THE ATLANTIC COUNCIL

OF THE UNITED STATES

A 21st Century Marshall Plan for Energy, Water and Agriculture In Developing Countries

Richard L. Lawson • Chairman
John R. Lyman • Project Director & Rapporteur
Erica R. McCarthy • Project Assistant Director

Policy Paper
September 2008

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OF THE UNITED STATES

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"…I need not tell you, gentlemen, that the world situation is very serious. That must be apparent to all intelligent people. I think one difficulty is that the problem is one of such enormous complexity that the very mass of facts presented to the public by press and radio make it exceedingly difficult for the man in the street to reach a clear appraisement of the situation. Furthermore, the people of this country are distant from the troubled areas of the Earth and it is hard for them to comprehend the plight and consequent reactions of the long-suffering peoples, and the effect of those reactions on their governments in connection with our efforts to promote peace in the world."

"An essential part of any successful action on the part of the United States is an understanding on the part of the people of America of the character of the problem and the remedies to be applied. Political passion and prejudice should have no part. With foresight, and a willingness on the part of our people to face up to the vast responsibility which history has clearly placed upon our country, the difficulties I have outlined can and will be overcome."

George Marshall
Commencement Speech
Harvard University
June 5, 1947

Foreword

The persistence of poverty and extreme deprivation in developing countries prevents the spread of freedom and democracy as certainly as any other factors. Starting points to alleviate that poverty are developing countries' ability to obtain the clean energy and water supplies that are necessary to promote economic growth and public health. Equally, we cannot alleviate hunger unless we tackle a series of agricultural challenges arising from diminishing arable land, the rapid depletion of water resources, and the need for a more nutritious diet. Meeting these challenges is increasingly central to U.S. foreign policy.

Against this background, the Atlantic Council of the United States launched a series of meetings of business, government and foreign policy experts to discuss an ambitious and, some might say, audacious new initiative – loosely modeled on the Marshall Plan – for the development of energy, water and food resources appropriate for application in developing countries.

The Atlantic Council believes that the time is right for America again to assert itself on the world stage with the sort of bold vision that drove the original Marshall Plan. The United States has the opportunity to again transform the world, through inspired action intended to interrupt the types of social decay and economic stagnation that set the stage for World War II and the September 11th attacks and is today adversely impacting much of the developing world.

The present report, third in a series, summarizes the conclusions of the experts convened by prior working groups and incorporates a more robust description of the processes to be undertaken based on the experience of Sandia National Laboratories in addressing many of the issues discussed in the policy paper over the past several years. In addition, an illustrative listing of energy, water and agricultural technologies that could be considered in the individual countries has been included. The first report, published in March 2005, focused on the interdependence of energy and water. The second report, published in April 2007, examines the interrelationships among the energy, water and agricultural sectors and proposes a new approach to the development of these three interdependent basic resources. That report underlines the view that without the availability, accessibility and affordability of clean energy, water and food provided by market-based approaches, the political stability in many developing countries that is a prerequisite for economic growth and sustainable democratic governance will not likely be achieved. Both reports can be found on the Council's Energy and Environment Program page at *www.acus.org/tags/energy-environment*.

This paper attempts to create a new paradigm for U.S. foreign policy, taking advantage of the vast (as yet untapped) resources of the U.S. technical capabilities in our research institutions to better understand the cause and effect of energy-water-agriculture interdependencies on national and regional instabilities, as well as the potential for transformational technological impacts on future development and stability. We envision a future where developing countries are more likely to economically succeed and socially develop in a manner that will be less likely to fall into corruption, decay, totalitarianism, and terrorism. The original Marshall Plan succeeded in a divided and destroyed Europe. We believe that similar concentrated efforts would succeed in creating comparable results in the developing world.

The Atlantic Council has identified criteria in this final report to support this bold new plan that are based on the World Bank's Governance Indicators data for 2008 as well as per capita income levels and country size. The implementation of the 21st Century Marshall Plan for Developing Countries requires verification and validation of a new process for implementing foreign policy and measuring its results in areas of the world that are of strategic importance. To this end, we have established a set of criteria to identify countries in Asia, Africa and Latin America, which are members of the WTO, and which will be considered for participation in an initial pilot program. The paper proposes an action plan for the project and recommends the establishment of a sponsors' advisory committee. This committee would provide oversight that would allow verification and validation of our new approach and would be available on request to provide participating countries with assistance on examining policy and regulatory options. The outcome of this initial phase will be reports, recommendations and plans emanating from the participating countries and will facilitate the commitment and support of financial institutions, governments and private corporations.

The Council would like to thank all those who have participated in the project to date: our energy program chairman and board member Richard L. Lawson for his vision and invaluable guidance; program director John Lyman for his skill in distilling the major points of the discussions; and all the meeting participants and experts (listed in *Annex 1*) for their gift of time and knowledge. Special thanks also go to the experts at Sandia National Laboratories who have developed the processes to be applied in implementing the plans in individual countries. The Council also thanks the generous donors who supported this work: the Otter Island Foundation, the National Energy Technology Laboratory, and the Office of Coal and Power Systems at the U.S. Department of Energy.

Frederick Kempe
President and CEO

A 21st Century Marshall Plan for Energy, Water and Agriculture In Developing Countries

Executive Summary

Today, water and energy scarcities, hunger, and overall poverty remain prevalent throughout much of the developing world. These conditions lead to low economic opportunity, disease, despair, unrest, tension, and conflict. If we are to live in a 21st century more prone to peace than violence, developed countries must move expeditiously to help developing countries increase their infrastructure and capacities for energy, water and agricultural production. The availability, accessibility and affordability of high-quality energy, water and food supplies are vital to the economic development that is required to alleviate global poverty, to reduce global tensions, to address global environmental degradation, and to provide the economic base for improving public health and social wellbeing. For the developed world, this provides not only altruistic but real economic return. Such a project creates new markets for goods and services, essentially raising the standard of living for the entire world through improved economic partnerships and reduced need for costly, and imperfect, interventions.

The challenge ahead is to ensure adequate supplies of energy, water and food to the billions of people currently deprived of these necessities. The needs of the developing countries cannot necessarily be met by following the historical patterns that were pursued by the industrialized countries. Growing concerns over resource availability and the potential adverse environmental consequences of following historical industrialization patterns lead many to conclude that the world is on an unsustainable growth path. In order to address such issues, the International Energy Agency recently concluded that "unprecedented cooperation will be needed between the developed and developing regions, and between industry and government." The magnitude of the challenge is immense and requires urgent action.

Without a radical change in policies in the developing and developed countries, there will still be about the same number of people without access to electricity (1.5 billion) and the same number of people continuing to rely on non-commercial biomass fuels (2.5 billion) in 2030 as today. This will occur even if the developing countries continue to consume nearly three quarters of the growth in global energy supplies, which will increase their share of global energy consumption from 41 percent today to more than half by 2030.

Today, one sixth of the world's population lack access to safe drinking water and 2.5 billion do not have access to improved sanitation. By 2030 those numbers will grow significantly. By then, over 60 percent of the world's population will continue to live in countries with significant imbalances between water requirements and supplies, largely in Asia, Africa and Latin America.

The United Nations (UN) estimates that only one-third of the world's population of 6.6 billion enjoys a nutritional food supply, while one billion are severely undernourished and one billion is over consuming. This means that almost a third of the world is facing health problems related to either an inadequate or unhealthy diet. Dietary-related health problems are most likely to be exacerbated by the world's growing population.

Energy, water and agricultural issues are inexorably bound together. Energy production requires water, and the treatment and pumping of water require energy. Agriculture consumes over seventy percent of available water supplies in many countries and there is a growing tension between the production of agricultural crops for energy and food. Energy, water and agriculture problems leading to insufficient supplies stem from many of the same issues:

- Insufficient financial resources
- Inefficient usage or production
- Inadequate institutional arrangements
- Lack of coordination between sectors
- Lack of political commitments
- Inadequate human resources
- Insufficient community involvement
- Inadequate operations and maintenance
- Insufficient information and communication

While the UN, the World Bank and numerous other development institutions and individual countries are addressing a number of energy, water and agriculture issues relating to sustainable development, it would be timely for the United States to undertake a private/governmental initiative to develop a 21st Century Marshall Plan for Energy, Water and Agriculture in Developing Countries. Recognizing the many agencies and organizations that are already working on these issues, the Plan would entail a new approach that would analyze the interfaces between the three sectors and utilize an inclusive collaborative dialogue in preparing the specific recommendations and investment programs. The plan would be initially focused on a few individual countries receptive to the concept and would work in conjunction, rather than in competition, with other organizations.

The original Marshall Plan enabled the countries devastated by World War II to rebuild and achieve economic growth rates far exceeding those experienced during the 1930s. Given substantial financial support, European nations were able to reprogram their economies and rapidly rebuild their industries and infrastructure. However, it was the European nations themselves that developed the programs and policies that enabled this revival. Europe was fortunate to be able to utilize existing institutions and internal professional expertise to devise the plans and programs that allowed external financial resources to be used wisely.

Today, the challenges facing many developing countries are greater, and in some ways more complex, than those facing Europe at the end of World War II. Many developing countries do not have sufficient institutions and professional expertise to develop appropriate policies and programs. Moreover, the global demand for economic prosperity has given rise to increased competition for resources. Energy-consuming countries are becoming increasingly concerned over attaining energy security, and global climate change is complicating the problems arising from growing consumption of water and energy.

Furthermore, demands upon agriculture may be challenged by changing weather patterns in ways that have been difficult to predict and adapt to. Fortunately, today's global financial markets and international businesses are in a position to finance investments that can help solve these problems, if they have the ability to make informed decisions about how to invest based on sound economics.

The proposed 21st Century Marshall Plan for Developing Countries would concentrate on enabling the participating countries to develop the policies, programs and institutional arrangements that will attract capital to support sustainable development. The Plan, relying on many of the principles embedded in the original Marshall Plan, would be developed as follows:

1 Public and private institutions should utilize a proven means of bettering the world through economic cooperation and development, and implementation of technology.
2. Experts in participating countries would work with an external team of experts to create their own unique development objectives and implementation plans, integrated across energy, water and agriculture.
3. Technical assistance for the transfer of techniques, procedures and know-how to help participating countries to define and meet their needs would be provided by Sandia National Laboratories.
4. A national-level, stakeholder-driven process in each participating country would build planning capacity and create a computerized planning model that will help integrate data and information, identify and evaluate development objectives and implementation plans, build consensus, and communicate the plans to other stakeholders, policy makers, and donor agencies around the world.
5. Development of infrastructure and human capacity in participating countries will allow long-term implementation and overall development to occur with less and less input from the international community.
6. Participating countries would be able to draw on a senior executive corps that would be made available to provide managerial and technical expertise. This expertise would be key in the implementation of approved projects and programs approved by the participating countries.
7. The developed world would provide capital, technology and know-how to the developing nations. Additionally, developing country organizations would be requested to provide know-how in areas for which they have expertise, such as the Grameen Bank.
8. Assistance should be provided on a country-by-country basis with specific time frames for assistance in each county, and metrics for success would be established country-by-country and region-by-region based on a *priori* defined goals.
9. Participating countries would be responsible for creating their own programs and development plans and for the implementation of necessary investments and institutional changes.

The Plan would initially be focused on a few (2-3) countries and over time be expanded to other countries based on success with initial participants. The planning phase would be followed by an implementation phase managed by individual countries with support from the original planning teams as needed. In each country, the initial planning and consensus-building phase, to be organized and coordinated by Sandia National Laboratories, would last about three years. This would be followed by an implementation phase managed by the individual countries. This phase will generate ongoing investments and development that would last many decades. While external assistance-type financing would be required during early phases, the policies and programs to be implemented have the potential to impact relations between developing countries and international lending institutions for many decades. This suggests that the U.S. government would need to be supportive of and engaged in the proposed 21st Century Marshall Plan for Developing Countries, even if it is ultimately funded from private sources, or from a combination of public and private institutions.

An advisory committee should be established to provide continuing oversight to the process and development of recommendations and plans originating from the participating countries. The Atlantic Council would assume a major role in coordinating the work of the advisory committee. Oversight by such a committee is critical for obtaining the commitment and support of major international financial institutions, supporting governments, private corporations, and foundations.

This initial proposal for creating a 21st Century Marshall Plan for Energy, Water and Agriculture has been developed by a working group organized by the Atlantic Council. The next step in this process is to refine the concept with input from U.S. government agencies, interest groups and private institutions. At a later date, it might be appropriate to expand input and participation to include key experts from the European Union, Japan, developing countries, development banks and NGOs. Input from the above groups would also be used to determine an appropriate organizational structure for managing the Plan activities.

The Plan would create a network of public and private institutions capable of raising the investment capital required to assist in the development of clean, affordable, viable and sustainable energy, water and agriculture programs in selected developing countries. Over time the Plan could bring large improvements to energy, water and agriculture infrastructure and capacities in developing nations, raise standards of living and quality of life for hundreds of millions of people, create hope and prosperity, and pave the way for a more peaceful 21st century. A developing world that becomes more prosperous and peaceful will in turn lead to an expansion of global economic growth and reduce the need for costly and often ineffective hard diplomacy.

A 21st Century Marshall Plan for Energy, Water and Agriculture In Developing Countries

The Challenge

Today, water and energy scarcities, hunger, and poverty remain prevalent throughout much of the developing world. If we are to live in a 21st century more prone to peace than violence, the developed countries must move expeditiously to address the developing countries' requirements for energy, water, and agricultural production. The availability, accessibility and affordability of energy, water and food supplies are vital to the economic development that is required to alleviate global poverty, to reduce global tensions, to address global environmental degradation, and to open new markets for global goods and services.

In today's world of modern communications, the discrepancies in living standards are readily apparent to even the most impoverished. These conditions can only lead to growing resentment and increasing friction between the 'haves' and 'have-nots'. Major initiatives are called for, and the industrial world does not have the luxury of postponing such initiatives. Without such actions, economic conditions in many developing countries will worsen and political instability will grow, decreasing the prospects for global economic growth.

The challenge ahead is to ensure adequate supplies of energy, water and food to the billions of people currently deprived of these necessities. The needs of the developing countries cannot be met by following the historical pattern of development in the industrialized countries. New options for economic development that address the interrelationship between food production, energy supplies and water requirements need to be considered, using new technologies that will require fewer resources.

Growing concerns over resource availability and the potential adverse environmental consequences of following historical industrialization patterns lead to the conclusion that the world is on an unsustainable growth path. In order to address such issues, the International Energy Agency (IEA) concluded in 2002 that "unprecedented co-operation will be needed between the developed and developing nations, and between industry and government."[1] Six years ago the magnitude of the challenge was seen as immense and requiring urgent action. Today, the consequences of inaction are even more severe as the IEA reports that "unsustainable pressure on natural resources and on the environment is inevitable if energy demand is not de-coupled from economic growth and fossil fuel

[1] International Energy Agency. Energy Technology Perspectives, 2008, page 31..

demand reduced."[2] Many countries are now also facing difficult choices between the use of water for human and industrial consumption and for food production, and there is growing debate over the use of agricultural production for energy.

