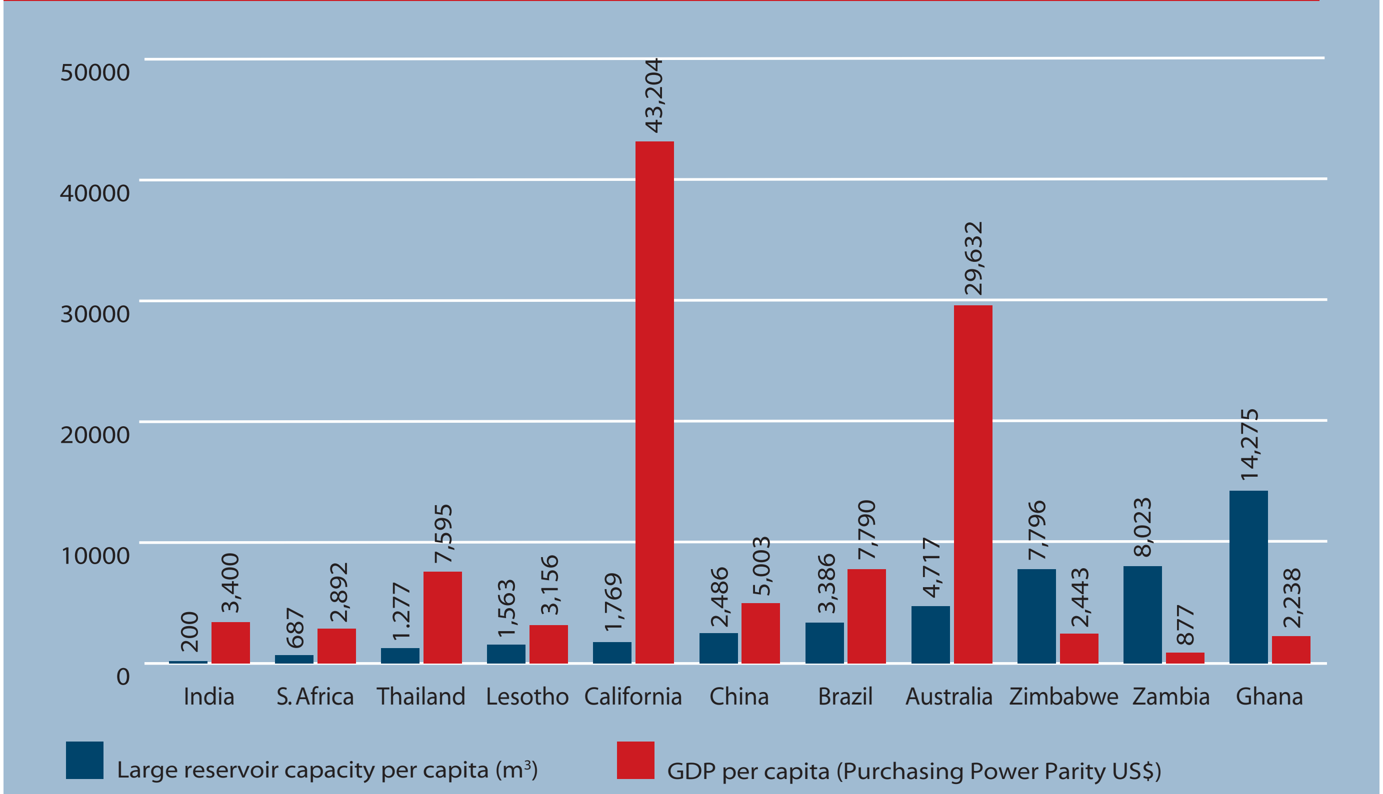
The Bank's figures do not actually show "water storage" – they show the storage capacity of large reservoirs, and thus exclude water stored in groundwater, lakes and wetlands, ponds and tanks. Given the many complexities of infrastructure economics, it is absurdly simplistic to take a single metric – per capita large reservoir storage – and claim that this is the key determinant of development differences between, say, Chad and the US. Development is much more complicated than that, as has been amply shown by countries such as Ghana, Mozambique and Paraguay, which have attempted to jump start development through the construction of massive water projects and have instead experienced huge debts, political instability and moribund economies.

Even if the Bank had a sound theoretical basis for its argument of a "poverty trap" for those countries with low per-capita large reservoir storage capacity, the argument would still fail based on the statistical evidence. A table entitled "water storage and the poverty trap" in a presentation by two senior Bank water sector staff at a recent large hydro industry conference gives data for eight countries and shows a progression from very poor Ethiopia with very low per capita large reservoir capacity to the very wealthy US with very high per capita large reservoir capacity.[28] However, had data for other countries been added the picture would look quite different (see graph below).

Zambia and Zimbabwe both have a greater per capita large reservoir capacity than the US. Ghana has a per capita large reservoir capacity three times higher than Australia. The same disconnect can be seen at the sub-national level. Montana and North Dakota both have considerably lower per capita incomes than California, yet both have a per capita large reservoir capacity around 29 times that of California.[29] A high per capita large reservoir capacity is also no insurance against the economic impacts of severe droughts – Zimbabwe's economic growth rate is closely linked to rainfall variability despite the country having one of the world's highest per capita large storage capacities.[30]

Lobbyists for more investment in big water infrastructure projects tend to conflate the issues of the huge unmet need for clean drinking water with the supposed need for more large-scale storage. Yet 80% of the people without access to water live in rural areas. Piping water from reservoirs is simply not relevant for rural

LARGE RESERVOIR CAPACITY AND GDP PER CAPITA



Notes: *Large reservoir capacity data from World Bank (India, S. Africa, Thailand, China, Brazil, Australia) and ICOLD World Register of Dams (Lesotho, California, Zimbabwe, Zambia, Ghana, N. Dakota). Zimbabwe and Zambia are each allocated 50% of the capacity of Kariba Reservoir. Per capita GDP from UNDP Human Development Report 2005. Gross State Product for California and N. Dakota from US Bureau of Economic Statistics 2004.*

areas in developing countries due to the high capital costs of building extensive systems of pipes, pumps and water treatment facilities. Supplying the domestic water needs of poor communities is best done through wells, springs and catching rainwater in household tanks and jars. Most of those in urban areas who lack access to water live in informal slum settlements, where again small-scale systems are most likely to provide reliable and affordable water.[31]

There is no shortage of water to meet domestic needs, which account for only 2-3% of water used by humans. As Frank Rijsberman, Director General of the International Water Management Institute, explains, "The water supply and sanitation challenge has everything to do with providing reliable and affordable 'water services', but for all but the largest cities and their immediate environment, it has little to do with the development and management of water resources. Scarcity is not the issue for all but the largest cities in dry areas."[32]

Storage for the Poor

The ability to store water for when it is most needed is certainly vital, especially for farmers in those regions of the world where rainfall varies widely over each year and between years. And global warming is making the ability to store water even more important. But large reservoirs are not the only form of water storage. Water stored in small reservoirs, in groundwater and in wetlands generally provides much greater economic benefits – and benefits that are much more likely to reach the poorest – than that in large reservoirs.

Small reservoirs and rainwater harvesting structures (such as the 300,000 agricultural "tanks" in South India and the seven million ponds in China)[33] are more likely to benefit poorer farmers as they are geographically widely dispersed and are more likely to be built and controlled at the community level. Large reservoirs, in contrast, mainly provide benefits to the relatively wealthy minority of large farmers living in the fertile plains areas that usually receive canal water.[34]

In many respects, the best way of storing water is underground. Groundwater does not evaporate, is well protected from biological contamination, is geographically dispersed and, provided labor or energy is available for pumping, can be accessed whenever needed. The fact that farmers rather than irrigation agencies control when groundwater is supplied to crops is the main reason why crop yields in areas irrigated by groundwater are often double those on large dam-and-canal irrigation schemes.[35]

In India, groundwater has recently overtaken rivers as the main supplier of water for India's crops, sustaining almost 60% of the country's irrigated area (and a much higher proportion of its food production). Aditi Deb Roy and Tushaar Shah from IWMI describe groundwater as "the primary democratic water source and poverty reduction tool in India's rural areas." Yet as Roy and Shah point out, "State irrigation departments currently focus most of their manpower and budgetary resources on centrally-created

HARVESTING RAIN, TRANSFORMING LIVES

Indian activist Rajendra Singh and his organization Tarun Bharat Sangh (TBS) have set off a rainwater harvesting movement in India that is changing lives.

Mandalwas is just one of more than 1,000 villages where TBS is working. Village residents have built 45 small dams and embankments in the past 15 years, and more are planned. Whereas before farmers had only enough water for grains, now people can grow vegetables and cash crops. Villagers who were forced to survive on one meal a day now eat 2-3 times a day. Women's chores have become much less time-consuming.

Since 1986, TBS has helped villagers build or restore nearly 10,000 water harvesting structures in Alwar and neighboring districts in hardscrabble northeastern Rajasthan, one of India's poorest states. Many additional structures have been built by villagers without TBS involvement. Villagers have also dug more than 1,000 wells to take advantage of the resulting rise in groundwater levels.

Monsoon rains fill ponds behind the structures. Their main purpose is to recharge the groundwater beneath. Several watercourses that had in recent decades held water only after monsoons now flow year-round due to the recharged groundwater. Forests have regenerated because of the raised water table and community-imposed restrictions on grazing animals and wood-cutting.

The beneficiary villagers contribute a quarter to a third of the cost of dams and embankments in both cash and kind. In-kind contributions are normally in the form of labor but they also can include construction materials and the value of land taken up by the structure and its pond. All the labor is provided by local villagers.

TBS's structures have provided irrigation water to an estimated 140,000 hectares. TBS calculates that around 700,000 people in Alwar and the neighboring districts benefit from improved access to water for household use, farm animals and crops. Each structure is small-scale, but the total benefits of TBS's work are most certainly large-scale.

Not a single family has been displaced to achieve these impressive benefits. Unlike big dams, the small dams have not destroyed any rivers or submerged huge areas of forests and farmland: on the contrary, TBS's work has actually created rivers and forests.

