Energy, Water and Global Climate Change as a Regional Agenda of the Americas

Results of the Pan-American Advanced Studies Institute

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1 EXECUTIVE SUMMARY

This document is the result of a conference organized by the Pan American Advanced Studies Institute (PASI), funded by the US National Science Foundation and entitled "PASI 2010: Energy, Water, and Global Climate Change as a Regional Agenda of the Americas". The conference took place from May 23rd to 28th in San Diego, California, USA and from May 28th to June 3rd in Ensenada, Baja California, Mexico. Distinguished engineers, scientists, economists, policy makers, and others from a diverse range of backgrounds were invited. Several papers were presented on a very wide range of topics linking energy, water, and climate change in the Americas. All PASI 2010 participants are responsible for this report, and the immense amount of work to put this document together is acknowledged in the list of authors above. In addition, the conference could not have taken place without the help of our sponsors: the National Science Foundation, San Diego State University, and the Ensenada Center for Scientific Research and Higher Education, also known as Centro de Investigación Científica y Educación Superior de Ensenada**,** (CICESE).

The topics covered at the meeting signify the challenges in bringing together scholars from different research areas to collaborate on a large scale problem such as the impending energy and water crisis, and its effect on climate change. The problem was viewed from many angles, including economic, social, political, environmental and engineering prospective, among others. To present the culmination of our efforts, this document is structured in such a way as to facilitate digestion of information for the reader. To this end, we have segregated the document into three main parts, namely energy, water, and climate change, and discussed the interdependence on a number of platforms for each. Later, we attempt to bring together the ideas presented in each part to initiate discussion on viable solution procedures.

When discussing any of the main three topics, first we attempt to present our current understanding from a number of different angles. For example, when looking at the sustainable energy supply in the Americas, we discuss the inter-American energy market, current technologies in use, as well as energy policies and interests in the Americas. When discussing water supply and sustainability, the policies and political dynamics of water use, as well as the balance between water use and energy use and our view of the climatic effects they accrue, are presented. The current view on climate change, including energy balances, numerical modeling, and scientific trends, are also addressed.

The current techniques and results of various engineering and scientific works assessing energy and water use, as well as climate change, were discussed. Particular attention was paid to future challenges and concerns projected by the attending scholars. An attempt was made to categorize the more important challenges facing the linkage of energy and water uses, and climate effects. For example, fresh water is used during power production such as hydroelectric power generation. This introduces cross border water rights and treaties resulting in complex political issues. Such political challenges can be within national boundaries, and need not necessarily be cross-border. For example, due to the large amount of fresh water required for crop growth, water use for ethanol can have a serious impact on micro-climate. It can also have significant effect on food security, if it replaces food crops. Thus, the issue of energy, water, and climate change are firmly interlinked at many levels – a solution to one affects the others. Therefore, these interlinks must be discussed as comprehensive research agendas before viable solutions are proposed.

Once an understanding was created regarding the state of the problem, and challenges or concerns were elaborated upon, the future target areas were defined in each area, which takes into account the interdependence between resources, policies, and solutions. For example, the weaknesses inherent in many climate models are discussed, and suggestions made to increase validity of the results. Concluding that climate change trends are valid nonetheless, mitigation measures, policies, and economic cost of the predicted changes were discussed. Once the goals in each area are attended to, the complicated problem of linking these research studies commence.

Recapping, the linkage of energy, water, and climate change studies in the Americas is a complicated topic involving many features requiring a thorough inventory of the current state of knowledge. It calls for a steady progress of research with access to better data and more powerful analytical tools, to make accurate predictions. The culmination of this conference is a solution strategy, which combines energy, water, and global climate change, targeting the wellbeing of future generations. In summary, a greater understanding of the key important problems and solution strategies facing a sustainable future was garnered, and summarized in this document. The most important facet of the proposed solutions and strategies is, and will continue to be collaboration among governments, scientists, engineers, communities, etc., so that information can be disseminated seamlessly in order to ultimately share natural resources in a sustainable manner, to benefit all humanity, both for today and tomorrow.

2 OVERVIEW

While our understanding of the interdependence between human beings and the environment continues to grow, we believe a consensus has been reached to better manage this relationship in order to reduce our untenable impact on the environment, and design a more sustainable future. The levels of challenges facing the transformation of our industry through a sustainable development vary from region to region. Policies as well as resources dutifully committed by nations to address these challenges also vary from highly propitious to negligible. These inconsistencies suggest that a more cooperative approach is needed to recognize and duplicate the good deeds, and encourage the lagging ones. This approach recognizes the ardent need for a serious cooperation to rally for a global effort, addressing energy, water, and climate change issues as complex themes encompassing social, economic, and research platforms.

The relentless drive of humanity for economic growth, the accompanying need for energy and water as fundamental resources, and failure of the society to strive for comfort without polluting the environment, motivate us to address energy, water, and climate change as an interlinked regional agenda.

Geographic settings, cultural predispositions, and variables driving regional economic growth in a globalized market, i.e., policy formulations, cross-border flow of resources, and migration of the impacts of industrialization, make the need for transnational discussions an essential component of agenda for a sustainable future. These cross-border socio-political conditions are superimposed as aggravating factors on complex and multi-disciplinary subjects affecting our relationship with the environment, which we plan to address by contributing to our understanding of the consequences of ill-equipped resource exploitation on climate.