Without a radical change in policies in the developing and the industrialized countries, there will be about the same number of people without access to electricity (1.5 billion) and the same number of people relying on non-commercial biomass fuels (2.5 billion) in 2030 as today.[3] It will be so despite a relatively rapid growth in energy consumption in the developing world. Forecasters generally agree that developing countries will consume almost 70 percent of the growth in energy supplies by 2030[4] and that their share of global energy supply will rise from 41 percent to more than half by 2030.[5] Despite this redistribution in energy consumption, per capita energy use in the developing world will still be only one-sixth that in the industrial countries.

Economic development will not take place without adequate supplies of energy, and water is also essential for sustaining life and health. Societies cannot exist and flourish without both energy and water. Today, nearly one billion people lack access to safe drinking water and 2.5 billion (nearly 40 percent of the world's population) lack access to improved sanitation.[6] Moreover, quality, sustainable water is scarcest where it is needed most, namely in the developing countries. By 2030, over 60 percent of the world's population will live in countries with significant imbalances between water requirements and water supplies, largely in Asia, Africa and Latin America. In 2000, it was estimated that to meet the needs of water supply and sanitation by 2015 for the half of the world's population then deficient, the following would be required:

a) Access to some form of improved water supply for an additional 1.5 billion people (100 million each year), and
b) Access to improved sanitation services for about 1.9 billion people (125 million each year).

Agriculture represents the third leg of the challenge to facilitate economic growth and raise per capita incomes, especially for the very poor, while contributing to significant improvements in health and welfare. Agricultural practices can affect water and energy requirements significantly and must be explicitly taken into account when examining the sustainability of water and energy resources.

In many developing countries agriculture consumes over 70 percent of available water resources. Inefficient irrigation practices are rapidly lowering water tables, and for many countries water withdrawal rates exceed replenishment rates. Often, very low tariffs on water and energy supplies encourage inefficient agricultural usage.

Agricultural practices affecting crops, livestock and fisheries can have a significant impact on the nutritional value of production as well as on water requirements. The UN recently estimated that nearly one billion people are severely undernourished.[7] At the same time, rising affluence has encouraged

[2] International Energy Agency. Energy Technology Perspectives, 2008, page 37.
[3] *Ibid.*
[4] International Energy Agency. *World Energy Outlook 2006*, page 1.
[5] International Energy Agency. *World Energy Outlook, 2008*, page 42.
[6] UNICEF-WHO. *Joint Monitoring Programme—Millennium Development Goals Assessment Report, 2008*, Progress on Drinking Water and Sanitation, p. 23.
[7] FAO. *Food Security Statistics*. www.fao.org/faostat/foodsecurity/index_en.htm

another billion people to over consume.[8] Both situations have led to growing health problems for a third of the global population. Hence, attention needs to be given to providing a greater, as well as more nutritious, mix of food supplies.

In some countries, such as the United States, the use of corn and soybeans for energy production is leading to a rise in food prices as well as impacting the availability of world food supplies for both human and animal consumption. Thus, energy, water and agriculture are inexorably bound together. Energy production is a major user of water as well as essential to the production, treatment and distribution of water. Agriculture is both a major user of water and a potential source of energy. Many countries are now also facing difficult choices between the use of water for human and industrial consumption and for food production, and there is growing debate over the use of agricultural production for energy resources. Whereas energy security (access to sufficient and sustainable energy supplies) has reached the top of the national agenda for the United States and Europe, it is also a major problem for developing nations that are struggling with a growing scarcity of water and food, particularly in those regions most affected by global climate change.

The working group concluded that a country's failure to adequately address energy, water and agricultural problems stem from many of the same issues: insufficient financial resources, inefficient usage, inadequate institutional arrangements, lack of sector coordination, lack of political commitments, inadequate human resources, insufficient community involvement, and inadequate operations and maintenance, as well as insufficient information and communication.

Meeting energy, water and agriculture requirements for all developing countries will take vast investments that go well beyond the developing countries' ability to finance by themselves. These requirements will be particularly large for the energy sector. Societal development will not occur unless these investments are undertaken. Societal development is a prerequisite for the developing countries to attain a level of economic prosperity that will enable them to seriously consider climate and other environmental concerns, and to enable society to focus on education and public health issues. Furthermore, it is becoming increasingly clear that meeting growing global concerns over environmental pollution and climate change impacts will require "unprecedented cooperation between the developed and developing nations, and between industry and government."

[8] WHO. *Obesity and Overweight*. www.who.int/dietphysicalactivity/publications/facts/obesity/en/

The Response

While the United Nations, the World Bank and numerous other development institutions and individual countries are addressing a number of energy, water and agricultural issues relating to sustainable development, it would be timely for the United States to undertake a private/governmental initiative to develop a 21st Century Marshall Plan for Energy, Water and Agriculture in Developing Countries. Recognizing the many agencies and organizations already working on these issues, the Plan would entail a sharply focused, systematic and sustainable approach, concentrating on individual countries receptive to the concept, and on working in conjunction, rather than in competition, with other organizations.

Like the proposal by Secretary of State George Marshall in his 1947 speech at Harvard, this plan should be against "hunger, poverty, desperation and chaos." As in the original Marshall Plan, the proposed recipients of assistance should be responsible in the first instance for deciding on their approach to addressing their own concerns—in this case, the development and utilization in each country of energy, water and agricultural resources critical for economic development.[9] The proposed 21st Century Marshall Plan for Developing Countries would concentrate on enabling the participating countries to develop the policies, programs and institutional arrangements that will attract capital to support sustainable development. The Plan, relying on many of the principles embedded in the original Marshall Plan, would be developed as follows:

1. Public and private institutions should utilize a proven means of bettering the world through economic cooperation and development, and implementation of technology.
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7. The developed world would provide capital, technology and know-how to the developing nations. Additionally, developing country organizations would be requested to provide know-how in areas for which they have expertise, such as the Grameen Bank.
8. Assistance should be provided on a country-by-country basis with specific time frames for assistance in each county, and metrics for success would be established country-by-country and region-by-region based on *a priori* defined goals.

[9] *www.MarshallFoundation.org*

9. Participating countries would be responsible for creating their own programs and development plans and for the implementation of necessary investments and institutional changes.

The Plan's overall goals would be to:

1. Strengthen governmental and private sector efforts to help meet key developing countries' needs for energy, water and agriculture. Significant private sector involvement should help expand the level of effort in the individual countries by energizing new players and encouraging a sustained effort by business. Such efforts would facilitate economic development and contribute to improving health and welfare in developing countries.
2. Organize a voluntary professional "senior executive corps," under the leadership of the Atlantic Council and Sandia National Laboratories, to help participating countries define and meet those needs.
3. Compile an extensive list of institutions that could provide capital and technology to support energy, water and agricultural infrastructure development.
4. Institute a restructuring of policies in developing and developed countries to significantly improve the availability, accessibility and affordability of energy, water and agriculture that is vital to improving economic conditions and general welfare throughout the world.
5. Assist the world's efforts to develop sustainable economic growth.
6. Directly address the developing world's economic aspirations so that political stability can be enhanced.
7. Develop quantifiable tools and metrics that would allow investors to assess the prospects for a return on their investments. This would also allow the real-time management and modification of longer-term implementation plans.

The Plan would take advantage of developed countries' technological capabilities and over time would create a network of institutions capable of raising the trillions of dollars in investment capital required to meet the rising demand for energy, water and agriculture.[10] In addition, a framework would be created for the provision of modern energy, water and agricultural services to a substantial portion of the billions of people who now lack them. By raising standards of living in developing countries, world economic prosperity will be enhanced, leading to greater economic growth for developing as well as developed countries.

[10] Energy investments figures are from *World Energy Investment Outlook 2006*, International Energy Agency. The World Commission on Water estimates that water investments over the next 20 years need to rise from $75 billion a year to $180 billion a year. The World Bank Development Committee, "Water–A priority for responsible growth and poverty reduction. An agenda for investment and policy change," March 17, 2003, presentation at the World Water Forum.

Proposed Actions

The proposed action plan for implementing a 21st Century Marshall Plan for Developing Countries is based on four years of discussions involving U.S. working group members. The first meeting of the working group was held in Washington, D.C. on September 8th, 2004 and was followed by a Preliminary Report in March 2005. Subsequently, a status report was released in August 2005 to publish the findings of the second meeting, held in July. Numerous recommendations led to another status report in February 2006, in preparation for the third meeting of the working group in Washington, D.C. on April 18, 2006 which included expanded representation by experts on water and agricultural issues. The second policy paper was a distillation of the views of the participants (identified in *Annex 1*).

The working group strongly supported the need to implement a 21st Century Marshall Plan for Energy, Water and Agriculture in Developing Countries. The goal of improving the world's political stability and attaining sustainable economic growth will not be achieved by accident. Meeting the challenges will require leadership by governments, institutions, businesses and individuals. The success of this effort is expected to result in the kind of stability and economic gains seen from the original Marshall Plan.

This third policy paper expands upon the concepts and processes proposed in the April 2007 policy paper:

(1) by providing an updated list of potential participating countries (*Annex 2*) and including updated charts in Annex 3 which provide basic country data on energy, water, agriculture and political and economic criteria, to assist sponsors in the selection of countries. Additional work will be needed before the final selection of countries, which will be affected by the availability and accessibility of data, as well as availability of professional expertise,

(2) by creating a more rigorous process in Annex 4 that includes manpower requirements and costs that reflect the processes and training deemed necessary based on the experience of Sandia National Laboratories, and adding several recent and relevant case studies (*Annex 5*),

(3) and by providing an initial listing and description of some specific technologies that could be particularly appropriate for developing countries (see *Annex 6*). This list is not intended to be all-inclusive and will change as new technologies are developed.

Because of the complexity of dealing with the challenges in each country, it is now proposed that the Plan start by focusing on only 2-3 countries from Africa, Asia and/or Latin America. These regions will provide meaningful opportunities to test the proposed process. A list of 24 potential participating countries was created, based on meetings with the World Bank and the Millennium Challenge Corporation. The World Bank's Governance Indicators data for 2008 were used with the caveat that the measurement on "political stability" was dropped for being potentially misleading, as it includes a measurement of third-party terrorist incidents.

The five governance indices used are:

Control of Corruption
Rule of Law
Regulatory Quality
Government Effectiveness
Voice and Accountability.

The list of potential participating countries was created by starting with the 109 countries in Africa, Asia and Latin America that are members of the WTO. In order to focus initially on countries with the greatest need for assistance and with a substantial population, only the 55 countries with populations greater than 5 million and GDP-PPP (purchasing power parity) per capita below $10,000 were considered. Median scores for each rating category were calculated for the 55 countries as a group, and only the 26 countries at the median or better on corruption were considered. It turned out that 24 of these countries also scored at or above the median on four or five of the five indicators. The resulting list of potential initial candidates is shown in *Annex 2*.

It is proposed that the Plan activities start in the first year by focusing on one or two countries, and then continue to add other countries as experience and support are gained. This staggered approach would allow for learning that could be applied to improve the process, increase the knowledge-base and build a core of experienced team leaders. If some of the larger countries were to be chosen, a region within the country would be selected, owing to the complexity of the analysis required and the level of interaction that will be needed with regional decision-makers. Following experience gained with the initial participants, activities would be undertaken in additional countries.

Each country's mix of resources of energy, water and agriculture is unique and interactions among the sectors will vary widely (see *Annex 3*). In order to handle this complexity, up to three years may be required to develop the initial plans for each country. Sandia National Laboratories has designed an integrated process for completing the 3-year initial project period. The process includes data-gathering, analysis and modeling of resources, requirements and interactions among the three sectors. The process includes extensive interaction with regional experts and collaboration with key government agencies, business, academia, environmental and human rights organizations, development banks, policy makers and citizens. A major element of the process is its inclusive collaborative approach which is designed to ensure a fuller consideration of each country's individual conditions and to build a commitment within each country to the plans developed. The outcome of this process will define key strategic actions involving technologies, policies and processes that can increase the effectiveness of government and private development assistance from the developed countries. In addition, the process will build a creditable base for financial institutions and international businesses to invest.

Following the initial project period, the implementation process will be initiated. Because of the iterative and interrelated nature of the implementation process, over time, implementation options will be compared to success metrics to allow the countries and investors to gauge progress, and thereby allow course corrections in future iterations.

A fuller description of the recommended initial processes, including preliminary manpower and cost requirements, is provided in *Annex 4*. *Annex 5* provides a description of recent activities that have utilized the approach outlined in this process. After completion of the initial planning process, each country would need to create its own implementation program that would involve in-country government agencies and investors, as well as international financing institutions. Individuals involved in the initial three-year planning phase would expect to remain involved in developing and monitoring the follow-on implementation. The external participants in the process would be available to help design metrics for determining the longer-term success of the approach.

With the release of this report the following action steps are proposed:

1) The policy paper will be reviewed with appropriate U.S. government officials in the Departments of State, Energy, Agriculture, and others, as well as international financial organizations, by a team from the Atlantic Council and Sandia National Laboratories, to obtain conceptual support for the proposal.
2) Government input should be obtained to determine an organizational structure and reporting relationships, and consideration should be given to establishing a public/private partnership.
3) Non-governmental organizations, including industry groups, private organizations and development organizations, should be given the opportunity to comment and provide financial support if appropriate.
4) Two or three countries should be approached to determine their interest in participating in the Plan, after developing additional information on the availability of resource-base data and professional expertise in the proposed countries. This step would most likely occur in the fall of 2009.
5) If there is interest among potential sponsors and participants, a 21st Century Marshall Plan Fund for Energy, Water and Agriculture would be established to finance activities during the initial program, which would cover four to five years, depending upon the number of participating countries. (Note: It is proposed to add one country a year during the initial phase.)
6) Financing for the initial program could come from a private foundation, a public/private partnership, the U.S. government, or some combination thereof.
7) A non-governmental sponsors' advisory committee consisting of subject experts should be established. The advisory committee would be responsible for remaining current on technological developments, periodically reporting back to sponsors and funders on progress, making recommendations on possible adjustments to the process, and providing a source of support for the participating countries in approaching international financial and industry organizations. In addition, the advisory committee would be available on request to provide participating countries assistance in the review of policy and regulatory options.

The Interface between Energy, Water and Agriculture

Affordable and plentiful energy, water and agricultural supplies are fundamental to enabling countries to develop socially and economically. Without adequate supplies of all three, the other major problems affecting health and biodiversity identified at the September 2002 World Summit on Sustainable Development (attended by 104 heads of state and government) will not be solved. Energy, water and agriculture are critical to alleviating global poverty and to enabling countries to develop the capability to address environmental degradation.