Patrick McCully

and managed large canal irrigation systems, allocating only a fraction to groundwater resources." Indian dam proponents have frequently claimed that groundwater use is most intensive where there are large surface irrigation schemes, and that farmers are pumping water that has seeped from canals. Thus, according to this argument, groundwater irrigation is actually mostly dependent on large reservoir storage. Roy and Shah, however, quote new research showing that the boom in groundwater irrigation is spread across India and has happened independently from surface-water irrigation expansion.[36]

The downside of groundwater use is that in many areas it is being used at a much faster rate than it is replenished via rainfall and floods. In some areas of India, groundwater mining has led to the collapse of agriculture and the contamination of drinking water supplies with saline water. From the perspective of food production and poverty alleviation it is far more important to implement policies to manage groundwater extraction and practices to recharge aquifers than to invest in more big dam projects.

Water stored in small reservoirs, in groundwater and in wetlands generally provides much greater economic benefits – and benefits that are much more likely to reach the poorest – than that in large reservoirs.

The large amount of natural water storage provided by wetlands not only has great ecological value, but also an economic and societal value that can be much higher per cubic meter than reservoir water. Wetlands provide water storage and purification, absorb floods, irrigate crops, and produce economic and livelihood resources such as game, fruits and vegetables, fodder and grazing, fuel, fish, building materials and tourist attractions.

A study of the proposed Kano River irrigation project in arid northern Nigeria which would have diverted water from the large Hadejia-Nguru wetland shows how much more valuable water can be when stored in a wetland than in an irrigation reservoir. The study predicted that every 1000 cubic meters of water used on the irrigation scheme would generate net economic benefits of four US cents (taking account of the costs of constructing and operating the project). Meanwhile the net economic benefits of traditional uses of the floodplain were calculated as at least $32 per 1000 cubic meters of water – *800 times greater* than using the water for irrigation.[37] Another estimate puts the total global economic value of wetlands at US$70 billion a year.[38]

An important recent analysis by economists Esther Duflo of the Massachusetts Institute of Technology and Rohini Pande of Yale University indicates that large reservoirs can help tighten the poverty trap. Duflo and Pande carried out the first ever aggregated calculation of the economic costs and benefits of irrigation dams throughout India's main dam-building states (95% of India's dams have irrigation as their main purpose). Their survey indicates that while districts downstream of dams that receive irrigation water see agricultural production increase and poverty fall, in the upstream districts where dams are built poverty increases, due mainly to submergence of land by the reservoir. "Overall," Duflo and Pande conclude, "our estimates suggest that large dam construction in India is a marginally cost-effective investment with significant [income distribution] implications, and has, in aggregate, increased poverty."[39]

The Dangers of Hydro Addiction

The argument, much used by the hydropower industry, that developing countries could escape poverty if only they could use more of their hydro potential, is as beset with over-simplification and irrelevance as the "per capita storage" myth. While there is a clear trend for countries to get richer as they increase their use of modern energy, the trend goes the other way for hydroelectricity dependency. Hydropower provides more than 50% of total electricity production in 58 countries, and more than 90% in 24 countries. The majority of these extremely hydro-dependent countries are among those with the lowest human development indicators as measured by the UN Development Programme. Of the world's 40 richest countries measured by per capita GNP, only one is more than 90% hydro-dependent; of the world's 40 poorest countries, 15 are more than 90% hydro-dependent.

Norway is the only extremely hydro-dependent country in the wealthiest 40, and it is often used by the hydro lobby to show how hydropower equals prosperity. Yet it is noteworthy that Norway's strategy was to focus on building small- and medium-sized projects (especially in the early years of hydro development) with assured benefits to local communities. This contrasts strongly with the centralized mega-project approach promoted in developing countries. The average size of a large hydro project in Norway is 82 megawatts (MW), while in Brazil the average size is 460 MW.

Numerous hydro-dependent countries have suffered drought-induced blackouts and energy rationing in recent years.[40] A two-year drought in Kenya (80% hydro-dependent at the time) in 1999-2000 cost the country at least $1.4 billion a year, equal to one-sixth of GDP. Of these losses, 84% were related to a loss of receipts from hydropower production and cuts in industrial production due to black-outs.[41]

Largely through expanding geothermal power, Kenya has reduced its hydro-dependence to 72% – but its disastrous drought experience in 1999-2000 is now being used by the World Bank as an argument for the country needing more large hydro dams![42] In reality, for Kenya and the world's other hydro-dependent countries, energy security means they should diversify their electrical systems away from hydropower. This is especially true given the changes in rainfall patterns due to global warming.

While developing countries have much more unexploited hydropower potential than developed countries, they also have massive unexploited potential for new renewable technologies such as wind, solar, geothermal and modern biomass energy. Ethiopia, for example, has exploited just over 2% of its estimated hydropower potential of 30,000 MW, the second largest hydro potential in Africa. Yet as of early 2006 it was exploiting none of its 700-2,000 MW of geothermal potential and none of its 10,000 MW wind energy potential.[43]

Because the little power supply that Ethiopia has developed is almost exclusively large hydropower, the country has had severe drought-related power supply problems. Furthermore, fewer than one in a hundred rural Ethiopians have access to electricity. Like most other countries in Africa, power sector investments in Ethiopia have gone almost exclusively to large power plants and transmission lines to the largest urban areas.[44] Ethiopia's small hydro potential could supply more than twice the national power needs projected for 2025 with benefits distributed throughout the country, yet only a handful of small and mini hydros have been built.[45]

While governments and international agencies have done extensive hydropower resource surveys over the past 50 years, assessments of the potentials for new renewables in most developing countries are based on largely inaccurate and incomplete data. An ongoing UN Environment Program resource mapping project has found that 13% of the land area in 13 developing countries is suitable for wind power production, compared to earlier estimates of just 1%. Nicaragua's wind power potential was estimated at 200 MW in the 1980s; the UNEP survey now puts its potential at 40,000 MW.[46]

Energy to End Poverty

Improved access to modern energy services is another key component of meeting the MDGs. But this does not mean that there is any credibility to claims that "developing hydropower resources, particularly in the developing world, is absolutely necessary."[47] What is absolutely necessary is to improve access to energy, and in some cases to electricity, in the most sustainable, effective and affordable way.

The UN Millennium Project states that: "Improved energy services – including modern cooking fuels, access to electricity, and motive power – are necessary for meeting almost all the Goals. They can reduce child mortality rates and improve maternal health by lowering indoor air pollution. They can reduce the time and transport burden of women and young girls by reducing the need to collect biomass. And they can lessen the pressure on fragile ecosystems. Electricity is critical for providing basic social services, including health and education, and for powering machines that support income-generating opportunities, such as food processing, apparel production, and light manufacturing."[48]

The Millennium Project proposes the following as key targets for energy services to help achieve the Goals by 2015:

"Reduce the number of people without effective access to modern cooking fuels by 50% and make improved cookstoves widely available."

World Health Organization figures indicate that respiratory illnesses due to smoke in the home from cooking with wood, dung and crop waste kills up to two million people a year, 80% of them women and children. Women and children are usually tasked with collecting fuelwood, a chore that takes up to five hours a day in sub-Saharan Africa. Where dung and crop waste are burned this means the nutrients they contain are not used to fertilize soils. Where poor people buy fuel for cooking, it can take up a fifth of their income.[49] In sub-Saharan Africa, domestic cooking accounts on average, for over 60% of total national energy use.[50]

Low-cost energy efficient stoves and alternative fuels can reduce this health threat and major drain on household income and free up time for rest, education or income-generating activities. Many tens of millions of improved cookstoves are in use worldwide, the great majority in rural areas in China. With well-designed subsidized dissemination programs their penetration could be far greater, especially in sub-Saharan Africa.[51]

Biogas digesters convert manure into a gas that can be used for cooking, lighting and heating. An estimated 16 million rural families worldwide benefit from household-scale digesters. The digesters are relatively affordable, can be built by the users, and do not require imported technology or expertise. A particular advantage of biogas is that digesters produce a soil amendment that can help boost farm yields.[52] Kerosene, liquid petroleum gas (LPG) and sustainably produced charcoal also have an important role to play as fuel for cooking and lighting in developing countries.[53]

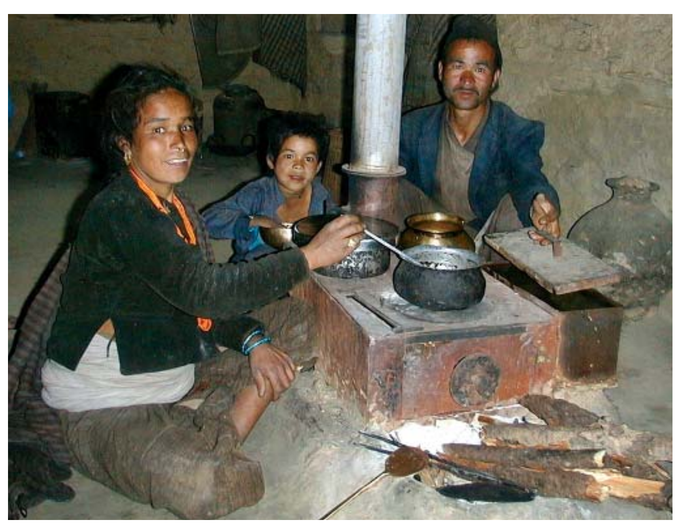
Proponents of big hydro sometimes contend that increasing electricity supply through large hydro schemes will help to reduce demand for woodfuel in countries such as Laos, Nepal and Uganda. There is, however, basically no connection between increasing grid electricity and reducing use of biomass as fuel. Even if the extremely poor people who use traditional biomass for cooking were to get access to electricity, it is extremely unlikely that they would be able to afford (or want to use) electric cookers, or indeed the electricity to run the cookers.[54]

"Provide access to electricity for all schools, health facilities, and other key community facilities."

A substantial proportion of the world's poorest communities live in rural areas without access to electricity. This is especially the case in sub-Saharan Africa where 92% of people have no access to electricity. Because of the remoteness of these communities, their poverty and very low demand for electricity, extending electrical grids to these areas requires extensive subsidies. It is frequently cheaper and faster to electrify these areas with decentralized systems such as diesel generators, small- and micro-hydro projects, small wind turbines and solar photovoltaics than by connecting them to national grids.[55]

"Ensure access to motive power in each community."

Cost-effective mechanical energy for driving sawmills, pumping water or grinding grain can be provided directly by small wind or water turbines, or, as with the treadle pump, by human labor. It can also be provided through biofuel or diesel motors.



Using an improved cookstove in Nepal.
Photo: Alex Zahnd

"Provide access to electricity and modern energy services for all urban and periurban poor."

Poor people living in and around cities will likely continue to meet most of their cooking needs from kerosene, LPG and charcoal. Electrical needs can be met through any of various generation sources – including large hydro. It will almost always be more cost-effective to improve the efficiency of existing supply technologies and cut losses in transmission and distribution before building more generating plants. Because poor people can afford to use very little power, the increased demand from investments in connecting slum areas to grids will not create a huge demand for extra supply.[56] In any case, increasing generation is less of a priority than changes in regulatory structures which force utilities to provide connections to the areas where the urban poor live.[57]

As explained above, in the many extremely poor countries that are over-dependent on hydropower, energy security will be helped by diversifying away from large hydro. Fossil fuels have well-known pollution problems and are currently relatively expensive. Sustainable technologies such as geothermal, modern biomass turbines based on burning crop wastes such as bagasse (sugar cane pulp), and wind power can all be competitive with fossil fuels. The decentralized nature of these technologies – and of efficient non-renewable technologies such as fossil fuel-powered "cogeneration" plants that provide both heat and power – is also an advantage, especially because they reduce the need to build expensive transmission lines.[58] Decentralized sustainable electricity generation creates more jobs than conventional power sources: wind power creates 4-10 times more jobs per megawatt-hour generated than large hydro; biomass and solar power can create many more jobs than wind.[59]

The Multiple Failures of Multipurpose Projects

Since the publication of its 2004 water strategy, the World Bank has revived its promotion of "multipurpose projects," by which it means massive schemes supposed to simultaneously provide hydropower, irrigation, flood control, navigation and other benefits. "Multipurpose investments in water and power are essential for growth," the Bank's senior water specialists told a hydropower conference in Norway in 2005.[60]

Multipurpose mega-projects epitomized water infrastructure for much of the twentieth century. But in the decade up to 2003, multipurpose projects seemed to be falling out of favor. This was partly due to public opposition to their harmful social and environmental impacts, and partly because of the reduction in state spending on major infrastructure projects, coupled with the aversion of the private sector to funding financially risky projects with huge up-front costs.

PER PERSON/HOUSEHOLD WATER SUPPLY COSTS

Letsibogo dam and pipeline (Botswana):
$500/person supplied with domestic water

Sardar Sarovar dam and canals (India):
$225/person supplied with domestic water
(30 million people)

Roof tanks (Sri Lanka):
$100-125/household supplied with domestic water
(2800 tanks)

Gansu rainwater harvesting project (China):
$12/person supplied with domestic water and irrigation
(1 million people)

Thailand rainwater jars:
$25-35/household supplied with domestic water
(10 million jars)

Alwar district rainwater harvesting:
$2.25/person supplied with domestic water
(700,000 people)

The Bank's effort to resuscitate the legitimacy of the multipurpose project flies in the face of a mass of evidence showing the repeated failure of these schemes to produce their supposed benefits. The World Commission on Dams' analysis of the performance of a cross-section of large dams of different ages, purposes and sizes around the world found that the projects frequently failed to meet their technical and economic targets. As is well-known, the Commission also found that large dams cumulatively had extremely negative environmental and social impacts. On all these counts, multipurpose projects tended to perform worse than single purpose projects. The WCD found that multipurpose projects frequently cost more than claimed in feasibility studies, produce less electricity, irrigate less land, displace more people, cause more environmental damage, and exacerbate rather than reduce flood damage.[61]

The WCD explains the particularly poor performance of multipurpose dams as being due to their greater complexity and to planners not properly taking account of conflicts between how dams need to be operated to serve different purposes. Maximizing power production, for example, means keeping a reservoir high; flood control requires keeping it low to provide space for absorbing flood waters. Operating reservoirs to optimize power production or water storage has frequently meant that dam operators have been caught with insufficient flood-trapping capacity during unexpected heavy storms. The result is that dam gates need to be opened, suddenly releasing huge surges of floodwaters. Many thousands of deaths have been blamed on such releases, most notably in India and Nigeria.[62]

In other cases multipurpose projects have performed particularly badly because benefits the dams were supposed to produce were added to project feasibility studies to increase the likelihood of them gaining political approval regardless of whether the "benefits" were technically achievable or economically useful.

Large multipurpose projects tend to be the most environmentally and socially disruptive of water infrastructure. They include large storage reservoirs which flood huge areas, displace numerous people, seriously alter the seasonal pattern of downstream flows and, in the tropics, release significant amounts of greenhouse gases. By diverting water for irrigation they reduce, sometimes with disastrous results, downstream flows.

A dam that is regularly used to illustrate the supposedly great economic benefits of multipurpose projects is Bhakra in northern India. Bhakra has an iconic role among Indian big-dam boosters and is regularly credited with pulling India out of humiliating dependency on foreign food aid. Yet the only detailed analysis of Bhakra indicates that the benefits of the project have been grossly exaggerated. The assessment, led by Shripad Dharmadhikary of Manthan Resource Center, was released in 2005 after three years' extensive research.

The rapid "Green Revolution" growth in agricultural production in the late 1960s and 1970s in Punjab and Haryana provinces is conventionally attributed to the Bhakra Dam. Yet Dharmadhikary shows that this growth was mainly due to massive inputs of financial subsidies and agrochemicals, and an explosive growth in groundwater pumping. The study also indicates that the Bhakra system is highly unsustainable. The growth rates of food grain production in the areas served by Bhakra are falling, and have even become negative in the case of some significant crops like rice. Soils are highly degraded, and require increasing amounts of fertilizers to maintain productivity.[63]

Dam promoters have responded to critiques of the economic performance of dams with data showing overall economic benefits of irrigation and the argument that conventional economic analyses do not take into account the "multiplier effects" of the services provided by big projects. While standard economic analysis, for example, will incorporate the increased value of crops due to irrigation, it usually fails to include the indirect economic benefits from farmers spending their increased revenues in nearby markets. Yet these multiplier effects will apply to any form of irrigation or other productive investments and can in no way be taken as proof of the supposedly superior benefits of large irrigation projects.

The Political Economy of Water Mega-infrastructure

It is easy to see why large dam industry lobby groups such as the International Hydropower Association (IHA) and the International Commission on Large Dams (ICOLD) would claim that big dams are essential in reducing poverty and environmental degradation. But it is less obvious why the World Bank, with its slogan of "Working for a World Free of Poverty," would become so committed to acting as global cheerleader for a resurgence of water mega-infrastructure projects, and so dismissive of the potential for low risk/high reward projects.

An answer to this puzzle lies in the bureaucratic imperatives of the World Bank to lend large sums of money cheaply. Since the late 1980s, growing social resistance has restricted the Bank's ability to support large infrastructure projects. The decline in Bank lending for big infrastructure is also, ironically, a result of the promotion of private infrastructure financing. Very little of this promised private finance, especially for major dams, has actually materialized.

Overall, loans from the International Bank of Reconstruction and Development, the largest of the Bank's four main arms, dropped by more than a quarter from the average of the 1990-97 period to 2002-03. The drop in lending alarms the Northern governments on the Bank's board because a shrinking portfolio means shrinking influence and less money from the Bank for their contractors. It alarms the Southern governments on the board because they don't want to lose the Bank as a source of cheap loans. And it alarms the Bank because the profits on IBRD loans help subsidize the rest of its operations. With shrinking IBRD lending, the Bank would have to depend more and more upon voluntary top-up contributions from its member governments.

So there is a strong institutional interest for the Bank to ramp up its ability to get more money out the door. And multi-billion dollar "high-risk/high reward hydraulic infrastructure" projects are excellent vehicles for moving very large loans.

While the World Bank is uniquely influential in terms of its policy setting role, they are far from the only political and economic force with a vested interest in promoting the hydro-industrial "hard path" of water management against the much more effective and cheaper community-based "soft path." Other big public and private banks have the same pressure to lend. Northern governments have an interest in using their aid and export credit agencies to support their own industries. There are few contracts for Northern companies in building rainwater harvesting jars and tanks, or helping farmers move to SRI farming methods. Water and power ministries tend to be staffed with engineers and planners stuck in the mega-project thinking of the past. Often their ministries' budgets and jobs depend on them controlling the funds for prestige projects and they see community-controlled initiatives as threats to their careers. Huge projects are also a lucrative source of kickbacks for politicians and bureaucrats.

The Way Forward

Intelligent water and energy infrastructure development alone cannot solve the scandal of global poverty and inequality. Many policy and institutional changes are needed, including land reform, changes to subsidy and trade policies, debt cancellation, a stronger role for local communities in decision-making, and an end to the ill-advised privatization and deregulation policies of the past two decades. But without a transformation of priorities in the water and energy sectors, none of the above can make a significant contribution to reducing poverty on a global scale.

Changing water sector priorities will require the World Bank to stop acting as the lobbying arm for the global big-dams industry. Aid funds need to be redirected to the research, development, and implementation of small-scale projects. Lack of money is however not the main obstacle for the rapid dissemination of small-scale projects, and the institutional limitations of the World Bank and other multilateral donors means they are not well positioned to directly finance such projects. The bulk of funding will need to come from bilateral institutions and NGOs. The World Bank needs to encourage a policy environment in which decentralized, small-scale solutions are supported rather than discouraged. It also needs to acknowledge the superior potential of small-scale solutions in its needs and options assessments, and to desist from undermining them by promoting megaprojects.