Solutions to energy, water and agricultural needs require countries to deal with many of the same issues. First, planning and executing a plan to address the resources, technologies, and human capabilities needed to build the required infrastructure entail very long lead times, especially in the energy and water sectors. Additionally, the need exists to develop institutional, structural and professional capabilities that will enable the individual countries on their own to continue the acceleration of developments that will result in long-term sustainable growth. This process will usually transcend several changes in governments and administrations over many years, and therefore must involve long-term commitments.

Second, in all three sectors, matching the availability of energy and water supplies with demand, and adjusting agricultural practices, will involve cultural and lifestyle changes that may be very difficult. The rationale for such changes and the benefits of new technology options must be compelling and well understood by the governments and populations affected.

Third, virtually all countries are already, and will increasingly become, dependent upon trade and international cooperation to meet their energy, water and agricultural requirements. Hence, a more stable peaceful world is seen as both a prerequisite for solving energy, water and agricultural problems as well the goal of social and economic development.

Fourth, the factors that constrain energy, water and agriculture availability in developing countries call for the following major issues to be addressed:

- Insufficient financial resources
- Inadequate institutional arrangements
- Inadequate human resources
- Lack of sector coordination
- Lack of long term political commitment
- Insufficient community involvement
- Inadequate operation and maintenance
- Insufficient information and communication

Fifth, energy, water and agriculture are highly dependent upon one another, for example:

- In the United States, up to 80 percent of the cost of pumping, transporting and processing water is for energy. Further study might indicate similar results in developing countries.
- In developing countries, agriculture typically consumes over 70 percent of the water supplies.
- Agricultural practices often lead to inefficient use of energy and over-consumption of water.

- A growing dependence upon water from transnational basins and international rivers will increase the need for storage and pumping, which in turn will increase energy consumption.
- In many countries, all three sectors are impacted by a lack of government-to-government treaties and agreements that allow the free flow of necessary energy and water supplies between countries.
- In the United States, electricity production requires the withdrawal of almost as much water as agriculture, and will be a growing issue in developing countries with the very rapid growth in electricity production.
- Water requirements for nuclear power are huge, as are those for other thermal power plants.
- The treatment of municipal and industrial wastewater requires energy for pumping and plant operations.
- The production of primary energy such as coal and petroleum is accompanied by substantial withdrawal of water.
- The pumping of water from underground aquifers for agriculture is dependent on reliable and inexpensive power.
- The production, treatment and delivery of reliable and adequate municipal water supplies is dependent upon energy.
- In the future, agriculture could become a significant source of transportation fuels.
- Agricultural production for food, wood products and energy are in growing competition for land and water supplies.

Major Energy Challenges

Meeting rising energy requirements is fundamental to ensuring economic development and rising per capita incomes in developing countries. Solutions must address a number of very difficult challenges:

- The strong projected energy demand growth (2.7 percent a year) in developing countries for the next 20 years will continue to tighten world oil supplies.
- Such growth has led to an upward pressure on oil prices that is likely to persist.
- Following current patterns, there will be a growing reliance on the Middle East for conventional oil supplies, which remains politically unstable.
- Following current patterns, there will be a significant shift in the oil and gas trade towards Asia, which could lead to greater friction with industrial countries.
- The IEA estimates that roughly $22 trillion in investments will be needed in developing countries to meet energy needs through 2025.[11] This would still leave about 2 billion people without access to electricity. Closing this gap would require a further $2 trillion.
- Capital investments at this level are well beyond the capabilities of developing country governments to raise on their own.
- With over 80 percent of the world's oil and gas reserves controlled by national companies, cash flows from the petroleum sector are frequently being diverted to non-energy related activities, reducing the reinvestment in petroleum resources, and accelerating the likelihood of supply shortfalls.
- Changes to large scale government investment and subsidy programs in developed nations can spur growth of alternative and renewable energy sources in both developed and developing nations.
- The development of alternative energy sources, such as solar, wind geothermal and tidal, has the potential to help solve energy scarcity problems in developing nations, and help them avoid environmental problems associated with consumption of traditional energy.
- All potential economic sources of energy should be utilized in an environmentally responsible manner:
    - Additional supplies of conventional energy sources may require greater transnational movements, especially for developing countries.
    - Greater coal demand should be accompanied by the use of clean coal technologies and more efficient and effective mining and burning.
    - When economically possible, alternative energies such as wind, solar and biomass conversion to gas should be encouraged.
    - New transportation solutions such as hybrid cars and replacements for conventional gasoline and diesel fuels should be encouraged. Urban planning, smart growth and mass transit systems need to be utilized in a way that reduces the consumption of traditional fuels for transportation.
    - Nuclear plants using new designs and standardized equipment should be developed in order to lead to safer operations, lower capital and maintenance costs, and a more efficient regulatory process.

[11] International Energy Agency, *World Energy Outlook 2007*.

- New technologies need to be developed to increase supply options and to improve efficiency of demand as well as of production.
- Energy conservation and efficiency improvements must be encouraged because they often represent the cheapest new source of energy.
- Energy intensity in developing countries, as measured by energy consumption per GDP, has been improving over time but remains over double that of industrialized countries. This partly reflects structural differences related to the stage of economic development, but it also reflects the inefficiencies in the production and utilization of power.
- In many developing countries, the electric power industry needs to become economically viable:
  - Many power companies do not cover costs.
  - Tariff structures often fail to fully reflect costs, including a return on capital.
  - Non-payment of bills, lack of metering and losses due to theft are common.
  - Transmission structures are often inadequate.
  - National grids that allow the efficient movement of power often do not exist.
  - Management and technical manpower need training and know-how.
- Realistic pricing of all energy is necessary. Uneconomic pricing reduces supplies and encourages wasteful consumption. Higher prices could encourage new supply alternatives. Pricing policies should recognize that adjustments will need to be made gradually for the poorest segments of the population.

Major Water Challenges

- Only 3 percent of the Earth's water is fresh, comprising only 35 million km^3.[12]
- Almost all of that fresh water is frozen in the icecaps of Antarctica and Greenland, found as soil moisture, or lies in deep underground aquifers. These sources are not economically accessible with current technology.[13]
- Just 0.3% of the fresh water on earth, 100,000 km^3, is found in lakes, rivers, reservoirs and underground sources shallow enough to be tapped at an affordable cost.[14]
- Underground reserves in arid areas replenish at very slow rates, usually less than 0.5 percent per year. If water is pumped too rapidly from aquifers, it is in effect mined and will deplete rapidly. The remaining water is often degraded by increased salinity, and over-mining often results in surface subsidence. This is a major issue for many developing countries.
- In the United States, power plants withdraw almost the same daily volumes of water as agriculture. Together, power and agriculture account for 80 percent of daily water withdrawals.
- In the United States, when water is withdrawn for irrigation, almost 60 percent is consumed (i.e., not returned to streams after use). When water is withdrawn for power plants, only 2 percent is consumed, but over time this repetitive process consumes substantial reserves. Water returned from power plants is often higher in temperature than natural waters, and this can have large ecological impacts.
- In the United States, the absolute levels of water withdrawals stopped increasing around 1980 even with economic growth and a rising population. As a result, per capita consumption has fallen by over 20 percent. It may be possible to achieve similar results in many developing countries.
- Water is scarce where it is needed most—in developing countries. Sub-Saharan Africa is particularly at risk. The risk is also growing in countries like China and India as ground water replenishment and river flows are reduced or temporarily changed from global climate change and the shrinkage of ice and snow cover in the mountains.
- Water supply and availability transcend national boundaries. More than 250 river basins in the world are shared by 2 or more countries. Over 30 countries receive more than one third of their water from outside their borders. Half of these countries are in the developing world. It is not known how many countries share groundwater basins, but as water scarcities increase, those numbers will become more apparent.
- In the developing countries, 70 to 90 percent of water withdrawal is for agriculture. The uses of water that have higher value (industry, domestic households and for drinking) receive disproportionately low levels of the water supply.
- Subsistence farming is marginal and contributes little to the economy but is a major cause of high water consumption. Subsistence farmers will require financial and training assistance during the transitional period.
- Water availability is often reduced because of a lack of wastewater treatment facilities, and because of the non-availability of reservoir and pipeline infrastructure.
- In large cities in Asia, Africa and Latin America, roughly 40 percent of water is unaccounted for as meters do not work and pipelines leak.

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[11] International Energy Agency, *World Energy Outlook 2007*.

[12] Gleick, P.H. 1993. An introduction to global freshwater issues. In P.H. Gleick, ed., Water in crisis, a guide to the world's freshwater resources. Oxford University Press. New York, NY. 473 pp.)

[13] Ibid.

[14] Ibid.

- Water conservation is essential but difficult to implement in water-poor areas.
- Political pressures often make governments reluctant to establish processes for targeting real costs.
- Considerable technological expertise is required to create the understanding of water cycles that is important to achieving balanced water systems.
- Providing adequate water supplies is a very long-term proposition. Planning and construction of the infrastructure must be started up to 20 years before needed.
- Political bodies are inherently reactive, whereas water supply shortfalls require long-range proactive decisions.
- In most developing countries there exists an urgent need to provide adequate water treatment plants to improve health conditions and to eliminate severe shortages of potable water.
- Climate change is likely to increase the incidence of some infectious diseases, such as malaria, dengue, cholera and yellow fever.
- Major water-borne diseases and limited supplies are huge detriments to economies and societies, for example:
  - Diarrheal diseases lead to 2.2 million deaths per year.
  - Malaria infects 300 million people each year. In sub-Sahara Africa alone, there are 1 million deaths each year.
  - Schistosomiasis infects 200 million each year, causing 20 million to suffer severe effects.
  - Limited accessible supplies impacts the potential productivity of women.

Major Agricultural Challenges[15]

- Hunger (insufficient caloric intake) is a major concern for the more than three billion people who live on less than $2 per day.
- The world's population of 6.4 billion will grow to almost 9 billion by 2050 with over 90 percent of the increase in the less-developed countries of Asia, Africa and Latin America.
- As economic prosperity increases, so will the desire to consume more animal protein, fruit, vegetables and edible oils. World agricultural output will have to double to meet this change in demand.
- How many presently low-income consumers are lifted out of poverty will be the most important determinant of the future size of the world's food and agricultural product markets.
- Productivity growth in agriculture is necessary but will probably not be sufficient to meet the potential gap.
- Small-scale (subsistence) farming has limited potential to reduce rural poverty. All the presently rich countries created non-farm rural employment so that farm families earn most of their income from employment off the farm.
- The creation of rural non-farm employment is heavily dependent on the availability and affordability of energy, especially electricity.
- Arable land and populations are distributed very differently. Fifty-three percent of the world's population is today concentrated in the Far East and Southeast Asia, which have only 29 percent of the world's arable land. On the other hand, OECD countries, the remainder of Europe and Central Asia contain 46 percent of the world's arable land but only 22 percent of the world's population. This picture will become further distorted over time with population growth that will exacerbate the problems in Asia and cause Africa, Latin America and the Middle East to experience a major shortfall in arable land.
- At most, there is only 12 percent more arable land currently available to double the world's agricultural production by 2050.
- Major investments in rural infrastructure and agricultural research to increase per acre productivity and disease resistance will be needed to relax some of the physical constraints.
- Keen competition for available land is coming among food production, commercial forest production, conservation of forests, and alternative energy production.
- The area of land in world food production could be doubled, but would probably require the massive destruction of forests and loss of wildlife habitat, biodiversity and carbon sequestration capacity.
- Considerable government support will be required to implement major environmentally sustainable alternatives, such as:
    - doubling productivity on the fertile, non-erodible soils already in crop production, and
    - requiring tradeoffs between increasing irrigable acreage and productivity.
- Farmers use 70 percent of the fresh water in the world. Water is priced at zero for most farmers, leading to very inefficient usage.
- Agricultural output will need to double using significantly less water than today, as cities are likely to outbid agriculture for available water

[15] Challenges presented by Robert L Thompson, Gardner Professor of Agricultural Policy, University of Illinois, April 18, 2006 to the Marshall Plan Working Group.

- Historically, public and private sector investments in agricultural research have increased productivity faster than demand growth. Major additional investments in irrigation, fertilizer and biotechnology are required to continue this trend.
- Biotechnology has the potential to improve the nutritional content of grains, to increase yields and/or planted area under adverse or variable conditions, to internalize resistance to diseases, to reduce pesticide use, and to slow down product deterioration.
- World agriculture is in disarray and new policies need to be considered:[16]
  - Most high-income countries subsidize agriculture, thereby distorting returns and investments in agriculture.
  - Many less-developed countries keep urban food prices artificially low, leading the agricultural sector to underperform relative to its potential.
  - Protectionist import policies and export subsidies further distort what is produced where.
- Developing countries' own policies impede their development, for example:
  - Corruption and/or macroeconomic instability
  - Inadequate property rights and contract sanctity
  - Under-investment in rural infrastructure, education and R&D
  - Lack of technology adapted to local agro-ecological conditions
  - Policies that discourage education and more productive roles for women
  - With arable land and fresh water not distributed around the world in the same proportions as population, food consumption in many less-developed countries will outstrip productive capacity with further population growth, urbanization and broad-based economic development.
- There is considerable political resistance to creating more open agricultural trading environments that are required from developed countries:
  - to provide market access for goods in which developing countries have a comparative advantage,
  - to stimulate faster economic growth worldwide, and
  - to eliminate import barriers and domestic export subsidies, which depress world market prices.

[16] Paraphrased from G. Gale Johnson's book *World Agriculture in Disarray.*

Annex 1

Participants and Advisers

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Affiliations are shown as of the time of participation.

Annex 2

Potential Country List

	Latin America	*Africa*	*Asia*
Score 5	Brazil Colombia Dominican Republic El Salvador	Benin Ghana Madagascar Mali Senegal South Africa Tanzania	India
Score 4	Peru (1) Honduras (1)	Burkina Faso (2) Egypt (3) Morocco (3) Mozambique (4) Tunisia (3) Zambia (4)	China (3) Sri Lanka (3) Thailand (3) Viet Nam (3)

(1) Rule of Law below median
(2) Government Effectiveness below median
(3) Voice and Accountability below median
(4) Regulatory Quality below median

Annex 3

Charts

These charts provide basic country data on energy, water, agriculture and political and economic criteria, to assist sponsors in the selection of countries. Additional work will need to be done before the final selection of countries, which will be affected by the availability and accessibility of data, as well as availability of professional expertise.