This paper has not sought to argue that all big dams are inherently bad, but it does argue that water strategies focused on big dams *cannot* significantly reduce poverty, and they divert money away from approaches that can. The hundreds of billions of dollars that the big-dam lobby is encouraging to be sunk into the "hard path" for water infrastructure could be put to work helping spread pro-poor technologies. If they were, the impacts could be nothing short of revolutionary. ■

Patrick McCully is Executive Director of International Rivers Network. He is author of Silenced Rivers: The Ecology and Politics of Large Dams *(Zed Books).*

Notes

1 See McCully, P. (2002) "Avoiding Solutions, Worsening Problems: A Critique of 'World Bank Water Resources Sector Strategy: Strategic Directions for World Bank Engagement Draft for Discussion of March 25, 2002.'" International Rivers Network, Berkeley, p.7.
2 World Commission on Dams (2000) *Dams and Development: A New Framework for Decision-Making.* Earthscan, London, p.14; UNDP/UNDESA/WEC (2004) *World Energy Assessment Overview 2004 Update.* UN Development Programme, New York, p.28.
3 Lenton, R., A.R. Wright and K. Lewis, *Health, dignity, and development: what will it take?* UN Millennium Project Task Force on Water and Sanitation, 2005.
4 "Poverty" and "the poor" are complex and contested terms. This report uses the terms as they are conventionally used in the development literature. Since 1990 the World Bank has used an income of $1 a day as an official "international poverty line." For a brief discussion on concepts of poverty see *World Resources 2005: The Wealth of the Poor – Managing Ecosystems to Fight Poverty.*WRI, Washington, DC, pp.6-12.
5 REN21 Renewable Energy Policy Network (2005) "Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals." Worldwatch Institute, Washington, DC.
6 Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington, DC.
7 World Bank (2004) "Water Resources Sector Strategy: Strategic Directions for World Bank Engagement." World Bank, Washington, DC.
8 Millennium Project (2005) *Investing in Development: A Practical Plan to Achieving the Millennium Development Goals.* Earthscan, p.17. The situation is different in Latin America and the Caribbean where 60% of the extreme poor live in urban areas.
9 Ibid. p.65.
10 Millennium Project (2005) p.33.
11 Falkenmark, M. and Rockström, J. (2004) *Balancing Water for Humans and Nature: The New Approach in Ecohydrology.* Earthscan, London, p.9.
12 Ibid. pp.47-63.
13 Ibid. p.77.
14 See e.g. Agarwal, A and S. Narain (1997) *Dying Wisdom: The Rise, Fall and Potential of India's Traditional Water Harvesting Systems.* Centre for Science and Environment, New Delhi; John Gould (2000) "Contributions Related to Rainwater Harvesting." Contributing paper for WCD Thematic Review IV.3: Assessment of Water Supply Options; McCully, P. (2002) "Water-Harvesting in India Transforms Lives," *World Rivers Review,* Dec.
15 Inocencio, A., H. Sally and D. J. Merrey (2003) "Innovative Approaches to Agricultural Water Use for Improving Food Security in Sub-Saharan Africa." IWMI, Colombo.
16 Thakker, H. (2005) "More rice for less water," InfoChange News & Features, June.
17 http://ciifad.cornell.edu/sri/countries/index.html
18 CIIFAD/Association Tefy Saina (2005) "SRI System of Rice Intensification."
19 Ibid.
20 Haviland, C. (2005) "Nepal farmers reap bumper harvest," http://news.bbc.co.uk/2/hi/south_asia/4200688.stm.
21 Uphoff, N. (2006) pers. com.
22 See e.g. InterAcademy Council (2004) *Realizing the Promise and Potential of African Agriculture.* Amsterdam.
23 Lipton, M. (2005) "The Family Farm in a Globalizing World." IFPRI Policy Brief 74.
24 WCD (2000) p.11.
25 Rijsberman, F. (2004) "The Water Challenge," in The Copenhagen Consensus Challenge Paper.
26 "Seven times" estimate calculated using Rijsberman (2004) figure of cost of meeting the MDG as $9 billion/year, and estimate from Sanctuary, M. and H. Tropp (2005) "Making Water a Part of Economic Development," SIWI/WHO, Stockholm, that achieving universal access to piped water and sewerage would cost $130 billion/year. This calculation assumes cost of meeting MDG is half that of universal access.
27 The Bank's 2005 "Turbulent Waters" report on India, for example, states that "Whereas arid rich countries (such as the United States and Australia) have built over 5000 cubic meters of water storage per capita, and middle-income countries like South Africa, Mexico, Morocco and China can store about 1000 cubic meters per capita, India's dams can store only 200 cubic meters per person."
28 Grey, D. and D. Fields (2005) "The New Hydropower Option and the World Bank: Beyond Energy," presented at HydroPower '05, Norway.
29 Large reservoir water storage calculated from ICOLD World Register of Dams. GNP data from CIA World Factbook.
30 Sanctuary and Tropp (2005). Zimbabwe suffered a 45% decline in agricultural production during drought in 1992 (Grey, D. (2002) "Water Resources and Poverty in Africa: Breaking the Vicious Cycle," presentation at AMCOW, Abuja, Nigeria.)
31 See e.g. Appleton, B. and A. Chatterjee, "Innovative Strategies For Water And Sanitation For The Poor: Access And Affordability." Thematic Background Paper, International Conference on Freshwater, Bonn 2001; Stockholm International Water Project and Millennium Project (2005) "Health, Dignity and Development: What Will It Take?"
32 Rijsberman (2004).
33 IWMI-Tata Water Policy Program (undated) "The Challenges of Integrated River Basin Management in India." *Water Policy Briefing 3.*
34 See e.g. Rijsberman (2004).
35 M. Moench, J. Burke and Y. Moench (2003) *Rethinking the Approach to Groundwater and Food Security.* UN FAO, Rome.
36 Ibid.
37 IUCN (2002) "Deciding the Future of Wetlands. Background information on the main issues of the 8th Conference of Parties to the Ramsar Convention on Wetlands."
38 Schuyt, K. and L. Brander (2004) "The Global Economic Value of Wetlands." WWF, Gland.
39 Esther, D. and Pande, R. (2005) "Dams." Yale University Economic Growth Center Discussion Paper No. 923.
40 Hydro-dependent countries that have suffered drought-related serious power shortages include Albania, Brazil, Chile, Colombia, Ecuador, Ethiopia, Ghana, Guatemala, Kenya, Malawi, Peru, Sri Lanka, Tanzania, Tajikistan, Thailand, Uganda, Vietnam, Zambia, and Zimbabwe.
41 World Bank (2005a) "Water Resources, Growth and Development: A Working Paper for Discussion." Prepared for the Panel of Finance Ministers, U.N. Commission on Sustainable Development, April.
42 See e.g. Ibid; World Bank (2005b) "Water Security, Growth and Development," Media Background Paper, April 21; Grey (2002). Partly through the addition of geothermal power Kenya reduced its hydro-dependency from 80% in 1999 to 66% in 2003/4. Drought can cause problems for power planners at even relatively low levels of hydro-dependency – a contributing factor to California's 2000-01 "power crisis" was reduced imports from drought-struck dams in the Columbia basin, which contributed only 11% of the state's total electricity supply. Also, www.water.go.ke/article3.html
43 Business Council for Sustainable Energy (2003) "Eastern Africa Geothermal Market Acceleration Conference – Market Assessment Report 2003."
44 Dalelo, A. (undated) "Rural Electrification in Ethiopia: Opportunities and Bottlenecks." www.zef.de/fileadmin/webfiles/renewables/praesentations/Dalelo_rural%20electrification%20ethiopia.pdf
45 According to the web site of the Ethiopian power utility only 3 small and micro hydro plants are in operation in the country (http://www.eepco.gov.et/brief.html).
46 "Most of Third World Fit for Wind Power: UN Study," World Bank Press Review, December 5, 2005.
47 Sanctuary and Tropp (2005) p.22.
48 Millennium Project (2005) p.30.
49 REN21 Renewable Energy Policy Network (2005) p.17.
50 Kammen, D. (1995) "From Energy Efficiency to Social Utility: Lessons from Cookstove Design, Dissemination, and Use," in *Energy as an Instrument for Socio-Economic Development.* UNDP, New York.
51 Ergeneman, A. (2003) "Dissemination of Improved Cookstoves in Rural Areas of the Developing World: Recommendations for the Eritrea Dissemination of Improved Stoves Program." Eritrea Energy Research and Training Center. Improved cookstove designs and dissemination programs have often proven disappointing. However there are success stories, such as the Kenyan Ceramic Jiko, with important lessons for other cookstove promotion programs (Kammen (1995)).
52 REN21 Renewable Energy Policy Network (2005a).
53 Bailis, R., M. Ezzati and D.M. Kammen (2005) "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa." Science 238, 1 April. Bailis et al. calculate that use in African households of LPG, kerosene and sustainable charcoal has significant greenhouse gas emission and health benefits compared to conventional biomass harvesting and combustion.
54 See e.g. Kammen, D.M., R. Bailis and A.V. Herzog (2002) "Clean Energy for Development and Economic Growth: Biomass and other renewable energy options to meet energy and development needs in poor nations." UNDP, New York.
55 See e.g. UN Development Programme (2005) "Energizing the Millennium Development Goals: A Guide to Energy's Role in Reducing Poverty." UNDP, New York; REN21 Renewable Energy Policy Network (2005b) "Energy for Development: The Potential Role of Renewable Energy in Meeting the Millennium Development Goals." Worldwatch Institute, Washington, DC.; Practical Action (2005) "Europe's Chance to Help Light Up Africa: Energizing Poverty Reduction in Africa." Practical Action, Rugby, England.
56 Fulkerson et al estimate that electrifying 1 billion people currently unserved with electricity would require about 50 gigawatts of new generating capacity, just over 1% of existing global installed capacity (Fulkerson, W., M.D. Levine, J.E. Sinton and A. Gadgil (2005) "Sustainable, efficient electricity service for one billion people," *Energy for Sustainable Development* 10:2, June.
57 See e.g. Saghir, J. (2005) "Energy and Poverty: Myths, Links, and Policy Issues," Energy Working Notes, World Bank.
58 See Greenpeace (2005) *Decentralising Power: An Energy Revolution for the 21st Century,* Greenpeace UK, London; World Association for Decentralized Energy www.localpower.org.
59 Goldemberg, J. (2004) "The Case for Renewable Energies." Thematic Background Paper for International Conference for Renewable Energies, Bonn.
60 Grey and Fields (2005).
61 The WCD reviewed 12 multipurpose projects funded by the World Bank, African Development Bank and Asian Development Bank and for which pre-construction appraisal and post-construction evaluation reports were available. The commission found that estimates of the economic internal rate of return of the projects were 4% lower at evaluation than at appraisal. Of the four AfDB projects, Bank evaluations had showed that only one was financially and economically viable (WCD (2000) p.62).
62 See e.g. WCD (2000) p.60; D'Souza, R. (2001) "Hundreds Flooded by Orissa's Hirakud Dam: Politics, Not Nature Made Orissa's Floods Calamitous," *World Rivers Review,* August.
63 Dharmadhikary, S. (2005) *Unravelling Bhakra: Assessing the Temple of Resurgent India.* Manthan Resource Centre.

The Big Potential of Small Farms

By Paul Polak
President, International Development Enterprises

With the help of affordable irrigation and access to markets, farmers in the developing world can grow more food and climb out of poverty.

Peter Mwete, an angular Zimbabwean man in his 20s, was weeding his tiny vegetable plot in the settlement of Marimari when I met him in 2002. The 100-square-meter plot – about the size of a typical suburban backyard – was enclosed by a two-meter-high fence of stout poles cut from the bush and wired together to keep wild and domestic animals out. Peter lived with his father and a 19-year-old brother; his mother had died from AIDS, and his brother was also dying. To feed his family and earn a living with fewer hands to do the work, Peter had installed a low-cost, gravity-fed drip-irrigation kit provided by International Development Enterprises (IDE), the organization I started in 1981.

Peter's plot consisted of eight raised beds neatly planted with rape leaves, cabbage and corn. In the middle of each bed, a movable drip line delivered water from a 40-liter plastic tank placed atop a wooden stand. Because the drip system brought water directly to the roots, it was far more efficient than watering the plants by bucket. As a result, the small plot produced enough corn and vegetables to meet most of the family's needs, and Peter expected to earn at least $90 – a substantial income for a farmer in Zimbabwe – from selling the surplus. He told me that in the following year he planned to double the size of his plot and triple his income by replacing some of the leafy vegetables with more valuable crops, such as tomatoes and Irish potatoes. He also planned to raise his plot's productivity by fertilizing it. Because he could not afford chemical fertilizers, he intended to dunk a burlap bag filled with cow manure into a water drum and apply this "manure tea" to the roots of his vegetables through the drip system.

If a small organization such as IDE, with an annual budget of $10 million and a staff of 600, can bring nearly one million people out of poverty every year, then surely the combined efforts of the wealthy nations can do much more.

Over the past three decades, I have spoken with thousands of small farmers in the developing world, and their stories are strikingly similar to Peter's. They can increase their earnings by as much as $500 a year by intensively farming 1,000-square-meter (quarter-acre) plots of fruits and vegetables, but they need better cultivation methods, affordable irrigation and access to markets for their crops. Their struggle is part of a global challenge: by 2050 the world's farmers must feed nine billion people – three billion more than the current population – without much expansion in the amount of land and water devoted to agriculture. Water, in particular, has emerged as the key to boosting farm production and easing poverty, because nearly 1,000 liters of water are needed to grow one kilogram of grain. We must store more water for irrigation and manage the supply we have more effectively.

Until now, governments and development agencies have tried to tackle the problem through large-scale projects: gigantic dams, sprawling irrigation canals and vast new fields of high-yield crops introduced during the Green Revolution, the famous campaign to increase grain harvests in developing nations. Traditional irrigation, however, has degraded the soil in many areas, and the reservoirs behind dams can quickly fill up with silt, reducing their storage capacity and depriving downstream farmers of fertile sediments. Furthermore, although the Green Revolution has greatly expanded worldwide farm production since 1950, poverty stubbornly persists in Africa, Asia and Latin America. Continued improvements in the productivity of large farms may play the main role in boosting food supply, but local efforts to provide cheap, individual irrigation systems to small farms may offer a better way to lift people out of poverty.

The Amazing Treadle Pump

Of all human activities, agriculture leaves the biggest footprint on Earth. About 70 percent of the water diverted for human use now goes to farming; another 19 percent goes to industry, 9 percent to homes and the rest to evaporation from reservoirs. One of the accomplishments of the Green Revolution was to enlarge the world's irrigated land, which grew from 100 million hectares in 1950 to 276 million today. (A hectare is equal to 10,000 square meters, or about 2.5 acres.) The resulting jump in harvests lowered the price of food, which contributed to reducing poverty among subsistence farmers and city dwellers. This effect, however, was offset by population growth. Between 1990 and 2001 the number of people worldwide living in extreme poverty – surviving on $1 a day or less – declined from 1.22 billion to 1.09 billion, but the number earning less than $2 a day rose from 2.65 billion to 2.74 billion. The trend was most dire in sub-Saharan Africa, where the population in extreme poverty leaped from 227 million to 313 million.

The Green Revolution was designed to increase the overall food supply, not to raise the incomes of the rural poor, so it should be no surprise that it did not eradicate poverty or hunger. India, for example, has been self-sufficient in food for 15 years, and its granaries are full, but more than 200 million Indians – one fifth of the country's population – are malnourished because they cannot afford the food they need and because the country's safety nets are deficient. In 2000, 189 nations committed to the Millennium Development Goals, which called for cutting world poverty in

Treadle pumps have enabled more than 1.5 million Bangladeshi farmers to grow marketable produce. Photo: IDE

half by 2015. With business as usual, however, we have little hope of achieving most of the Millennium goals, no matter how much money rich countries contribute to poor ones.

American agricultural researcher Norman Borlaug – who received the Nobel Peace Prize in 1970 for his contributions to the Green Revolution – was recently asked what wealthy countries should do to reduce hunger in the world. He said that they should send food during emergencies but that the long-range solution is revolutionizing agricultural production, especially among subsistence farmers in developing countries. This plan would not only increase food supply but also create jobs and generate new income from selling excess grain.

The supply-driven strategies of the Green Revolution, however, may not help subsistence farmers, who must play to their strengths to compete in the global marketplace. The average size of a family farm is less than four acres in India, 1.8 acres in Bangladesh and about half an acre in China. Combines and other modern farming tools are too expensive to be used on such small areas. An Indian farmer selling surplus wheat grown on his one-acre plot could not possibly compete with the highly efficient and subsidized Canadian wheat farms that typically stretch over thousands of acres. Instead, subsistence farmers should exploit the fact that their labor costs are the lowest in the world, giving them a comparative advantage in growing and selling high-value, intensely farmed crops.

I saw firsthand the need for a small-scale strategy in 1981 when I met Abdul Rahman, a farmer in the Noakhali district of Bangladesh. From his three quarter-acre plots of rain-fed rice fields, Abdul could grow only 700 kilograms of rice each year – 300 kilograms less than what he needed to feed his family. During the three months before the October rice harvest came in, Abdul and his wife had to watch silently while their three children survived on one meal a day or less. As I walked with him through the scattered fields he had inherited from his father, I asked what he needed to move out of poverty. "Control of water for my crops," he said, "at a price I can afford."

Soon I learned about a simple device that could help Abdul achieve his goal: the treadle pump. Developed in the late 1970s by Norwegian engineer Gunnar Barnes, the pump is operated by a person walking in place on a pair of treadles made of bamboo or another locally available material. The human-powered pump can irrigate half an acre of vegetables and costs only $25 (including the expense of drilling a tube well down to the groundwater). Abdul heard about the treadle pump from a cousin and was one of the first farmers in Bangladesh to buy one. He borrowed the $25 from an uncle and easily repaid the loan four months later. During the five-month dry season, when Bangladeshis typically farm very little, Abdul used the treadle pump to grow a quarter-acre of chili peppers, tomatoes, cabbage and eggplants. He also improved the yield of one of his rice plots by irrigating it. His family ate some of the vegetables and sold the rest at the village market, earning a net profit of $100. With his new income, Abdul was able to buy rice for his family to eat, keep his two sons in school until they were 16 and set aside a little money for his daughter's dowry.

When I visited him again in 1984, he had doubled the size of his vegetable plot and replaced the thatched roof on his house with corrugated tin. His family was raising a calf and some chickens. He told me that the treadle pump was a gift from God.

Bangladesh is particularly well suited for the treadle pump because a huge reservoir of groundwater lies just a few meters below the farmers' feet. In the early 1980s IDE initiated a campaign to market the pump, encouraging 75 small private-sector companies to manufacture the devices and several thousand village dealers and tube-well drillers to sell and install them. Over the next 12 years one and a half million farm families purchased treadle pumps, which increased the farmers' net income by a total of $150 million a year. The cost of IDE's market-creation activities was only $12 million, leveraged by the investment of $37.5 million from the farmers themselves. In contrast, the expense of building a conventional dam and canal system to irrigate an equivalent area of farmland would be in the range of $2,000 per acre, or $1.5 billion.

In terms of reducing poverty, the treadle pump has proved superior to more technologically advanced irrigation schemes. Starting in the 1970s, for example, the World Bank made low-interest loans enabling the government of Bangladesh to import diesel pumps for deep tube wells, a technology used in Nebraska to pull water out of the Ogallala aquifer. Each system cost $15,000 and could irrigate 40 acres. The government made them available to farmers for free. Another loan program allowed the government to import 10,000 diesel pumps for shallow wells, each of which cost $900 and irrigated 12 acres. Bank appraisers rated the program a success because it moved Bangladesh closer to rice self-sufficiency, but when the government subsidies ran out, farmers abandoned most of the deep wells because of their high operating costs. The shallow wells remained popular among larger, richer farmers, who became water lords and put many small farmers out of business.

The cost per irrigated acre was $375 for the deep diesel pumps, $133 for the shallow diesel pumps and only $66 for the treadle pumps – $50 of which came from the farmers. By focusing on creating a sustainable market, the treadle-pump project produced more income and left a gentler footprint on the environment. A similar approach is now needed to address the problem of naturally occurring arsenic in Bangladesh's groundwater, which is poisoning farmers. Because many Bangladeshis are willing and able to pay for a $7 household filter to rid their drinking water of arsenic, the obvious solution is to find private-sector distributors and subsidize purchases for those who cannot afford it. (IDE's organization in Bangladesh is currently promoting the filter.) As usual, though, the government and the donor community are calling for large-scale solutions such as centralized piped-water systems, which have not been effective in Bangladesh in the past.

CROSSROADS FOR AGRICULTURE AND WATER

The Problem

Although the Green Revolution significantly increased worldwide grain harvests, hunger and poverty stubbornly persist in Africa, Asia and Latin America. Farmers working small plots of marginal land cannot grow enough food to support their families.

- In sub-Saharan Africa alone, more than 300 million people survive on $1 a day or less. In India, more than 200 million people are malnourished.

The Plan

- Continued improvements in the productivity of large farms will expand the overall food supply, but efforts to reduce poverty should focus on increasing the incomes of small farmers.
- Individual irrigation systems employing inexpensive equipment, such as drip lines and storage tanks, can greatly enhance the yields of small plots. If farmers raise high-value crops such as tomatoes or chili peppers, they can boost their earnings

Drop by Drop

Obtaining water from wells or reservoirs is only half the challenge; farmers must also find better ways to deliver the water to their crops. Most irrigated farms in the developing world rely on inefficient surface-flooding methods that have remained unchanged for centuries. As a result, millions of acres of good cropland have been lost to waterlogging, salinization and excessive pumping from aquifers. The poorest farmers face an additional problem: many work on marginal land in semiarid areas. Some have limited access to surface water or wells, and others are totally dependent on rainfall. Drip irrigation, one of the most miserly ways of applying water to crops, would be a godsend for them, but most drip systems are too big, complicated and expensive to fit their needs.