Political and Economic Criteria

	Population (millions)	Surface Area (millions sq km)	Estimate GDP (PPP) (billions US$)	Estimate GDP Growth (%)	Estimate GDP Per Capita (thousands US$)	Industrial Production Growth Rate (%)	Economic Aid Received (millions US$)	Inflation (%)
LATIN AMERICA								
Brazil	192	8.5	1836	5.4	9.7	4.9	192	9
Columbia	45	1.1	320	7	6.7	9.4	511	8.1
Dominican Republic	10	0.5	62	8.5	7	2.4	77	6.8
El Salvador*	7	0.02	42	4.7	5.8	3.4	268	3.9
Honduras*	8	0.1	31	6.3	4.1	4.4	681	6.9
Peru*	29	1.3	219	9	7.8	9.3	398	11.1
AFRICA								
Benin*	8	0.1	12	5.4	1.5	4.5	375	2.5
Burkina Faso*	15	0.3	17	4.2	1.3	5.2	660	-0.2
Egypt	82	1	432	7.2	5.4	13.8	926	8.8
Ghana*	23	0.2	31	6.2	1.4	7.4	1316	11
Madagascar*	20	0.6	18	6.3	1.1	6	929	10.3
Mali*	12	1.2	13	2.5	1	NA	692	2.5
Morocco*	34	0.4	127	2.1	3.8	6	652	2.1
Mozambique*	21	0.8	17	7	0.8	10	1286	7.9
Senegal*	13	0.2	21	5	1.7	2.7	477	5.9
South Africa	44	1.2	467	5.1	9.8	4.4	700	7.1
Tanzania*	40	0.9	49	7.3	1.3	8.2	1505	7
Tunisia	10	0.2	77	6.3	7.5	7.2	377	3.1
Zambia*	12	0.7	16	5.3	1.3	7.3	504	10.7
ASIA								
China	1330	9.3	6991	11.4	5.3	13.4	1641	4.8
India	1148	3.3	2989	9.2	2.7	8.9	1724	6.4
Sri Lanka	21	0.1	81	6.3	4.1	7.4	1189	19.7
Thailand	65	0.5	519	4.8	7.9	5.4	171	2.2
Vietnam	86	0.3	221	8.5	2.6	17.1	5400	8.3

*Millenium Challenge Eligible Country

*Source for all columns:
https://www.cia.gov/cia/publications/factbook/

Energy

	Primary Energy Production Quadrillion (10^15) BTU*	Primary Energy Consumption Quadrillion (10^15) BTU*	Surplus/Deficit (%)	Energy Consumption Per Capita Kilograms of oil equivalent (kgoe)	Sources of Energy Production (fossil fuels)	Electricity Production (BkWh)*	Electricity Consumption (BkWh)*	Electricity Consumption Per Capita (1000 kWh)
LATIN AMERICA								
Brazil	7.712	9.332	17% deficit	1067.6	oil, natural gas, coal	396.36	368.53	2.19
Columbia	3.378	1.254	63% surplus	636.9	oil, natural gas, coal	50.47	38.91	0.95
Dominican Republic	0.019	0.276	93% deficit	922.4	none	12.22	0.276	1.49
El Salvador	0.037	0.127	71% deficit	683.2	none	4.69	4.36	0.75
Honduras	0.019	0.115	83% deficit	521.9	none	5.34	4.04	0.64
Peru	0.473	0.638	26% deficit	431.5	oil, natural gas, coal	24.97	22.59	0.78
AFRICA								
Benin	0	0.034	100% deficit	301.4	none	0.11	0.59	0.07
Burkina Faso	0.001	0.018	94% deficit	N/A	none	0.52	0.48	0.03
Egypt	3.19	2.752	14% surplus	761.3	oil, natural gas, coal	102.45	84.49	1.05
Ghana	0.066	0.149	56% deficit	400.2	oil	6.65	5.85	0.31
Madagascar	0.006	0.042	86% deficit	N/A	oil	1.05	0.97	0.05
Mali	0.002	0.012	83% deficit	N/A	none	0.44	0.41	0.03
Morocco	0.019	0.558	97% deficit	357.3	oil, natural gas	21.37	20.67	0.56
Mozambique	0.139	0.157	11% deficit	435.8	natural gas, coal	13.17	9.13	0.46
Senegal	0.004	0.081	95% deficit	233.2	natural gas	2.22	1.46	0.11
South Africa	6.05	5.041	17% surplus	2596.9	oil, natural gas, coal	228.33	210.71	4.70
Tanzania	0.02	0.072	72% deficit	464.9	coal	1.88	1.2	0.06
Tunisia	0.264	0.36	27% deficit	833.3	oil, natural gas	12.85	11.17	1.07
Zambia	0.094	0.122	23% deficit	600.6	oil, coal	8.85	8.66	0.58
ASIA								
China	63.229	67.093	6% deficit	1138.3	oil, natural gas, coal	2371.83	2197.11	1.89
India	11.731	16.205	28% deficit	512.4	oil, natural gas, coal	661.64	488.53	0.52
Sri Lanka	0.034	0.213	84% deficit	423.8	none	8.41	7.07	0.39
Thailand	1.758	3.626	52% deficit	1405.7	oil, natural gas, coal	124.59	117.65	1.79
Vietnam	1.939	1.225	37% surplus	539.4	oil, natural gas, coal	51.33	45.46	0.44
*Source: EIA Country Energy Profiles Total Primary Energy http://tonto.eia.doe.gov/country/	*may include non-fossil sources of production		Difference between energy production and consumption	*Source: Data Tables. Earth Trends World Resources Institute. http://earthtrends.wri.org Accessed 8/19/08	*Billion kWh Source: http://tonto.eia.doe.gov/country/			Source: www.nationmaster.com/graph/ene_ele_con_percap-energy-electricity-consumption-per-capita

Water

	Internal Renewable Water Resources Km³	Actual Renewable Water Resources Km³	Dependency Ratio*	Total Water Withdrawls Km³	Suffering from Water Stress/Scarcity (2025 projection)	Access to Improved Drinking Water Supply (% of Population 2006)	Access to Improved Sanitation (% of population 2006)
LATIN AMERICA							
Brazil	5418	8233	34	54.9	No	91	77
Columbia	2112	2132	1	8.9	No	93	78
Dominican Republic	21	21	0	8.3	No	95	79
El Salvador	18	25	30	0.7	No	84	86
Honduras	96	96	0	1.5	No	84	66
Peru	1616	1913	16	19.0	No	84	72
AFRICA							
Benin*	10	25	58	0.1	No	65	30
Burkina Faso*	13	13	0	0.4	Stress	72	5
Egypt	2	58	97	66.0	Scarcity	98	66
Ghana*	30	53	43	0.3	Stress	80	10
Madagascar*	337	337	0	16.3	No	47	12
Mali*	60	100	40	1.4	No	60	45
Morocco*	29	29	0	11.5	Scarcity	83	72
Mozambique*	99	216	54	0.6	Stress	42	31
Senegal*	26	39	33	1.4	No	77	28
South Africa	45	50	10	13.3	Scarcity	93	59
Tanzania*	82	91	10	1.2	No	62	41
Tunisia	4	5	20	2.8	Scarcity	94	85
Zambia	80	105	24	1.7	No	58	52
AISA							
China	2812	2830	1	525.5	No	88	65
Sri Lanka	50	50	0	9.8	No	82	86
Thailand	210	410	49	33.1	No	98	96
Vietnam	367	891	59	54.3	No	92	65
	*Source: http://earthtrends.wri.org/country_profiles/index.php?theme=2 *Dependency Ratio is the percentage difference between internal and actual renewable water resources.			*Source: http://earthtrends.wri.org/country_profiles/index.php?theme=2	Based on Falkenmark's system: water stress occurs when annual water supplies drop below 1000 m3 per person www.unep.org/dewa/assessments/ecosystems/water/vitalwater/21.htm	WHO + UNICEF Joint monitoring Program for Water Supply and Sanitation http://www.childinfo.org/files/mdg_country_regional_tables.pdf	

Agriculture

	Agricultural Productivity Per Capita* (tons/person)	Nutritional Calorie Intake Per Capita* (2001-2003)	Percent of Population Undernourished* (2001-2003)	Agricultural Water Withdrawls* As percent of total water withrdrawl	Energy Consumed by Agriculture* (% of total energy used, 2001)
LATIN AMERICA					
Brazil	293	3060	8	62	5.0%
Columbia	86	2580	14	46	7.9%
Dominican Republic	79	2290	27	66	1.5%
El Salvador	127	2560	11	59	0.2%
Hondrusa	92	2360	22	80	0.1%
Peru	140	2570	12	82	4.8%
AFRICA					
Benin	141	2530	14	45.4	0.0%
Burkina Faso	225	2460	17	86.3	n/a
Egypt	290	3350	3	86.4	0.7%
Ghana	88	2650	12	66.4	2.7%
Madagascar	162	2040	38	95.7	n/a
Mali	237	2230	28	90.1	n/a
Morocco	117	3070	6	87.4	0.7%
Mozambique	91	2070	45	87.3	0.1%
Senegal	113	2310	23	93	2.7%
South Africa	257	2940	4	62.7	2.7%
Tanzania	108	1960	44	89.4	4.6%
Tunisia	n/a	3250	<2.5	82	6.3%
Zambia	n/a	1930	47	76	0.4%
ASIA					
China	331	2940	12	67	4.2%
India	232	2440	20	86.5	2.0%
Sri Lanka	153	2390	22	95.2	0.1%
Thailand	472	2410	21	95	5.4%
Vietnam	n/a	2580	17	68	1.4%
	*Source: http://earthtrends.wri.org/country_profiles/index.php?theme=8	*Source: http://www.fao.org/es/ess/yearbook/vol_1_2/site_en.asp?page=cp			*Source: http://earthtrends.wri.org/pdf_library/data_tables/ene3_2005.pdf

Annex 4

Process for Creating and Implementing a 21st Century Marshall Plan in Individual Countries

This annex describes the steps necessary to create and implement a 21st Century Marshall Plan for enhancing regional and global stability, security and economic growth by building integrated water, energy, and agricultural infrastructure and capacities in developing nations. The process described below is stakeholder-driven, meaning that regional experts and leaders in participating countries will guide and ultimately own the process, with input and assistance from experts representing the Atlantic Council and Sandia National Laboratories (Sandia), and with funding from sponsors. The end result of the initial three-year effort will be a long-term sustainable (10-30 year) roadmap for development of infrastructure and capacity in a participating country. We will arrive at the roadmap through a collaborative computer simulation modeling process which transforms data to actionable knowledge from multiple sectors and institutions, identifying past, current and projected future trends and patterns, illuminating interconnections and interdependencies between systems, evaluating tradeoffs associated with different development plans, and educating and communicating with policy and decision makers, donor agencies, businesses leaders, other stakeholders, and the public. In this way, the process should create ownership for rejuvenating capacity-building with the individual countries/ regions taking responsibility for their own future. The process encourages guidance from domestic and foreign investors to lead the development effort. This aims to decrease the role of donors over time and ultimate reduce dependency and increase each country's self-reliance.

To be successful, this complex endeavor requires careful planning and implementation, and commitment to follow-through by all participants. Key features of this fully collaborative process include goal setting, data and information collection, current state analysis, future state goals, systems analysis, planning, success metrics definition, stakeholder engagement and buy-in, development of recommendations, funding for implementation of recommendations, implementation itself, measurement of initial success of implementation, and finally, long-term sustainability metrics. Some measures of success are described below, and continual monitoring of progress and comparison to target goals is an essential part of the overall process. While this annex describes the process for implementing a 21st Century Marshall Plan in individual countries, elements of this approach are consistent with a broader approach for regional application. Because energy, water, and agriculture are inexorably linked, and because their production, distribution, and consumption typically span political boundaries, the 21st Century Marshall Plan must be sufficiently robust to allow its application to broader reaches than those falling neatly within political boundaries.

The process is described in Figure 1 on the following page, and then specific steps for implementation are described in the text below.

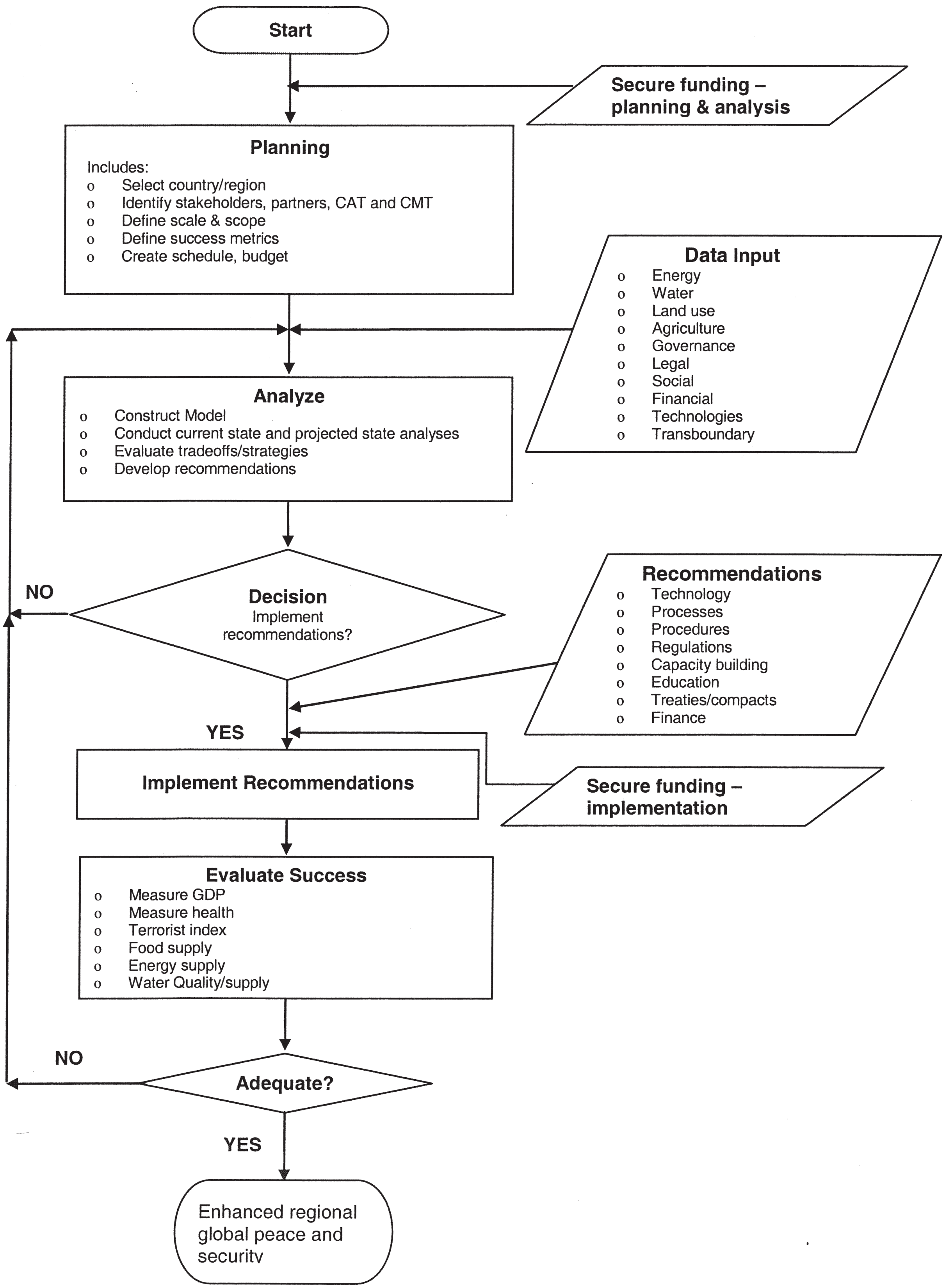

Figure 1. Process flow chart for implementation of the Marshall Plan process

The Process, in brief

The project begins with several activities concurrently: a) an early start to the collection of data and information about water, energy and agriculture in the participating country, b) the development of a Collaborative Advisory Team (CAT) made of influential national experts and leaders who will oversee the project and develop the roadmap and implementation plan, and c) the development of a Collaborative Modeling Team (CMT) that will work under the CAT throughout the project to collect data, and build, analyze and interpret models. A period of about 20 months will be devoted to modeling the national/regional systems. Modeling will lead to the creation of a roadmap for development for the nation/region based on CAT and other stakeholder input, and the creation of a concrete plan for implementing the roadmap. All the results of this phase will be used to seek funding for the implementation phase, which will unfold following a schedule set by the CAT and other stakeholders, and may progress over the course of a decade or more.

The Process, step by step

***Step 1* – Select a team of ~6 regional experts on water, energy and agriculture and related issues** in the first four months after initiation of the project, who will then spend the next six months (months 5-10) supervising the assembly of existing data for a participating country, or region within the country. These experts will be the first members of the CAT, although the full CAT will not be formed until a little later (see schedule in Figure 2). It is important to begin with data collection immediately so that once the full CAT is formed, and the CMT is formed and trained, there will be sufficient data and information to begin conceptualizing the systems, identify data gaps and requirements, and begin modeling. The early data and information gathering jumpstarts the beginning of activities once other preliminary preparations have been made.

Work includes gathering data and information on:

- Historic, current, and projected surface water and ground water supply and demand, climate and precipitation patterns, trans boundary dynamics, and storage, pumping, treatment, and transfer facilities.
- Historic, current and projected energy supply and demand, energy resources and infrastructure, and import/export dynamics.
- Historic, current and projected food supply and demand, diet, cultivation and irrigation methods, and import/export dynamics.

In addition to the information described above, a baseline assessment of the economic, legal and regulatory structures must be completed. This information will be used for developing success metrics. This includes:

- Macroeconomic fundamentals of the country such as GDP, debt, and fiscal policies
- Overall governmental performance including measures of rule of law, access to offshore arbitration, respect for contracts and international property rights, level of corruption, and sector-specific regulatory and legislative framework and its evolution and direction
- Market conditions including scale and growth of market, measures of private sector vs. state participation, and depth and breadth of local capital markets
- Financial structures including loan and credit opportunities, fiscal incentives and pricing structures.

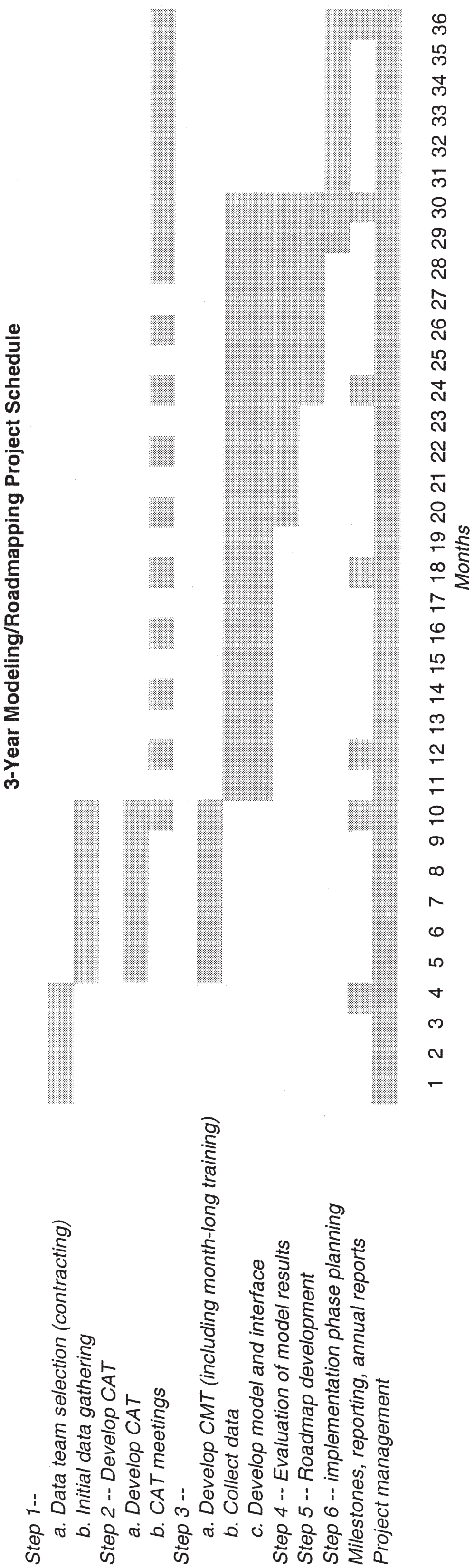

Figure 2: Schedule for a 21st Marshall Plan process

All data and information gathering will take place in an integrated and coordinated fashion and will keep in mind and examine the linkages between food, water and energy. Data collection staff will meet once every two weeks to review progress, consider overlaps, avoid redundancy, and generally integrate efforts and thinking.

***Step 2* – Select a regional collaborative advisory team** (CAT), which would include the 6 regional experts already involved in data and information gather but also 14 - 18 other members of key government agencies, business, development banks, economics, academia, environmental and human rights organizations, as well as policy makers and citizens. This team would be selected over a period concurrent with the data gathering efforts described above (months 5-10) and would be ready to meet in month 11. This team will meet every other month to review progress from months 10-28, and then monthly after that to integrate results, advise ongoing activities, create the roadmap and create the implementation plan. The meetings will be joined in person by Atlantic Council/Sandia staff when possible, and otherwise by telecon/webcon, and video link if possible. An expert facilitator/coordinator should be engaged to assist this advisory group and to generally oversee regional logistics and organizational matters.

It is important that this team be comprised of members who are sufficiently influential in their country to both have credibility in the government and in the business community. CAT members will receive a generous stipend for their attendance in meetings. This team, in addition to overseeing the project in general, will help craft the development roadmap and the implementation plan. Once the implementation plan is funded, the CAT will have oversight for implementation. The full engagement of the CAT in the overall project will give it ownership of and buy in for the end products. It is expected that champions will emerge, and help confer credibility and broad acceptance of the project and its outcome's credibility.

***Step 3* – Develop a sustainable energy-water-agriculture framework.** Establish a collaborative modeling team (CMT) (up to 10 modelers) train modelers, and begin modeling with expert modelers from SNL. This team may be drawn from agencies and organizations represented in the CAT. Since the educational background, work experience and English skills of this team will be crucial to overall success, a 5-day hiring clinic in the region will occur in month 7 or 8. Thirty prospective CMT members will be invited to the hiring clinic, and the 10 most promising modelers will be invited to join the CMT. The hiring clinic itself will be a capacity building effort, since regional modelers will learn new systems and approaches. The 10-member CMT will be brought to the U.S. for an intensive, month-long training program in month 10. In months 11 – 30 the CMT, with help from Sandia modelers will develop decision support, computer simulation and modeling tools to integrate and quantify the dynamic interdependencies between water, energy and food systems that are too complex to be quantified by human intuition alone. This modeling team will take over major responsibilities for data and information gathering. This phase will include 6 1-week regional workshops interspersed in the 20 month modeling period. An important part of this step includes the regional capacity building for modeling processes and technologies. Ultimately regional modelers can continue with model maintenance and development with less and less input from Sandia, and they can use modeling skills gained in this project to begin other regional projects. The ultimate goal is for the national/regional personnel to assume increasingly greater responsibility for decision-making and likewise responsibility for implementing the recommended decisions using indigenously trained personnel, companies and resources.

***Step 4* – Use the teams and models to evaluate tradeoffs and consequences associated with multiple development strategies** spanning energy, water and food, as projected into the future. This spans months 24-30, after model development has proceeded sufficiently so that evaluation of scenarios can begin. During months 28-30 the CAT will begin meeting monthly, rather than every two months, in order to engage more fully in this part of the project. Their review of various scenarios and their consequences is essential both for keeping them fully informed, and for composing scenarios that match national needs and objectives. Composition of final report on data and information used in the model, and model structure, function and results begin in this step.

Step 5 – Use the model results and the knowledge and expertise gained in the group throughout the collaborative model development process to **draft a water-energy-agriculture development roadmap with specific goals and objectives.** The roadmap will lay out explicit plans and timetables for the implementation of different technologies, including scales, schedules and budgeting for development of policy-level and fiscal initiatives, grant programs, initiatives that would probably include establishment of small and large businesses and manufacturing, training programs, urban planning, and small and large scale water, energy and agriculture development plans -- all in concrete terms, and all with rigorous, quantitative outcomes that follow model results. The model will be used to help communicate the thinking and planning behind the roadmap to policy makers, funding institutions, and citizens. This step includes composition of a full-scale report on the model, in addition to the draft roadmap.

***Step 6* – Plan implementation phase.** The CAT, with input from the Atlantic Council and Sandia, and using the roadmap and the model, will conceptualize the implementation phase. The roadmap will lay out the pattern of development and the money required, but it will not describe how decisions about distribution should be made. For example, the CAT might wish to put out a request for proposals from industrialists, large and small businesses, banks, academic institutions, and others, for implementation of the roadmap. Various funding rounds may be considered. The CAT might want to make funding available to entities both within and outside national borders, to one or the other, or to distribute funding according to some proportion between the two. Other topics that must be considered and decided upon include:

- Measures to prevent corrupt business practices
- Guidelines for proposal review and acceptance criteria
- Funding mechanisms
- Financial reporting requirements from funded entities
- Success metrics
- Future roles for CAT, CMT, Atlantic Council, and Sandia.

Preliminary Manpower and Cost Estimates *

Estimates are for initial three-year Phase I process in an individual country

Cost Center	**Manpower**	**Total cost - three years**
Sandia National Labs	10 professionals	$2.0 - 2.5 Million
Atlantic Council	3 professionals	$0.6 - 0.8 Million**
In-country	6 - 10 full-time 0 - 30 part time	$0.5 - 0.7 Million
	Total Costs	$3.1 - 4.0 Million

* Estimates include an allowance for travel and communications support, but do not include estimates for inflation or additional costs arising from any delayed start-up of the plan.

**As more countries are added, the incremental costs would decrease

Annex 5

Case Studies

Sandia National Laboratories Collaborative Modeling Projects

The approach described in this paper has been implemented to greater and lesser degrees in various settings in the U.S. and around the world. Following are select case studies that describe some of the projects. These case studies come from the paper *Collaborative, Stakeholder-driven Resource Modeling and Management* by Howard Passell, Wael Khairy, Marissa Reno, Jesse Roach, and Vince Tidwell. The paper will be presented at the Nile Basin Development Forum in Khartoum in November, 2008.

Aral Sea Basin, Central Asia: Since 1999 scientists from the Institutes of Physics and from the regional Gidromets (hydrometeorological bureaus) in the Central Asian republics of Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan have collaborated with Sandia National Laboratories (SNL) to collect data on the transboundary rivers of the Syr Darya and Amu Darya of the transboundary Aral Sea Basin, and to develop decision support models for the basin. Sampling and data analyses were standardized across the four participating countries so that data would be comparable from one country to the next. The data have been shared throughout the course of the project, and are also available to other scientists and the public, at the following website, maintained by SNL: https://waterportal.sandia.gov. The website is also used as a repository for other documents, information and models associated with the project. The ongoing modeling effort is aimed at modeling hydrology in the transboundary Syr Darya basin, shared by all four participating countries, and the impacts on that hydrology of various challenges associated with municipal uses, agriculture, power generation, and environmental uses, as well as fate and transport of potentially dangerous metals and radionuclides in the system. The project has included many face-to-face meetings and workshops between project members, both in the U.S. and in Central Asia.

Middle Rio Grande, North America: This project represented a collaboration between SNL and the Middle Rio Grande Water Assembly (MRGWA) in central New Mexico. The MRGWA is an NGO made up of diverse stakeholders including scientists, water managers, farmers and ranchers, urban developers, environmentalists and citizens. It was created by the State of New Mexico in order to develop a 50-year plan for sustainable water resources in the Middle Rio Grande. The Rio Grande Basin includes three states in the U.S., and three states in Mexico, so many transboundary issues exist. The model was created over a three-year period involving many regular meetings of the stakeholder team to review model development, provide data and information, and to use the model for evaluating different management strategies. Competing uses for water in the basin include agricultural, municipal and industrial, and ecological, and are complicated by treaties and other legal obligations that regional water managers and policy makers must follow. The project provided a water plan for the region that was accepted by the State of New Mexico.

Tigris-Euphrates Basin, Middle East: SNL is collaborating with scientists in the Ministry of Water Resources (MoWR) in Iraq, the U.S. Department of State and UNESCO to develop a decision support model of the transboundary Tigris-Euphrates basin. The 2-year project began in 2007 and is ongoing, and when it is complete will have included five face-to-face modeling workshops between SNL and MoWR modelers. The project is aimed at supporting the Strategy for Water and Land Resources in Iraq

(SWLRI), a very large, multi-sector project initiated by the Iraqi government and intended to help the government with long-term strategic planning of Iraqi resources. The project includes an important capacity building aspect, where engineers from the MoWR are being trained in the use of the modeling approaches and software, and becoming capable of modifying the existing model and building new models of their own. The primary competing uses for water in Iraq include municipal and industrial development, agriculture, power generation, and the Mesopotamian Marshes of southern Iraq. Iraq is the downstream riparian in the transboundary river basin, so upstream development in Turkey, Syria and Iran are very important.

Willamette Basin, North America: Water managers and the public in the Willamette Basin face challenges that include competing demands for water from municipalities, agriculture, environmentalists, power generation, and recreationalists, along with special challenges associated with U.S. federal regulations on water quality associated with legislation known as the Endangered Species Act, and the Clean Water Act. The Willamette and its tributaries are a spawning ground for endangered salmon, and so extensive efforts are being made in the Willamette to balance human uses of the water with the needs of the fish for reproduction. The U.S. Army Corps of Engineers (USACE) operates 11 major water storage reservoirs on tributaries to the Willamette River to provide irrigation water, inexpensive power and flood control, and regulation and operation of those dams is a major regional issue. SNL engaged with a group of stakeholders in the Willamette Basin to gather data and information and to build a model, in collaboration with the USACE and several NGOs, to help address problems with water quality (including temperature), and aquatic and terrestrial biological communities. An interesting feature of the modeling done in this basin is focused on economics, which lets users simulate the potential economic returns from tourism and recreation, based on different river and reservoir management scenarios.