In 1992 I visited a hill village in Nepal called Madan Pokhara where sprinkler systems supplied from small reservoirs irrigated the farms. I was disappointed to learn that the systems, each of which served three farmers, cost $1,000 apiece. I resolved to find a way to make it cheaper. I discovered that just about every other house in the village got its washing water from a small plastic pipe stuck in a stream above the house. Why not use the same cheap piping to bring water from streams to crops? We could replace the expensive reservoirs of the sprinkler system with used 55-gallon drums sunk in the stream. To replace the sprinklers, we could punch holes in the pipe with a hammer and nail and let water dribble out to the plants. I thought I was pretty smart until I ran this idea past Dan Spare, an irrigation engineer building a canal in Nepal's Kali Gandaki River basin. "You have just invented drip irrigation," he said. "The only problem is that the Israelis invented it 35 years ago."

I was convinced that drip irrigation could be tailored to the needs of subsistence farmers. In 2001, after seven years of development and field tests, IDE introduced an effective, low-cost drip system that resisted clogging and sold for one fifth the price of conventional equipment. Families could invest as little as $3 to buy a kit that irrigated a 40-square-meter kitchen garden, then reinvest some of the 300 percent annual return it generated to expand the system's coverage up to an acre or more. In 2004 farmers in India purchased enough IDE equipment to irrigate

20,000 acres. Within 10 years I expect that low-cost drip systems will irrigate several million hectares in India alone, an amount larger than the total worldwide area under drip irrigation today.

Drip systems can also be used to irrigate crops with stored rainwater. Throughout history, farmers have devised ways to collect the copious water rushing off the fields during the monsoons that batter East Africa and South Asia every year. IDE is now developing a system that employs small settling ponds to remove silt from the rainwater, which is then diverted to an enclosed 10,000-liter storage tank. In the ensuing months, farmers use a hand pump to send water through the drip piping to their crops, which can be sold for high prices during the dry season. Because this system carries out the functions of a big dam for a small farm, we gave it the ironic name of NAWSA MAD, which is Aswan Dam spelled backward. (Aswan is perhaps the most controversial of the big dam systems in the developing world.) NAWSA MAD's storage tank, which will cost only $40, is undergoing final field tests in India and Africa.

A family in Zimbabwe shows off their drip-irrigated coffee crop. Photo: IDE

To Dam or Not to Dam?

People use only about 10 percent of the freshwater that falls on our planet; the other 90 percent falls in underpopulated places such as the Amazon or comes all at once during rainy seasons and rushes past farmers' fields to the sea. The easiest way to produce more food for a growing population is to use the existing supply of irrigation water more productively, but that is not the only answer. Farmers currently use about 2,500 cubic kilometers of water every year, and the consensus is that even with improvements in productivity they will require about 20 percent more by 2025.

I have been a vocal critic of big dams that are built mindlessly, but I believe it would be a mistake to halt all dam construction. Careful planning is the key. The World Commission on Dams recently released a report that offered sensible procedures for mitigating the negative impacts of dams on the environment. The report also advocated examining alternatives to dams such as storing water underground, which eliminates evaporation losses and provides water closer to where it is needed.

In many places, groundwater tables are dropping two meters a year or more because of overpumping. Some aquifers can be replenished, though, by trapping monsoon rainwater and directing it underground. The state of Gujarat in India is a good example: it is hot and dry most of the year, and most of its rain falls during the monsoon season, when flooding is common. Starting in the 1980s, a Hindu religious movement called Swadhyaya Parivar led thousands of farmers in Gujarat to build waterways that direct monsoon runoff into large open wells. This collective action restored groundwater aquifers and significantly increased agricultural productivity. Development agencies should immediately conduct hundreds of Gujarat-type experiments and launch a major global initiative to scale up the most successful ones.

Another promising idea is to use drip and sprinkler systems in combination with the irrigation canals that lace croplands in India, China and other countries. Farmers on canals can get water only when their turn comes, and canal systems typically deliver water every two to three weeks, instead of the two- to four-day cycle that most high-value crops thrive on. Installing small storage tanks along the canals would enable farmers to irrigate their fields between the scheduled times of water delivery. Farmers in China are already successfully adopting this system, which they call "melons on a vine." In addition to increasing the amount of food grown and money earned for each liter of water, such efforts alleviate the damaging effects of waterlogging and salinization, both of which are made much worse by applying too much water at once.

New irrigation systems for farmers could also provide clean drinking water to many of the 1.1 billion people who lack access to it. Because more than 80 percent of these people live in poor rural areas rather than cities, building large, centralized, piped-water complexes to serve them all would be impractical and prohibitively expensive, costing hundreds of billions of dollars. But a system that combines irrigation with delivering drinking water can actually pay for itself. In 2004 IDE's organization in Nepal built small water-supply systems in eight hill villages. In addition to providing drinking water from clean springs for 10 to 15 families, each system delivered enough water to drip-irrigate several plots of off-season vegetables. We expect that the sales of these vegetables will pay for the water systems within one to two years and provide continuing income for the families after that.

In much of Africa, rural villagers get water for both drinking and irrigation from nearby wells. Unlike the situation in Bangladesh, the water table is too deep to be accessed by treadle pumps. Hand pumps make it easier to get the water out of the ground, but most Africans cannot afford the $1,500 installation cost. (The hand pump that Peter Mwete used to obtain water for his plot in Marimari was donated to his village by a church group.) If the villagers form a water-users group, however, they can borrow the money for the hand pump. Assume that each of 30 families agrees to pay the group $7 a year for clean drinking water and that 15 of the families invest an additional $20 each to buy drip-irrigation systems. Each farming family earns an extra $100 a year from selling fruits and vegetables, out of which $30 is given to the water-users group. The group collects $210 a year from the water users and $450 a year from the farmers, which is enough to cover operating expenses and pay off the $1,500 loan in four years.

African governments and development agencies can encourage such arrangements by organizing the water-users groups, training the farmers and facilitating their access to markets. This strategy is much more effective than subsidizing the cost of installing the hand pumps, because the villagers are more likely to properly maintain the pumps if they own them. Of course, this approach may not work for every village; in some cases, for example, the wells may not produce enough water for both drinking and irrigation. But I believe that at least half the new rural drinking-water systems can be self-financing.

FAST FACTS ON SMALL SCALE IRRIGATION

1,500,000
Bangladeshi farmers who have purchased treadle pumps

$49.5 million
Total investment in the pumps

$150 million
Total increase in the farmers' annual income

$1.5 billion
The cost of irrigating the same farmland with a conventional dam and canal system

The Price Tag

How much will it cost to feed three billion more people and cut poverty levels in half? All one can do is make an educated guess. On larger farms with good soils, where most of the gains in agricultural productivity have been made so far, I estimate that boosting harvests further will require a total investment of $20 billion over the next 10 years. It will take about $10 billion to support the continuing agricultural research at universities, national institutions and the centers in the Consultative Group on International Agricultural Research. Another $10 billion or more will be needed to double the productivity of existing irrigation systems and to build a small number of new large dams.

Reducing poverty, however, is more complicated than simply expanding the food supply, and estimates of the cost of achieving the Millennium Development Goals vary widely. Jeffrey D. Sachs of Columbia University and his committees of United Nations experts say wealthy countries must provide a total of more than $1.5 trillion of assistance funds to developing nations over the next 10 years, with the lion's share devoted to improving health, education, energy and road infrastructure. My work with IDE, however, leads me to a different set of conclusions. First, although investments from the West are critical to prime the pump, it is absolutely essential that the rural poor invest their own time and money in the effort to move out of poverty. The crucial step is releasing the energy of Third World entrepreneurs. The good news is that one-acre farmers are already entrepreneurs and are surrounded by thousands of other businesspeople operating small stores and repair shops.

For each of the past several years, IDE's projects have increased the net annual income of more than 100,000 poor rural families by $500 at a cost of less than $200 per family. Assuming that pace can continue, reaching the Millennium Development Goals – which require bringing some 600 million people, or about 100 million families, out of poverty – would cost $20 billion. This investment would not cover all the infrastructure improvements that Sachs and others have advocated, but it would give rural families new income to educate their children and improve their farms, homes and health. What is more, I am confident that such a program would spur private agribusinesses to make a similar investment to build a market infrastructure for processing, grading, packaging and distributing the tomatoes, eggplants, chili peppers and other high-value produce grown by the newly empowered farmers.

If a small organization such as IDE, with an annual budget of $10 million and a staff of 600, can bring nearly one million people out of poverty every year, then surely the combined efforts of the wealthy nations can do much more. But development agencies must be willing to start at the bottom – at the level of the small farmer walking quietly on his treadle pump – and work their way up. ■

Paul Polak is founder and president of International Development Enterprises (IDE), a nonprofit grassroots organization that has brought more than 12 million people living on small farms out of poverty since 1981. For more information on IDE, see www.ide-international.org

This article originally appeared in Scientific American, September 2005. Reprinted with permission.

Water Innovators: Low Tech, Low Cost, High Reward Solutions

Tackling the world's water problems will require a shift from "business-as-usual" practices. The following is just a small sampling of the many innovative programs and inventions in the world of water.

1. In Africa, children are often tasked with collecting water. The Playpump converts a playground roundabout into the engine that drives a pump, turning a dull chore into child's play. www.roundabout.co.za

2. Rice is one of the world's most important staple crops, but it is very water-intensive. The International Rice Research Institute estimates that if conventionally grown, it takes 5,000 liters of water to produce one kilogram of rice. Agricultural scientists have made huge breakthroughs in reducing the amount of water needed to grow rice, while improving yields. Researchers at Cornell University and the Association Tefy Saina (Madagascar) have developed a "System of Rice Intensification" that reduces water use by 25-50%, increases yields by 50-100%, and does not require expensive chemical inputs or hybrid seeds. An estimated 90% of agricultural water use in Asia goes for rice production, so the savings could be huge. http://ciifad.cornell.edu/sri/

3. In Brazil's dry northeast, where millions live without regular access to clean drinking water, a community-driven initiative is building low-cost cisterns for the poor. The Million Cisterns Project aims to provide drinking water to five million people in the next decade. www.rhythmofhope.org/article_cisterns.php

4. Switzerland's Federal Institute for Environmental Science and Technology has created the cheapest, simplest water purification system ever. Solar water disinfection (known as SODIS) is so simple that many believe it can't work – but it does, as people in at least 20 countries have shown. Just fill plastic water bottles, shake to oxygenate, then leave them in the sun for 6-8 hours – if possible, on a surface that will increase the heat, such as corrugated metal roofing or black plastic. The radiation from sunlight and the increased temperature of the water are enough to kill many forms of bacteria and viruses. www.sodis.ch/

5. Pump Aid has modified an ancient Chinese design to develop a bicycle- or hand-powered water pump that can be built from local materials available in remote African villages, at a cost that is an order of magnitude less than the cheapest alternative. www.pumpaid.org

6. A mutant strain of cholera that killed thousands in Asia in 1993 prompted Dr. Ashok Gadgil of Berkeley Lab to devise a portable, inexpensive water disinfection system. UVWaterworks uses ultraviolet light to disinfect water of deadly waterborne diseases. One device produces four gallons of water per minute, and can supply a village of 6,000 with adequate potable water for about $3 per person per year. The company that manufactures the units takes an integrated approach to eradicating waterborne disease, combining the technology with community education. http://waterhealth.com/

7. The Rainwater Harvesting Implementation Network (RAIN) focuses on field implementation of small-scale rainwater harvesting projects, capacity building of local groups, and knowledge exchange on a global scale. During the first two years of operations, RAIN helped create a total storage capacity of approximately 369,840 gallons in Ethiopia, Senegal and Nepal. The group also sets up training centers where it works. http://www.rainfoundation.org/

Children in Bolivia purify water using solar-water disinfection method. Photo: EAWAG

8. Solar Powered Ozone Water Treatment Systems (SPOWTS) has reduced water-bottle litter and fuelwood use in the remote Himalayan region frequented by trekking tourists, reduced water-borne illnesses in the local population, and created jobs in mountain communities. Revenues generated after the cost of the equipment has been covered are used for local development projects as decided by individual communities. http://www.mpwr.co.nz/udo.php?p=southasia&id=89

9. A program called Mother's Underground Water Tank has built more than 90,000 underground water tanks in China's most water stressed regions during the past five years, benefiting about one million rural residents. The program also has built 1,100 water supply facilities. A project of the China Women Development Foundation, it has now expanded from drought-stricken northwestern China to include to rural communities in the southwestern Carst region.
http://www.cwdf.org.cn/zhuati/xiangmujiangjian/zhuati01.htm (Chinese language only)

10. It can take as much as 114 gallons of water to produce just one pound of sugar. The World Wildlife Foundation's Sustainable Sugar Initiative is working with farmers around the world to help them adopt more ecologically friendly methods sof raising this water-intensive crop. www.panda.org

11. Two South African inventors are working on waterless toilets. The ZerH2O waterless toilet, invented by a South African grandfather, could provide environmentally friendly waste disposal where waterborne sanitation is not feasible. www.zerho.co.za

And Enviro Loo turns human waste into sanitized fertilizer using solar power and no water or chemicals. www.eloo.co.za/

12. The South African water department is tackling water waste in a number of ways, but perhaps the most innovative is its Working for Water program, which removes water-sucking invasive alien plants from watersheds, while also providing jobs to the poor. www.dwaf.gov.za/wfw/

DAMS, RIVERS AND PEOPLE IN 2005: AN OVERVIEW

■ **China's environmentalists flex their muscles:** On January 18, China's State Environmental Protection Agency (SEPA) announced the suspension of 30 large infrastructure projects, including 26 power projects that failed to meet the country's environmental standards. SEPA's announcement followed a decision by the prime minister in April 2004 to suspend 13 proposed dams on the Nu/Salween River. While construction on the 30 projects later resumed, SEPA's decision and the vocal campaigns by Chinese NGOs against destructive dams are signs of a growing concern about the state of China's rivers.

■ **Dangerous Dams:** The warming world's changing hydrology and a lack of maintenance are affecting the safety of dams around the world. On February 10, the Shadi Kor Dam burst in Pakistan's Balochistan province. In the following days, two other dams were also washed away in Pakistan. The dam failures left at least 300 people dead. On March 29, the collapse of the Band-e Sultan dam in Afghanistan killed at least ten people and displaced thousands. On April 7, the operators of India's Indira Sagar Dam discharged water as thousands of pilgrims bathed in the Narmada River. At least 65 drowned in the incident. Brazil's Camara Dam burst on June 17, leaving at least six dead and destroying hundreds of homes.

■ **Water for Life Decade:** On March 22, the UN Secretary General launched the International Decade for Action "Water for Life." The main goals of the decade are to reduce by half the proportion of people without access to safe drinking water and to stop unsustainable exploitation of water resources. In launching the water decade, Kofi Annan called on the world "to increase water efficiency, especially in agriculture" and to "involve women and girls in decision-making on water management."

■ **World Bank approves Nam Theun 2:** On March 31, the World Bank approved funding for the controversial Nam Theun 2 Dam in Laos. In the following weeks, several other multilateral development banks, export credit agencies and private banks also approved funding for the 1,070 MW project. Nam Theun 2 is the first prominent example of the World Bank's return to funding large dams. The project will displace 6,200 people, and will seriously impact the livelihoods of at least another 100,000 people.

■ **Major bank adopts WCD framework:** On May 27, Great Britain's HSBC, one of the world's largest banks, adopted the World Commission on Dams (WCD) framework in its new water policy. The policy prohibits lending for dams that do not comply with the recommendations of the WCD. In following months, the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD) announced that they would also take the WCD framework into account when purchasing carbon credits from large hydro projects.

■ **New guidelines for export credits for hydropower projects:** On November 15, the OECD governments decided to extend export credits with special financial terms for future hydropower projects if they comply with the World Bank's ten safeguard policies. At the same time the governments said they "recognized the value" of the WCD report.

■ **Sweden supports WCD framework:** On December 1, a national multi-stakeholder group on large dams published recommendations on how to implement the WCD framework in Sweden. Representatives of all major interest groups participated in the dialogue process and endorsed the recommendations.

■ **Fifth anniversary of WCD report:** In November, representatives of governments, NGOs, academia and private banks commemorated the launch of the WCD report five years earlier at an international conference organized by IRN in Berlin. The participants took stock of the implementation of the WCD's recommendations, and discussed the report's future perspectives.

Tributary, Xingu River, Brazil.
Photo: Pedro Martinelli

■ **Amazon dam authorized:** In July, Brazil's Congress authorized the construction of the 11,182 MW Belo Monte Dam on the Xingu River in the Amazon. The project is strongly opposed by social movements and NGOs. Environmental and social impact assessments still need to be carried out.

■ **Troubled waters in India's Northeast:** The Indian government plans to make the Northeastern states the center of its hydropower development. The plans have provoked strong opposition from rebel groups, social movements and NGOs. In Arunachal Pradesh, where the largest number of new dams is planned, the state government announced its opposition to all new reservoirs. Several large projects in the region, including Lower Subansiri, Middle Siang and Tipaimukh, have been delayed or suspended, and the planned Loktak Downstream Project was declared uneconomic by its developer. The dam authorities have not yet succeeded in arranging international finance for these projects.

■ **Stockholm Water Prize for CSE:** The 2005 Stockholm Water Prize was awarded to India's Centre for Science and Environment, an NGO that is forcefully promoting rainwater harvesting techniques and the empowerment of women in the water sector.

■ **Katrina disaster shows need for sustainable flood management:** In late August, Hurricane Katrina ravaged the coastal regions of Louisiana, Mississippi, and parts of Alabama. Katrina's impacts were greatly worsened by many decades of misguided efforts to control flooding. The Mississippi's hundreds of dams and thousands of miles of levees have almost eliminated the flow of sediment needed to replenish coastal wetlands, and have made these areas more vulnerable to storm surges. Louisiana alone has lost almost 5,000 square kilometers of coastal lands since the 1930s.

■ **New US dam relicensing rule favors industry:** In August, President George Bush signed into law new rules for dam relicensing which critics say give power companies more rights than states, Indian tribes and others with a stake in dam relicensing. The new rules allow utilities to challenge conditions written into dam licenses by federal agencies (such as requirements for better fish protections or more natural flows), and limit input from dam critics. The rules could make it harder to contest more than 200 dam projects in 36 states which are due to apply for new 50-year operating licenses by 2020. In late December, a coalition of environmental groups filed suit to block the rules.

■ **Dams decommissioned in the US:** In 2005, 56 dams were removed in the United States (down from 65 in 2004). On August 31, the US federal government announced a new "Open Rivers Initiative," under which local communities will receive funding and technical expertise to remove small dams.

■ **New water strategy for Pakistan:** On September 19, the World Bank presented a new country assistance strategy for Pakistan's water sector. The Bank announced that it would increase its lending for the sector to $1 billion in the 2006-2010 period, and would support infrastructure investments and reform programs. The Bank's senior water advisor encouraged Pakistan to ask for support for the hugely controversial Kalabagh Dam on the Indus River.

Hurricane Katrina devastated the US South. Photo: NOAA

■ **Norway's last untouched river protected:** After a campaign by environmental groups, the Norwegian government on October 13 protected the Vefsna River, which is the habitat for a large trout population, against future hydropower development.

■ **Dams vs. salmon in the US Northwest:** Salmon, key to both ecosystems and cultures in the Pacific Northwest, are being decimated by dams on the Snake and Columbia rivers. In October 2005, a US district judge ordered the federal government to prepare a new plan to protect the salmon. According to the court order, the government must also consider decommissioning four large dams on the Snake River.

■ **Chinese dam builders expand abroad:** In early December, Sinohydro Corporation and the government of Ghana signed a memorandum of understanding to build the 400 MW Bui Hydropower Project. Sinohydro's rapidly growing international portfolio already includes contracts for controversial hydropower dams such as Bakun (Malaysia), Chalillo (Belize), Lower Kafue Gorge (Zambia), Merowe (Sudan), Tekeze (Ethiopia), and Yeywa (Burma). Chinese dam builders and financiers have so far disregarded the environmental and human rights impacts of their projects.