Amman Zarqa Basin, Jordan: In 2006 SNL and UNESCO hosted a modeling workshop in Amman, Jordan, that included 34 scientists from 18 institutions in 10 countries, including Jordan, Iraq, Syria, Turkey, Japan, Kazakhstan, Uzbekistan, Tajikistan, Kyrgyzstan, and the U.S. The workshop was aimed primarily at demonstration of modeling technologies and approaches, and at capacity building and training of regional scientists. The workshop included extensive instruction in model development. The workshop participants split into four regional groups and as part of the workshop developed preliminary models on four subjects: a) Amman-Zarqa Basin agricultural water use conservation approaches in Jordan; b) hydrological dynamics in the Syr Darya in Central Asia; c) restoration of Mesopotamian Marshes in Iraq; and d) transboundary water sharing issues in the Tigris-Euphrates Basin. This project grew from a collaboration between SNL and UNESCO on the development of a water-energy-food model for Iraq. This project yielded four working models and has led to continued collaboration with various partners.

Great Man Made River Basin, Libya: The country of Libya faces severe water shortages and is actively working on reducing demand and increasing supply. SNL scientists held a single "demonstration" modeling workshop with 26 participants from Libya's General Water Authority, the Renewable Energy and Water Desalination Research Center, the Libyan Petroleum Institute, and the Libyan Information Technology and Programming Center. Efforts during the workshop led to the development of a preliminary model of water resources and their interaction with agricultural and energy dynamics. All data values in the model derived from input from workshop participants and literature available at the workshop. These efforts led to the development of a full scale water-energy-agriculture modeling project planned to begin in late 2008. This project will include multiple workshops aimed and model development, capacity building and creation of draft development and implementation plans.

Annex 6

Technology Tables

Introduction to the Technology Tables:

The technology tables address existing and near-term potential technologies for water, agriculture and energy, in the following categories.

Water
- Water storage
- Water distribution
- Water source
- Treatment of groundwater
- Treatment of brackish groundwater
- Treatment of surface water
- Wastewater treatment
- Wastewater reuse

Agriculture
- Plant selection and breeding
- Tillage
- Irrigation designs
- Pest management
- Harvest technologies
- Greenhouse technologies
- Aquaculture
- Post harvest technologies
- Food processing

Energy
- Electric power generation
- Energy efficiency
- Transportation fuels

The information in the tables is organized hierarchically. Some sections begin with small-scale applications (e.g., household), and lead to large-scale applications (e.g., large community). Others begin with basic technologies and lead to advanced. These distinctions are noted in the tables.

These tables are a work in progress. The authors do not assume that these tables are complete.

WATER TECHNOLOGIES

Water Storage		
Technology	**Process**	**Notes**
General		Effective storage supports clean water for many uses.
Water Storage: Household	Roof Tank	Frequently used to supply all non-drinking household water under pressure. The tank is often black plastic and warms the water during the day. Is often used in conjunction with a barrel for drinking water, and a cistern to fill the tank. Pump to fill the tank is often small photovoltaic powered pump that runs all day.
Water Storage: Household	Cistern	This is usually either at grade or below grade and is usually not a sealed vessel. Water from this storage device is usually disinfected prior to use. (See household disinfection of water.)
Water Storage: Household	Barrel	Sealed suitable for potable use water. Often used to provide water for crock. Wagon or trailer transport to source or larger tank comes to barrel and fills it. Must prevent contamination in transit and at home. Education is key to good hygiene.
Water Storage: Household	Crock	Clay pot in kitchen to provide household potable water, cooled by crock sweating. Must prevent contamination in transit and at home. Education is key to good hygiene.
Water Storage: Small Community	Standpipe	A vertical pipe that provides pressure and a minimum of storage. No fire protection. Common in very small systems.
Water Storage: Small Community	Elevated Storage (water tower)	Elevated tower provides both storage and pressure.
Water Storage: Small Community	Pressure tank	Usually for small service areas, a ground level pressurized tank provides storage and pressure. May have a bladder to prevent gas exchange or without a bladder to encourage gas exchange. Overall maintenance and upkeep of all these small community solutions can be problematic without strong community support and local ownership.
Water Storage: Medium Community	Small water tower	Elevated tower provides both storage and pressure.
Water Storage: Medium Community	Ground level storage and pumping	Unpressurized ground-level storage tank with high service pump. These were common in countries assisted by the former Soviet Union. Commonly had problems associated with pressure regulation.
Water Storage: Large Community	Impoundment reservoirs	These are usually to capture run-off upstream from the community. They can act as a combination of water resource and flood protection. There should always be a spillway provided. Filtration usually is provided after the reservoir.
Water Storage: Large Community	Elevated tanks	Elevated tanks provide storage and pressure without undue attention other then periodic maintenance. This is the common means of providing pressure in waster distribution systems world wide. The decision to provide fire protection is based on local policy.
Water Storage: Large Community	Ground level storage	See previous. The Soviets also had a tendency to use a large number of subsurface pumping reservoirs instead of a water tower. The thought was the water towers were easy to see and thus were targets for military aggressors. This design approach created a need for a large number of pumps, valves, and operators to provide uniform pressure over the system. These systems may require a large cash investment before they are truly operable, since many of them are well past the useful life of their distribution system. Many of these systems also have challenges getting parts since their currencies tend to be soft.
Water Storage: Large Community	Water-Energy nexus	Water can be pumped at night to higher storage elevation when electricity rates and water usage are low and then allowed to flow down during the day when water usage is higher. Turbines could be included to capture energy when water is flowing back down. This could also be done with reclaimed water or reused water.

Water Distribution		
Technology	**Process**	**Notes**
Water Distribution: Household	Crock in Kitchen	For these small-scale container solutions, contamination must be prevented. Education is a key to good hygiene.
Water Distribution: Household	Water bottles	
Water Distribution: Small Community	Cart/Barrel	
Water Distribution: Small Community	Centralized hydrant	
Water Distribution: Small Community	Urban Cluster hydrants	
Water Distribution: Small Community	Pressure distribution system	
Water Distribution: Medium Community	Urban Cluster hydrants	
Water Distribution: Medium Community	Pressure distribution system	Losses from leaky distribution can be very large, exceeding 50 percent in extreme cases. Contamination entering leaky systems can also be a threat. These comments apply to both medium and large communities.
Water Distribution: Large Community	Pressure distribution system	If a distribution system does not currently exist, it is very expensive to build water distribution infrastructure. Although local materials are desirable, it is suggested that any new distribution systems should be constructed of PVC pipe. PVC has the advantage of resisting corrosion, which provides long-term service with low probability of water loss and cross contamination. If the community is one of many that received Soviet aid prior to the collapse of the Soviet Union, the distribution system must be carefully evaluated. The Soviets had a development philosophy which encouraged using mild steel pipe, considering replacement in 20-30 years less expensive then installing a 100 year life product (cast iron pipe or PVC pipe).
Water Distribution: Large Community	Leak Detection	Sound based system, water escaping through pinhole in pipe makes noise; sound detector, hand held, detects leaks.

Water Source		
Technology	**Process**	**Notes**
	Groundwater	Groundwater is almost always safer then surface water from a public health perspective. Proper placement of septic systems is critical.
	Freshwater distributed source	Distributed source/treatment with a well field spread through a portion of the service area with treatment done at the well head.
	Freshwater centralized source	Centralized treatment where all of the water is brought to a central location, treated and redistributed after treatment.
	Brackish groundwater source	Options under fresh groundwater also hold here; higher tech treatment than fresh water; is not recharged and thus is a mining activity.
	Surface water	The single most important concern with regard to public health and potable water is pathogens that will cause death in a short period of time. Surface waters represent a major risk particularly when upstream wastewaters are not handled adequately.
	Sea water	Essential source for large scale desalination. Large energy consumption and brine production both present difficulties.

Treatment of Groundwater		
Technology	**Process**	**Notes**
	No Treatment	Developing country's first goal of water treatment should be low energy/low tech.
Treatment of Groundwater: <u>Household</u>	Chlorination	Effective at inactivating bacteria and viruses. Can be packaged to easily add to water at point-of-use. In four trials, chlorination "reduced the risk of diarrheal disease by 44–84 percent." Low concentration of chlorine solution means minimal environmental impact. Continued protection against contamination after discontinued use. Very low cost—a 250mL bottle can be produced for $0.34. Lantagne, Daniele, Robert Quick and Eric D. Mintz, "Household Water Treatment and Safe Storage Options in Developing Countries," a report by the Wilson Center. The disinfection can be done at a barrel level as well as at a small bottle scale. Bad taste is a deterrent. Education is key.
Treatment of Groundwater: <u>Household</u>	Solar Disinfection	Plastic soda bottles are filled with water, placed on a roof or other high-sunlight areas, and left in the sun. Virtually cost-free. Reduces bacteria by up to 97%. A German company called Georg Fischer AG provided the bottles for $0.80 per person, but discarded soda bottles work equally well. Reduces bacteria, protozoa, and viruses. One of the few processes that reduces viruses. Easy to use. No negative impact on water taste or appearance. Water consumed directly from bottles. Lantagne, Daniele, Robert Quick and Eric D. Mintz, "Household Water Treatment and Safe Storage Options in Developing Countries," a report by the Wilson Center. Hourly variation in sunlight can impact treatment times, so treatment must be monitored.
Treatment of Groundwater: <u>Household</u>	Filtration	*Slow-sand filter:* Can be done with locally-available, inexpensive materials. *BioSand Filter (BSF):*  A Bolivian study found a 64% decrease in diarrhea incidence with BSF. Can be used at the household level. Concrete container filled with sand. Testing shows a reduction in bacteria by 81–100%, and in protozoa by 99.98–100%. One time unit costs to implement $67. Easy to use. Little maintenance required. Long life. *Ceramic Filters:* Potters for Peace© filter, shaped like a flower pot. 20–30 liter plastic or ceramic bin with a tap. Filters bacteria, then the colloidal silver in the bin inactivates the bacteria. Filters 99.99% of protozoa. Filter lasts a long time. Low cost due to use of local materials. Lantagne, Daniele, Robert Quick and Eric D. Mintz, "Household Water Treatment and Safe Storage Options in Developing Countries," a report by the Wilson Center.
Treatment of Groundwater: <u>Household</u>	Combined filtration/ chlorination	Uses two buckets, collect water in top bucket, add chlorine, water is then filtered through to bottom bucket. Reduces bacteria enough to meet WHO guidelines. Residual protection. Easy to use. Lantagne, Daniele, Robert Quick and Eric D. Mintz, "Household Water Treatment and Safe Storage Options in Developing Countries," a report by the Wilson Center.

Technology	Process	Notes
Treatment of Groundwater: Household	Combined flocculation/ chlorination	Proctor & Gamble has developed a PūR Purifier of Water system, consisting of a sachet filled with ferrous sulfate (the flocculant) and calcium hypochlorite. Add contents of sachet to 10 liters of water, mix, let the solids settle, strain through cotton cloth, wait 20 minutes, drink. Removes particles and disinfects. High removal rates of bacteria, protozoa, and viruses, even in highly contaminated water. Up to 90% diarrhea incidence reduction. Can also remove heavy metals like arsenic. Can be produced for $0.035 per 10 liters (sachet). No concern about carcinogen effects of chlorine because the flocculant removes all chlorine residue. Lantagne, Daniele, Robert Quick and Eric D. Mintz, "Household Water Treatment and Safe Storage Options in Developing Countries," a report by the Wilson Center. Mildly bad taste and discoloration can be a deterrent; education is key.
Treatment of Groundwater: Small Community	Slow sand filter	This doesn't work well for pathogen removal from shallow groundwater unless some coagulant is also added. The layer of material removed (smudzdeck) actually does the filtration, not the sand. Thus really clean water is difficult to treat. This technology works much better for surface waters with some turbidity.
Treatment of Groundwater: Small Community	Coagulation/ rapid sand filter	Small communities have great difficulty with the coagulant dosing, filter maintenance, and ongoing cash outflow for coagulant.
Treatment of Groundwater: Small Community	Rapid sand filters with specialty media (Activated Alumina, BIRM, MGS)	Small communities have great difficulty with the chemical dosing, filter maintenance, and ongoing cash outflow for coagulant, chemical feed, and media replacement as needed.
Treatment of Groundwater: Small Community	Coagulation/ rapid sand filter	Small communities have great difficulty with the coagulant dosing, filter maintenance, and ongoing cash outflow for coagulant.
Treatment of Groundwater: Small Community	Rapid sand filters with specialty media (Activated Alumina, BIRM, MGS)	Small communities have great difficulty with the chemical dosing, filter maintenance, and ongoing cash outflow for coagulant, chemical feed, and media replacement as needed.
Treatment of Groundwater: Medium Community	Slow sand filter	A medium size community may have the resources to add coagulant required for pathogen control in shallow groundwater. (See previous comments on slow sand filters above.)
Treatment of Groundwater: Medium Community	Coagulation/ rapid sand filter	This is one of the best medium community technologies if a fixed coagulant dose will remove contamination of interest, filter maintenance, and ongoing cash outflow for coagulant are still a concern. This technology is useful in limited inorganics removal and pathogen removal.
Treatment of Groundwater: Medium Community	Rapid sand filters with specialty media (Activated Alumina, BIRM, MGS)	Medium communities may need assistance with setting the initial chemical dose, filter maintenance, and ongoing cash outflow for coagulant, chemical feed, and media replacement again can be a challenge. This technology is useful in inorganics removal, pH adjustment, and pathogen removal.

Technology	Process	Notes
Treatment of Groundwater: Large Community	Coagulation/ rapid sand filter	This is an excellent large community technology. This technology is useful in limited inorganics removal and pathogen removal.
Treatment of Groundwater: Large Community	Rapid sand filters with specialty media (Activated Alumina, BIRM, MGS)	Excellent large community technology. This technology is useful in inorganics removal, pH adjustment, and pathogen removal.
Treatment of Groundwater: Large Community	Ion Exchange	
Treatment of Groundwater: Large Community	Membranes (RO, Tight Nanofiltration)	

Treatment of Brackish Groundwater		
Technology	**Process**	**Notes**
Treatment of Brackish Groundwater: Household	Solar Still	The solar still requires constant maintenance. If you let still go dry while in the sun precipitate films forms on surfaces. This may or may not be a serious problem depending on the still design.
Treatment of Brackish Groundwater: Small Community	Ion exchange treatment train (very small system)	Community resources for media replacement and regenerant are required. Sophisticated operational staff is required.
Treatment of Brackish Groundwater: Small Community	Solar Still	See previous comments. There are a number of successful community-scale solar still projects. Better at a small community scale since more to share in oversight.
Treatment of Brackish Groundwater: Medium Community	Reverse Osmosis (RO)/Tight Nanofiltration	Improvements have reduced power requirements and lengthened membrane life. Membrane replacement every 7–10 years, chemical cleaning multiple times/year. Microfilter prefilters need to be changed on a regular basis. May need a hydrocyclone for sand removal. Computer management is common, so some familiarity with computers is required. Removes inorganic dissolved materials and pathogens. Requires high degree of training for operation and maintenance.
Treatment of Brackish Groundwater: Large Community	Electricity-powered desalinations (nuclear and solar)	Costs just as much, or slightly less, than traditional fossil fuel-powered desalination, without the harmful environmental effects. Nuclear desalination plants have been operating in Kazakhstan and Japan. A Mobile Solar Water desalination has been developed by Puredrop Israel, based in Haifa, and is available for individual household use. www.uic.com.au/nip74.htm www.export.gov.il/Eng/_Articles/Article.asp?ArticleID=1266&CategoryID=593 Stills frequently do not respond well to being run dry and may have significant maintenance involved. Especially critical is de-scaling activities that may be chemical intensive. High capital costs, and high degree of training required for operation and maintenance. Also presents a proliferation concern.

Technology	Process	Notes
Treatment of Brackish Groundwater: Large Community	RO/Tight Nanofiltration	See previous comments.
Treatment of Brackish Groundwater: Large Community	EDR	Has many of the benefits and short comings of RO. Removes dissolved inorganics, but does not remove pathogens.
Treatment of Brackish Groundwater: Large Community	Traditional distillation	Typically very expensive due to energy cost. Long record of use, so strengths and weaknesses are well established.

Treatment of Surface Water		
Technology	**Process**	**Notes**
General		Highest probability of pathogen contamination, makes disinfection a very high priority.
Treatment of Surface Water: Household	See previous comments under filtration, combined filtration/chlorination, combined flocculation/ chlorination, chlorination, and solar disinfection discussed under Treatment of Groundwater.	Hygiene is critical, education is key.
Treatment of Surface Water: Small Community	Slow sand filtration	See previous comments under slow sand filtration discussed under Treatment of Groundwater.
Treatment of Surface Water: Small Community	Rapid Sand Filtration (Direct Filtration, Inline Direct Filtration, declining rate filtration or influent flow splitting) with disinfection	With appropriate source water this is a suitably simple technology, but if there is significant pretreatment required due to high turbidity, algae, or color, the system can be operationally very complex. Metal salts (alum and iron) are most widely used and best known.
Treatment of Surface Water: Medium Community	Slow sand filter with disinfection	See previous.
Treatment of Surface Water: Medium Community	Rapid Sand Filtration (Direct Filtration, Inline Direct Filtration, declining rate filtration or influent flow splitting) with disinfection	See previous.
Treatment of Surface Water: Large Community	Conventional Filtration Plant (alternate technologies include ballasted flocculation, dissolved aeration, conventional clarifier or a plate settler). Declining rate filtration or influent flow splitting. Direct Filtration. Inline Direct Filtration	See previous comments The decision to use inline filtration, direct filtration, or conventional filtration is a "dirt load" question. However, leaving in sedimentation basins and flocculation always improves the removal of pathogens. There is always a trade off between chemical usage, cast, and operational complexity.

Technology	Process	Notes
Treatment of Surface Water: Large Community	Cake filtration (DE) with body feed	Another system that ranges from operationally complex to extremely simple depending on use strategy. Must have a source of cake; diatomaceous earth, perolite. System that requires regular maintenance.
Treatment of Surface Water: Large Community	Coagulation microfiltration	Similar to conventional filtration, but the rapid sand filter is replaced with a microfilter or ultrafilter. Membrane replacement and cleaning are a concern. Other previous comments on coagulation and membranes should be considered in this application also.

Wastewater Treatment		
Technology	**Process**	**Notes**
General		All comments here apply to residential wastewater. Any application that includes industrial high strength commercial wastewater need to consider nutrient balance and toxicity issues. Influent waste strength is a function of per capita water use. Regardless of water consumption, each human being generates a certain mass of BOD each day, the water consumption provides the dilution water that sets the waste strength. In the U.S., BOD is roughly 250 mg/L in a larger community and 350 mg/L in a small community. In Mexico it is very similar. However, in Yemen, the waste strength will exceed 1200 mg/L. These differences will have a significant impact on technology selection and sizing. In a small remote community the system of choice will have no maintenance and no energy consumption. In general: No Treatment is not an option in wastewater.
Wastewater Treatment: Household	Pit Privy	Forest service has some new well thought out designs that are seeing significant use in Mexico. These control flies as a disease vector and control odors. Hygiene is critical, education is key. Privy's and all septic systems must be sufficiently separated from water sources.
Wastewater Treatment: Household	Septic tank/ drainfield	This is a solid liquid separation with anaerobic treatment followed by secondary treatment in the soil column. If there is suitable separation between groundwater and bottom of the drainfield, these work very well for low density applications.
Wastewater Treatment: Household	Facultative pond	Very effective treatment, but should be controlled access, especially the first pond in the system if it is a multiple pond system.
Wastewater Treatment: Household	Composting Toilets	This is a labor intensive, high maintenance system. The user must have some minimal level of understanding if the system is to be successful. It also has potential to place the user in direct contact with pathogens. Having said that there are some very good things about this technology. *Batch System:* Container is filled, set aside, then replaced with another. Composting occurs inside sealed container after replacement. *Continual Process System:* Constant state of composting. Composting waste moves down. Use composting and dehydration. End-product is a valuable soil additive. Cause no environmental damage. Require little to no water (20–50% reduction in water use). Air flow is designed to eliminate odor. Reduces potential human infection compared to spreading raw sewage on the land. Recycles plant nutrients. Can be used in locations not accessible to traditional sewage, such as rocky areas, high water table, areas with no water storage facilities, and swamps. www.compostingtoilet.org
Wastewater Treatment: Small Community	Septic tank/ drainfield	See previous comments.
Wastewater Treatment: Small Community	Anaerobic Treatment	If the influent waste strength is greater then 350 mg/L BOD anaerobic pretreatment should be considered. See following comments under medium size community.

Technology	Process	Notes
Wastewater Treatment: Small Community	Facultative pond	The lagoon or pond is a passive systems designed based not on a biological reaction rate, but on the rate at which oxygen is passively transferred into the system. This passive transfer rate, which is expressed as an areal BOD loading per day, should be corrected for elevation and temperature. Most mass loadings are established for mean sea level and as an example at an elevation of 8,000 feet above sea level must be reduced by 25%. For an increase in temperature of 10 degrees, the loading rate must be decreased another 18%. Ponds can be designed to be zero discharge (except for ET), intermittent discharge, or continuous discharge. Discharge can be either to a receiving stream or to a subsurface drainfield depending on the size of the system.
Wastewater Treatment: Small Community	Advanced Integrated Pond System (AIPS)	This is very similar to the facultative pond system, but approximately half as large. There is an anaerobic cell imbedded in the first pond that reduces the over all BOD loading by approximately half. The facultative portion is designed as usual, taking into account the reduction in loading from the anaerobic cell. One advantage of the AIPS over the facultative lagoon is the nearly complete removal of cysts which breaks the parasite cycle, if the design is done correctly.
Wastewater Treatment: Small Community	Constructed wetlands; vegetated bed submerged flow and free water surface	The wetlands systems are a passive system in the energy sense, but they are also a system that takes attention if they are to function correctly. They are as maintenance free as a healthy garden. The submerged vegetative bed wetlands for developing country use should have a large media under the pea rock cap and the width should be significantly longer then the length to minimize plugging. Vegetation harvesting can either be done annually or more frequently by hand or can be done annually using fire.
Wastewater Treatment: Medium Community	Anaerobic Treatment	If the influent waste strength is greater then 350 mg/L BOD anaerobic pretreatment should be considered. Treatment can vary from free standing anaerobic ponds to sealed fixed film anaerobic reactors using pieces of pvc pipe as media. Care must be taken to avoid plugging with grit or biosolids. Odor must be considered. It is common with anaerobic ponds to recirculate final effluent and pump a layer of aerobic water on the top of the anaerobic pond to contain the odor. The recirculated water in a warm climate will form a layer on top. This technique does not work well in a cold climate.
Wastewater Treatment: Medium Community	Facultative pond	See previous comments.
Wastewater Treatment: Medium Community	Advanced Integrated Pond System (AIPS)	See previous comments.
Wastewater Treatment: Medium Community	Constructed wetlands	See previous comments.
Wastewater Treatment: Medium Community	Hybrid mechanical system	System that may require energy input, increased maintenance, increased operational attention, or any combination of the following: - Aerated pond systems - Dutch ditch - Oxidation ditch or race track) - Biotower or trickling filter

Technology	Process	Notes
Wastewater Treatment: Large Community		Appropriate technology is a strong function of required effluent quality. If an influent BOD of 1250 mg/L can be reduced to 300 mg/L, it may be practical to use an anaerobic fixed film system. This would allow treatment without recirculation pumps or electricity for aerators. If an effluent BOD of 25 mg/L is required, there is no possibility of using an anaerobic technology. Local regulations will drive technology selection. It is not possible to preselect appropriate technologies if the treatment goals are unknown.
Wastewater Treatment: Large Community	Full mechanical plant: - Activated Sludge - Bio tower	Worldwide, large systems need to seriously consider traditional mechanical plants for wastewater treatment. The full-scale mechanical plant uses electricity and operational complexity to provide a smaller plant footprint and operational flexibility. There is a great deal of experience world wide in operating full-scale mechanical plants. In Quarshi, Uzbekistan, population 250,000 people, there is an activated sludge plant designed and built by the Soviets that appears to have come right out of Metcalf and Eddy. Unfortunately, due to cost and availability of parts, approximately half of the facility was not operating when the author visited the plant. One must constantly be aware of local parts availability and currency issues.
Wastewater Treatment: Large Community	Hybrid mechanical systems	See previous comments.
Wastewater Treatment: Large Community	High tech systems: - Sequencing batch reactor - Pure Oxygen Activated Sludge - Membrane Bio Reactors - Biological nutrient control systems (Bardenpho,4 and 5 stage systems)	The high tech systems for various reasons are probably inappropriate in a developing economy.

Wastewater Reuse		
Technology	**Process**	**Notes**
Wastewater Reuse: Household	Graywater Recycling System	Plants can grow well with used water since it contains many nutrients. Low fresh-water use. Practical for disconnected, rural areas.
Wastewater Reuse: Small and Medium Community	Reuse of treated wastewater	There is very little opportunity for a small community in a developing country to do reuse of treated wastewater. The educational base related to pathogen transmission is not present. If water is to be reused in this environment, the system must be completely self sustaining and must be fail proof. This is very difficult. Any system proposed should be put through a failure analysis in which the engineers and planners develop perspective failure scenarios. Ideally a system fails by shutting off, but in passive systems, this seldom happens; they usually fail through exposing downstream users to pathogens.
Wastewater Reuse: Small and Medium Community	System of ponds	On of the few reasonable systems in this setting is a series of ponds that both treat and disinfect wastewater passively. The series would have a minimum of 4–5 ponds in series. The ponds would consist of: either an anaerobic or a facultative pond followed by two facultative ponds, followed by two aerobic ponds. The facultative ponds will have a maximum depth of 2 meters and a detention time of at least 100 days. The two aerobic ponds will have a maximum depth of 0.66 meters. The aerobic ponds are really for disinfection. The final aerobic pond can be used for irrigation, construction water, or aquaculture.

Technology	Process	Notes
Wastewater Reuse: Large Community	Purple pipe and indirect potable	This is a parallel system. May be applicable if the technology base is present. The challenge as always is the strength of the local currency and the availability of parts in a technology-poor economy. Again, a failure analysis is critical for any system being considered.
Wastewater Reuse: Large Community	Purple pipe: advanced biological with filtration: Activated sludge/filtration Biotower/filtration SBR/filtration Membrane Bio-Reactor (MBR)	The goal is not to remove all BOD and nutrients. The goal is to consistently produce a water of high quality that can be effectively disinfected. BOD and nutrients are not a major concern as long as treated quality does not produce odor during irrigation.
Wastewater Reuse: Large Community	MBR/RO	For indirect potable reuse, as system that shuts down in failure is very desirable. The system listed here is an example of two membrane processes that foul and shut down if not properly cared for. Major expense and operation expertise associated with this type of system.
Wastewater Reuse: Large Community	Aquifer recharge	Good potential storage location. Contamination of groundwater is an important issue.

AGRICULTURE TECHNOLOGIES

Plant Selection and Breeding (Basic)		
Technology	**Process**	**Notes**
Seed selection	Analytical seed selection of traditional crops exhibiting desirable traits	Compromises food reserves with portion of yield committed to seed.

Plant Selection and Breeding (Intermediate)		
Technology	**Process**	**Notes**
Improved varieties	Scientifically bred for pest, drought, and disease resistance and higher yield	Traditional crops may offer uses other than food, e.g., forage, fuel, construction, etc., which improved varieties may not compliment.

Plant Selection and Breeding (Advanced)		
Technology	**Process**	**Notes**
Genetically modified varieties	Engineered for improved human nutrition and disease immunization, pest resistance, pesticide applications	Typically non-sustainable sterile seed secured from commercial source.

Tillage (Basic)		
Technology	**Process**	**Notes**
Long-handled tillage tools	Reduce stoop and kneel practices of primitive cultures	Addresses human ergonomics and orthopedic maladies.
Improved animal drawn implements	Design considerations for specific draft animals; modern material construction	Increase draft animal efficiency/productivity for non-mechanized systems. Plow beam and frog designs may be unique for animal species. Plow share and moldboard designs could be improved for many cultures.
Improved primary tillage equip. designs	Modernization of deep tillage and seedbed preparation equipment	Improves soil tilth, increases humus, liberates nutrients.

Tillage (Intermediate)		
Technology	**Process**	**Notes**
Secondary tillage equipment	Provides options for improved management practices	Less energy requirements, improves pest controls, conserves moisture, etc.
Mechanized systems	Internal combustion power units for improving and expanding tillage operations	Expands pest control options, allows non-tillage mechanized complimentary operations, reduces labor inputs. Displaces labor, consumes energy, requires commercial support, increases fixed and variable costs.

Tillage (Advanced)		
Technology	**Process**	**Notes**
Minimum and No-Till systems	Management of residue for mulch	Reduces soil erosion, increases soil organic matter, facilitates alternative pest controls, conserves soil moisture, reduces fuel inputs. Loss of crop residue for non-food requirements, e.g., fodder, fuel, etc.
Plant growth models	Computer decision support tools	Provides decision options for water, pest, nutrient management, and yields.

Irrigation Designs (Basic)		
Technology	**Process**	**Notes**
Gravity flow design: Open channel diversions	Acequia model, community ditch systems	Contingent upon seasonal stream flows; flow diversion structures essential.
Gravity flow design: Rainfall capture and harvesting techniques	Collection and storage from constructed surfaces	Best used to supplement small rain-fed plots during drier periods.
Gravity flow design: Engineered entrapment structures and water diversions	Pond and reservoir storage with conveyances to adjacent plots. Delivery to low-pressure piped system	Requires dedicated land area and ditch construction. Can be compatible with wastewater re-use. Requires dependable water source flow or storage.
Gravity flow design: Transit leveled fields	Field scale elevations used to determine leveling needs for flood and rainfall irrigations	Arguably the single most important practice affecting flooding efficiency. Engineered slopes on small scale terracing can effectively divert run-off, optimizing capture and infiltration.