■ **Construction begins on huge Vietnam dam:** Electricity of Vietnam began construction on Son La, the country's largest hydropower project. The 115 m high dam will displace more than 100,000 ethnic minority people. A major concern is a shortage of arable land for sustaining the livelihoods of the tens of thousands of people who will lose their homes, land and natural resources to the dam's reservoir.

■ **Thailand and Burma agree to develop Salween Dams:** The Thai electricity utility and Burmese government signed a memorandum of understanding in December to build the first of up to six hydropower dams on the Salween River. The projects will flood 68 villages in Karen state in Burma and 18 villages in Thailand, and dam the region's last major free-flowing river. Construction of large infrastructure projects in Burma has led to serious human rights violations, including the use of forced labor.

■ **Uganda moves forward with Nile dam:** The Aga Khan's Industrial Promotion Services and the government of Uganda signed a power purchase agreement (PPA) for the 200 MW Bujagali hydropower project in December. The controversial project had collapsed in 2003 due to bribery and other problems. In 2002, Uganda's High Court decided that the Bujagali PPA must be made available to the public. The new contract has so far not been released. The project is moving forward at a time when Lake Victoria's water level has been dropping rapidly, which puts the viability of dams on the upper Nile in doubt. Some experts lay part of the blame for the falling lake level on excessive water releases through two existing dams, just upstream from the Bujagali Falls.

■ **Protestors killed in India:** Three civilians were killed and more than 30 injured on December 14 when security forces opened fire on demonstrators protesting the construction of Khuga Dam in India's Manipur state. Dam-affected people and NGO activists were also subjected to severe repression in other incidents in India's Narmada valley, in Brazil, China, Ecuador, Honduras, Mexico, Sudan and other countries in 2005.

"Overview" and "Hotspots" by Peter Bosshard

2006 RIVER HOTSPOTS

North America

1. Rupert River diversion to begin: Hydro-Québec intends to start work on a four-dam project that would divert at least half of the flow of the Rupert River north to its hydro plants on the Eastmain River. Many local people from the Cree Nations are strongly opposed to the project and favor building wind power on their territory instead of more dams.

2. California water wars loom: Crumbling levees, a massive spending program proposed by the governor, and a federal trend toward weakening environmental protections is expected to lead to heated battles over California's rivers and water supply system. Hurricane Katrina and levee breaks and flooding in California in early 2006 are giving impetus to major new engineering works.

3. Dam removal proposed for Yosemite National Park: Restore Hetch Hetchy is pressing for a feasibility study on decommissioning the Hetch Hetchy Dam in Yosemite National Park. Because the dam's downstream water-supply system needs major repairs soon, this battle will continue to heat up this year.

Latin America

4. La Parota Dam: Mexico's Federal Electricity Commission plans to begin construction on the 900 MW La Parota Dam. The reservoir will affect 25,000 people. Resistance is strong, and has so far been met by violent repression.

5. Amazon dams: The Brazilian government plans to proceed with the Belo Monte, Santo Antonio and Jirau Dams on the Xingu and Madeira rivers in the Amazon region. The dams will have a combined capacity of 17,600 MW. NGOs plan to challenge the constitutionality of Belo Monte due to its impacts on indigenous people.

6. Patagonia for sale: Spanish company Endesa plans to build four dams with a total capacity of 2,400 MW in Chilean Patagonia. Connecting the dams to the national power grid will require a 2,000 km-long transmission line. Environmen-tal groups argue that Patagonia's preservation in a natural state offers more permanent economic benefits.

Africa

7. African Hydropower Conference: In early March, Africa's water and energy ministers gathered to discuss and promote hydropower projects for the continent. The conference was co-organized by the International Hydropower Association.

8. Bujagali Dam: After signing a contract with the Aga Khan's Industrial Promotion Services for this hydropower dam in December, the Ugandan government is expected to submit the project to the World Bank for financing this year. Ongoing drought is seriously reducing output from two dams upstream of Bujagali – further calling into question the wisdom of increasing Uganda's almost total dependence on hydropower. Ugandan NGOs are pressing for geothermal projects instead of more dams.

9. Lom Pangar Dam: A private investor, AES Sonel, plans to develop the Lom Pangar Dam in Cameroon, which would primarily serve an aluminum smelter. The reservoir would flood part of the protected Deng Deng Forest.

10. Merowe Dam: The Merowe Dam in Sudan, the largest hydropower project currently under construction in Africa, will displace tens of thousands of people from the Nile Valley to barren sites in the Nubian desert this year.

Europe

11. New floods directive: The European Commission has proposed a directive on the management of floods for Europe's shared rivers that is based on prevention, protection and preparedness. The directive calls for restoring natural flood control systems such as wetlands and floodplains, and avoiding new development of floodplains – a positive shift from past reliance on river-engineering schemes.

12. Elbe River to be engineered: The new German government has decided to deepen and channelize the Elbe to make it more navigable between Hamburg and the German-Czech border. The decision has been strongly opposed by NGOs. The Mittlere Elbe is designated as a UNESCO biosphere and two World heritage sites are located along its banks.

Asia

13. Ilisu Dam: The Turkish government and a private consortium are negotiating over the development of the Ilisu Dam Project in Southeast Anatolia. If the project goes ahead, export credit agencies will be approached for funding. An earlier project effort collapsed in 2001.

14. Northeast India: With projects such as the Tipaimukh and Lower Subansiri dams still in the pipeline, India's Northeast will remain a hotspot. The dams are strongly opposed by the affected indigenous communities and NGOs. Some of the projects are also opposed by state governments and the Bangladesh government.

15. Nu/Salween River Dams: In January 2006, China's environmental review panel recommended that four of 13 planned dams on the Nu River (known downstream as the Salween) be built. The projects will dam one of only two free-flowing major rivers in China, and have triggered vocal protests. The government still needs to give final approval for the projects.

16. Polavaram Dam: The state government of Andhra Pradesh in India plans to proceed with the construction of the Polavaram Dam, a hydropower and irrigation project. The dam would displace about 200,000 mainly indigenous people.

17. Pugubou Dam: The Chinese government recently started construction on the $2.5 billion Pugubou hydropower project on a tributary of the Yangtze River. The dam will displace about 100,000 people. The project was suspended in 2004 after triggering protests that drew up to 100,000 participants.

Fast Facts on Water and Poverty

The Grim Statistics of Water

Annual child deaths due to dirty water and poor sanitation and hygiene: 2.2 million

Number of people without easy access to safe water: 1.1 billion (85% rural)

Number of people without easy access to decent sanitation: 2.4 billion (78% rural)

Number of undernourished people: 842 million (75% rural)

Number of people living on less than two dollars a day: 2.7 billion (75% rural)

Number of people displaced by dams: 40-80 million

Percent of world's food grown on rain-fed lands: 60-70%

The Good News: Comparative Costs of Solutions

Annual cost of bringing 100 million small farming families out of extreme poverty by 2015 with low-cost water technologies: $2 billion

As percentage of annual investment in large dams in developing countries the 1990s: <10%

Average cost of drinking water, per person, from community-built rainwater harvesting schemes in Alwar, India: $2

Estimated cost for drinking water, per person, from the notorious Sardar Sarovar dam project: $200

Cost of conventional irrigation in Africa: $5,000-$25,000 per hectare (ha)

Cost of irrigation through Sardar Sarovar dam and canals (India): $3,800/ha

Cost of treadle pumps and wells: $117/ha (India/Bangladesh); $233/ha (Africa)

Cost of Nepal drip irrigation kits: $250/ha

Energy and the Poor

Number of people without electricity in their homes: 1.6 billion (80% rural)

Number of people relying on traditional biomass fuels for cooking and heating: 2.4 billion

Number of people killed annually from health problems associated with open-fire cooking: 2 million

Percent of total energy consumption used for domestic cooking in sub-Saharan Africa: 60%

Cost of an improved cookstove in China (not subsidized): $10-12

Estimated number of such stoves distributed in China by 2000: 180 million

Number of rural families worldwide using clean biogas digesters to convert manure into cooking/heating gas: 16 million

Percent of South Africa's urban energy use that could be offset by solar water heating: 18%

Sources:

World Resources 2005: The Wealth of the Poor – Managing Ecosystems to Fight Poverty; World Population Data Sheet 2005; WHO/UNICEF Joint Monitoring Programme; FAO "Counting the hungry: latest estimates"; www.who.int/water_sanitation_health/diseases/schisto/en/; FAO & CIFOR (2005) Forests and floods;World Commission on Dams (2000) Dams and Development; REN21 Renewable Energy Policy Network (2005) "Energy for Development"; Health, dignity, and development: what will it take?, UN Millennium Project Task Force on Water and Sanitation, 2005.

Frausto, K. (2000) "Developing Irrigation Options for Small Farmers," contributing paper to WCD Thematic Review of Irrigation Options.

McCully, P. (2002) "Water-Harvesting in India Transforms Lives," World Rivers Review, December.

InterAcademy Council (2004) Realizing the Promise and Potential of African Agriculture.

Acknowledgments

This publication has been supported by Oxfam America, Oxfam Australia and Oxfam Great Britain, and the Ford Foundation. The views in the report are those of IRN and do not necessarily represent those of our funders.

Thanks to *Scientific American* for allowing us to reprint Paul Polak's article from their magazine.

On Patrick McCully's essay: For their editing and fundraising help and comments on the text, many thanks to Peter Bosshard and Aviva Imhof. For research help, thanks to Jamie Greenblatt and Tracy Andres. For informational help, thanks to Norman Uphoff of Cornell International Institute for Food, Agriculture and Development. For inspiration, thanks to Shripad Dharmadhikary, Himanshu Thakker, Paul Polak, Rajendra Singh and the water harvesters of Alwar. For all of the above thanks to Lori Pottinger. Thanks also to Warwick Browne, Kate Geary, Matt Grainger, John Magrath, and Michael Simon of Oxfam. For writing help and encouragement, thanks to Sarah Bardeen.

About International Rivers Network

IRN's mission is to protect rivers and defend the rights of communities that depend on them. IRN opposes destructive dams and the development model they advance, and encourages better ways of meeting people's needs for water and energy and protection from destructive floods.

International Rivers Network
1847 Berkeley Way
Berkeley, California 94703 USA
Tel: +510.848.1155

This report can be downloaded at www.irn.org

IRN

International Rivers Network

Linking Human Rights and Environmental Protection

IRN

International Rivers Network

Linking Human Rights and Environmental Protection