Irrigation Designs (Intermediate)		
Technology	**Process**	**Notes**
Pressurized design: Controlled delivery of aerial or surface discharge irrigation	Pumped to sprinklers, gated pipe, bubbler, or other form of application device	Energy requirements, supply, and infrastructure needs (spare parts, well drilling, etc.). Should be compatible with protection of drinking water sources.

Irrigation Designs (Advanced)		
Technology	**Process**	**Notes**
Micro irrigation designs	Efficient low flow delivery by regulated emitters at precise locations	Capital costs substantial, water conservation and increased yields conversely related, advanced operator skills required, water quality criteria operative. Can be maintained by solar energy design where limited lift is required
Remote/electronically controlled systems	Sensors determine soil/water/ plant needs to schedule irrigations	Compatible with various mechanical designs. Remotely sensed and farm level sensors provide stress level indicators (data) to determine irrigation timing. High technical skill level required.

Pest Management (Basic)		
Technology	**Process**	**Notes**
Crop rotations	Removes host plant to control population	For *Crop rotations* through *Trap and reppellent crops*, all these 'technologies' are processes of learned knowledge. Application is more a function of practice rather than materials.
Pest exclusions	Net and screen material	
Process for pest ID	Taxonomic processes	
Process for determining acceptable thresholds	Allowing limited damage without risking health or return	
Trap and repellent crops	Non-crop vegetative controls	
Cultivation	Mechanical controls	
Pest habitat control	Management of residues, over-wintering shelters, perimeters, etc.	Labor intensive, good management practice at low infestation levels of pests known to be undesirable. Contributes to preventive measures, minimizes spread of limited mobility pests.

Pest Management (Intermediate)		
Technology	**Process**	**Notes**
Resistant crop varieties	Genetically resistant plants	
Chemical controls	Specific chemical compounds to control known target pests	Obvious human health and environmental risks when used by unskilled applicators.

Pest Management (Advanced)		
Technology	**Process**	**Notes**
Biological controls	Introduction of natural pest enemies	Known beneficials are laboratory reared for release on target pests.
Infrared and remote plant stress monitors	Handheld, aerial, and satellite monitoring of pest stress	Field scale scouting and control of pest outbreaks before becoming wider spread.

Harvest Technologies (Basic)		
Technology	**Process**	**Notes**
Ergonomically designed hand harvesting tools	Improve efficiency of human labor harvesting with safer, efficient hand tools	Potentially inefficient and unsafe practices caused by poor selection and accessibility of hand harvest tools.
Load handling and transport equipment	Introduce simple designs of pulleys, levers, fulcrums, screws, etc.	Determine load handling needs to design simple machines using available materials to reduce stressful labor.

Harvest Technologies (Intermediate)		
Technology	**Process**	**Notes**
Mechanized systems	Identify labor intensive tasks adaptable to small scale mechanized operations	Animal drawn, ground wheel drives, small engine powered, wind powered, falling water wheels, etc. Specific tasks may be widely adaptable to various mechanized designs.

Harvest Technologies (Advanced)		
Technology	**Process**	**Notes**
Modernized machinery and equipment	Introduce complex harvesting machinery	More appropriate for large operations requiring more horsepower output capacity, faster harvest to reduce losses, longer post-harvest transport, and other logistical concerns.

Greenhouse Technologies (Basic)		
Technology	**Process**	**Notes**
Hot house	Small scale germination sheds for transplant production	Simple construction with local materials. Transplants provide a head start for earlier season crops. May result in double cropping seasons.

Greenhouse Technologies (Intermediate)		
Technology	**Process**	**Notes**
Hoop construction	Year round production of high value crops	May provide cash crops, e.g., high value vegetables or non-food crops.

Greenhouse Technologies (Advanced)		
Technology	**Process**	**Notes**
Climate controlled	Sophisticated designs allowing wide selection of crops grown in controlled environment	High quality produce, can lower production costs, capital costs increased, will increase energy costs.
Hydroponic	High value production in artificial mediums	High yields, high inputs, useful where premium markets can provide returns.

Aquaculture (Basic)		
Technology	**Process**	**Notes**
Fish in a tank or farm pond	Stock earthen tank with or without inflow or simple farm pond stocked	A large range of water quality conditions that can support these basic and intermediate operations with koi or catfish.

Aquaculture (Intermediate)		
Technology	**Process**	**Notes**
Caged fish in farm pond	Greater control for feeding, harvest, disease management, and uniformity of product	

Aquaculture (Advanced)		
Technology	**Process**	**Notes**
Hatcheries	Highly controlled water quality, concrete tank, with medications, control breeding and growth, greater uniformity of product; higher production levels	

Post Harvest Technologies (Basic)		
Technology	**Process**	**Notes**
Washing/cleaning	Use clean practices for removing field/soil borne contaminants	Clean water source essential. Detergents very important.
Packing, storage and transport	Provide commodity specific needs for on- and off-farm practices for short-term handling	Essential supplies and materials should compliment grading, selection, cleaning, perishability, and pre-processing for long-term storage.
Ripening and de-greening	Pre-storage steps for handling fruits and 'soft' vegetables	May require temperature and humidity controls. Ripening must be interrupted prior to senescence. Longer storage requires processing.
"Root Cellar" storage facilities	Introduce storage options using natural environment	Optimize natural resources for food storage, e.g., cold water sources, subterranean cellars, rock/masonry designs, etc.

Post Harvest Technologies (Intermediate)		
Technology	**Process**	**Notes**
Grading and packaging facilities	Availability to grading, sorting, packaging facility with multiple produce capability	Communal facility benefiting local food needs and marketing economy.
Cold storage	Farm level cold storage	Solar powered refrigeration designs emerging.
Improved intermodal transport	Thermal transport containers to extend farm-gate to market life	Truck or trailer mounted boxes for ice packing, refrigeration, or other means of maintaining produce quality and expanding market territory.

Post Harvest Technologies (Advanced)		
Technology	**Process**	**Notes**
Chemical suppressants	Rooting and sprouting suppressed to prolong shelf life	Effective with certain crops. Compatible with long dormancy and proper curing.
Fungus/mold controls	Alternative methods to prevent stored food fungus and rotting	Simple techniques using chemical solutions. Options available for both fruits and vegetables.
Bioprocess Engineering (Bio-fuel)	Farm scale bio-diesel production from farm produce	Small scale technologies are improving. Contributes to reducing energy dependency and costs.

ENERGY TECHNOLOGIES

Technology	Process	Notes
Basic	Electric Power Generation, Energy Efficiency, and Transportation Fuels	Technologies identified should be appropriate to rural developing areas with minimal existing or expected infrastructure. Technologies need to be low cost, low maintenance, require lower technical sophistication to operate, enable flexible construction practices, require minimal electric power distribution infrastructure, and require low natural resource use such as water, energy, or land. Need to be affordable and sustainable.

Electric Power Generation (Basic)		
Technology	**Process**	**Notes**
Small hydro, kinetic hydro	Uses either small dams on tributary water sources or velocity of river or stream flows to generate 50–250 kW of electric power	- Emerging designs are being optimized for lower head or low flow hydro applications of 1–10 kW - Compatible with more rural or remote developing areas with low per capita energy needs - Renewable resource often requiring only minimal maintenance.
Small-scale wind turbines	Uses small wind turbines to meet individual home electric power needs or	- Significant emergence of small off-grid wind systems in the 0.5–1 kW range are appropriate for remote areas with low energy needs - Several can be easily connected to provide small-scale electric power - Intermittent resource will require energy storage, backup, and load matching for best performance.
Photovoltaics (PV)	PV panels convert sunlight directly into electricity	- Several emerging technologies are lower cost and lower maintenance - Low tech 100 W–300 W DC systems for rural or remote areas could provide low cost and low maintenance options - Since capital costs are high, need to carefully limit energy demands - Intermittent resource will require energy storage, backup, or load matching for best performance.
Local microgrid	Combines electric power resources into a local mini-electric grid	- Enables connection of distributed generation technologies such as wind, solar, diesel gen sets, etc., into an effective local electric grid requiring minimal electric distribution infrastructure. - Provides developing rural areas or small settlements with opportunities to pool energy generation resources to meet demands - Requires some minimal level of distribution infrastructure development or upgrades and load and demand management.
Combined heat and power	Uses waste heat for energy applications	- Low grade heat at remote locations can be used for cooling and refrigeration with minimal infrastructure - Cooling and refrigeration provide significant health and economic benefits in remote or rural areas.

Energy Efficiency to reduce energy demand (Basic)		
Technology	**Process**	**Notes**
Increased building energy efficiency	Improve building standards with increased energy efficiency objectives	- Low cost materials along with elementary design and building material modifications can reduce heating, cooling, and lighting demands significantly.
Solar hot water systems	Both passive and active systems	- Passive systems most applicable in remote or rural areas - One of the most effective renewable energy applications, often cost effective in most locales for individual residence hot water.
Low energy use lighting	Efficient lighting, LEDs	- Significantly reduces lighting electric power needsCompatible with low cost, low output energy systems in remote areas.

Transportation Fuels (Basic)		
Technology	**Process**	**Notes**
		Low cost transportation fuel alternatives for remote and rural developing areas will continue to be a major challenge. Many current approaches for alternative fuels are focused on high-tech solutions such as cellulosic ethanol, fuel cells, advanced batteries, etc., that are often not compatible with remote and rural economies, technology base, or energy and transportation infrastructures.
Intermediate	Electric Power Generation, Energy Efficiency, and Transportation Fuels	Technologies should be appropriate for small villages, communities, or towns with some existing infrastructure and industrial base to expand energy development. Technologies need to be of intermediate cost and sophistication since some experience and ability to operate these systems can reside in the communities. Still, simple, low cost, and low maintenance systems that are sustainable and affordable are needed that can be supported by a modest industrial capability.

Electric Power Generation (Intermediate)		
Technology	**Process**	**Notes**
Small hydropower	Consideration of small hydro as well as new run-of-river hydro approaches have many applications. Hydro is a good complement to support other renewables, such as wind and solar technologies, to better enable load matching.	- Small hydro can be 0.5–1 MW with very small dams on tributaries or dynamic hydro in channels with high flow velocities - In small developing communities, 1–2 MW can be a substantial electric power resource - Small hydro infrastructure development can be much less costly than large hydro development.
Intermediate Wind	While current technology focus is on larger wind systems, some small intermediate wind systems are being developed	- Appropriate for off-grid or more remote or localized applications like small developing communities with lower electric power demands - 50–100 kW systems available, may be a need for 100–300 kW systems but no major manufacturers - Larger communities might be able to support 10–20 MW of wind systems using advanced technology as economic development base - Will require some industrial or technology base to maintain systems.
Solar power	Both PV and trough concentrating solar systems can provide reasonable electric power supplies	- Small systems in the 100 kW – 500 kW range are becoming attractive and take about 1–3 acres of land - Two or three systems per small community tied with other resources could be a substantial resource.
Waste to energy	Waste to energy can be in many forms, agricultural, domestic, or industrial wastes that can be used for combined heat and power	- Emerging technology development in smaller waste to energy systems compatible with small community waste generation - Provides opportunities to address waste related health issues with processes to generate both electricity and steam for district heating, cooling, or small industrial processes.
Community microgrids	Combines electric power resources into a local mini-electric grid	- Enables connection of distributed generation technologies such as wind, solar, diesel gen sets, etc., within a small community into an effective local electric grid - Provides developing communities with opportunities to pool energy generation resources to increase electric power availability - Scalable to level of electric distribution infrastructure available or that can be developed in a small village, community, or city.

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Intermediate Wind	While current technology focus is on larger wind systems, some small intermediate wind systems are being developed	- Appropriate for off-grid or more remote or localized applications like small developing communities with lower electric power demands - 50–100 kW systems available, may be a need for 100–300 kW systems but no major manufacturers - Larger communities might be able to support 10–20 MW of wind systems using advanced technology as economic development base - Will require some industrial or technology base to maintain systems.
Solar power	Both PV and trough concentrating solar systems can provide reasonable electric power supplies	- Small systems in the 100 kW – 500 kW range are becoming attractive and take about 1–3 acres of land - Two or three systems per small community tied with other resources could be a substantial resource.
Waste to energy	Waste to energy can be in many forms, agricultural, domestic, or industrial wastes that can be used for combined heat and power	- Emerging technology development in smaller waste to energy systems compatible with small community waste generation - Provides opportunities to address waste related health issues with processes to generate both electricity and steam for district heating, cooling, or small industrial processes.
Community microgrids	Combines electric power resources into a local mini-electric grid	- Enables connection of distributed generation technologies such as wind, solar, diesel gen sets, etc., within a small community into an effective local electric grid - Provides developing communities with opportunities to pool energy generation resources to increase electric power availability - Scalable to level of electric distribution infrastructure available or that can be developed in a small village, community, or city.

Technology	Process	Notes
Small Nuclear Power	Emerging designs for small nuclear plants	- Current designs for 100 MW thermal, 25 MW electric nuclear power plants - Footprint is relatively small, buried 30 feet deep can provide both waste heat and electricity - Potential options for off-grid applications for remote cities to reduce infrastructure needs.
Waste to Energy	Waste to energy and combined heat and power (CHP) technologies are more appropriate in areas with large populations	- Large communities or cities generate extensive wastes that can be used for energy generation - Landfill gas, waste water treatment plant digester gas, or incineration or gasification of garbage can all be used to generate energy and heat - Waste heat and steam can be used for industrial processes.
Microgrids		- Minimizes need for large electric distribution systems to be developed and maintained - Enables local grids with distributed generation to function together with less central control - Minimizes need to large single power plants and the associated capital intensive operations and maintenance.

Energy Efficiency to Reduce Energy Demand (Advanced)		
Technology	**Process**	**Notes**
Increased building energy efficiency	Improve building standards with increased energy efficiency objectives	- Changes in building codes and design and building material modifications can reduce heating, cooling, and lighting demands significantly in larger cities - In many countries, new buildings could be made 70% more efficient than existing buildings.
Solar hot water systems	Both passive and active systems	- One of the most effective renewable energy applications, often cost effective in most locales for individual residence hot water - Reduce residential hot water energy by 40–80%.
Low energy use lighting	Efficient lighting, LEDs	- Significantly reduces lighting electric power needs, street lighting, traffic light energy needs, etc.

Transportation Fuels (Advanced)		
Technology	**Process**	**Notes**
Electric powered local transportation	With increased opportunities for electric power generation options for increased electric powered local transportation	- Community local transportation can be integrated with electric power generation infrastructure - Saves transportation fuels for more economic uses.
Biofuels	Competition for land, water, and food resources may limit applicability	- Cellulosic ethanol or algal biodiesel have better promise in developing areas to not impact agricultural lands or fresh water supplies yet provide alternative fuels - While still in infancy stage, these two might be better choices for developing countries to consider from a sustainability standpoint.

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