Mapping interlinks of energy, water, and climate change for regionally diverse conditions is spatially and temporally variable; a multi-dimensional problem requiring gross mobilization of resources and talents. The issues are mutually interdependent; water is needed to generate energy, and energy is required to treat and deliver water. The power generation process emits large amounts of pollutants to the environment. The entwined nature of these issues must be strategized with clarity that sifts through ideas and avoids flawed solutions. For example, biofuels have received a great deal of attention in recent years, and it is still not clear whether such fuels have a net beneficial effect on security and sustainability under all conditions. In order to provide acceptable and valid sustainable use strategies for energy and water, steps must be taken to improve efficiency, deploy a larger number of “clean” technologies, and design more creative ways to use finite and limited resources. This workshop is a step towards achieving this goal.

3 SUSTAINABLE ENERGY SUPPLY, STRATEGIC SOLUTIONS AND RELEVANCE

3.1 Current State in the Americas

Energy markets in the Americas face a trend of booming demand, particularly in developing economies where infrastructure improvements are greatly increasing electricity availability to rural populations. At the same time, the energy markets face a heightened scrutiny of the environmental effects of converting, transporting, and using energy. In this context, renewable energy and energy efficiency are of core importance as strategic solutions for the future of sustainable development in the Americas.

3.1.1 Transnational Grids

An electrical grid is a power network which supports all the distinct operations: electricity generation, power transmission, and distribution. A transnational grid refers to an electrical network belonging to more than one country or an entire continent. While current transmission networks are controlled in real time, in many American countries, they are antiquated compared with current standards, and unable to handle modern challenges such as the intermittent nature of alternative electricity generation, or continental scale bulk energy transmission. To address this issue, a smart grid is recommended to more efficiently manage local power networks (Hansen, 2008).

A smart grid is an upgrade of the current grids which “broadcast” power from a few central power generators to a large number of users (Kannberg, 2008). The smart grid is capable of routing power more effectively than the traditional grid, and it can operate in a wide range of load conditions. Smart grid systems are equipped with smart meters; electrical meters which record usage in much shorter intervals (an hour or two) and communicate usage information back to the utility. In essence, smart grids will have the ability to transport electric energy from power suppliers to consumers using two-way digital technology. Because of such two-way communication capability, the system can be set up to charge a premium to those end users that use energy during peak hours – a demand-driven pricing. The technology is capable of controlling appliances at customers' homes to save energy resulting in cost reduction, and also increase reliability (Marks, 2008). Such electricity network is promoted by governments of the Americas as a means to address energy independence, climate change, and resilience in power distribution, especially at times of crisis. The plans for upgrading electric power grids and connecting the Americas are discussed for each American region in the sections below.

NORTH AMERICA

The regulation of electric distribution in North America is enforced by a combination of state, provincial, and federal jurisdictions. In the United States, the Federal Energy Regulatory Commission (FERC) regulates rates and transmission of electricity in interstate commerce. FERC acts under the legal authority of the Federal Power Act of 1935, the Public Utility Regulatory Policies Act of 1978, the Energy Policy Act of 1992, and the Energy Policy Act of 2005. One of the most important current projects is the

Unified National Smart Grid, a proposal for a nation-wide inter-connection of smart grids relying on high capacity electric power transmission lines linking all the nation's local electrical networks, (Marks, 2008). An important international initiative is the Trans-Texas Corridor, extending from the US-Mexican border through the United States along I-69 and into Canada via Port Huron in Michigan. This transnational grid may be viewed as a U.S. counterpart to Plan Puebla Panama transportation initiatives. Plan Puebla Panama, also known as the Mesoamerican Integration and Development Project or Project Mesoamerica, is a multi-billion dollar development plan initiated in 2001, to integrate regional development of the southern states of Mexico with Central American countries as well as Colombia. As originally envisioned, the network would be composed of a 4,000-mile (6,400 km) network of super-corridors, up to 1,200 feet (370 m) wide to carry parallel links of toll ways, rails, and utility lines. The network would be funded by private investors and built and expanded as demand warrants.

MESOAMERICA

Mesoamerica is the region beginning from central Mexico and extending south, occupying all or part of the countries of Belize, Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica. The region has a unique opportunity to take full advantage of the economic opportunities presented by its strategic location between the two land masses of the Americas, as well as the regional grid trade agreements. However, to employ this, the region must overcome series of challenges that affect its competitiveness and strive for access to renewable and reliable power. Once such resources are secured, greater emphasis must be placed on the development of a fully integrated and networked power market, centered around the effectiveness of the two transnational grids, the Electric Integration System for Central America, (SIEPAC, see Figure 3.1) and the Puebla-Panama Plan, (see Figure 3.2). Together these two projects are also known as Mesoamerican Integration and Development Project. This multi-billion dollar development plan is intended to promote the regional integration and development of the nine southern states of Mexico (Puebla, Guerrero, Veracruz and all states situated south or east) with all of Central American countries and Colombia (Pickard, 2004).

Figure 3.1: SIEPAC interconnection grid (Source: Guatemala Energy)

The initiative was championed by Mexico and agreed to by the governments of the participating states. The Plan Puebla Panama and SIEPAC consist of transnational production and grid integration. The projects are ostensibly intended to promote investment and stimulate trade in the region by improving infrastructures such as electric and telecommunication grids. The proposed projects to take place along five principal corridors include:

- Pacific Axis, which supports majority of the regional trade,
- The Gulf of Honduras Axis, for trade between the Pacific side and the Caribbean region,
- The Peten Corridor for trade linking Puerto Cortes, Honduras, Villahermosa, and Mexico,
- The Mexican - Isthmus of Tehuantepec Corridor,
- The Guatemala - Yucatán Corridor.

By March of 2005, $7.7 billion in funding for the Plan Puebla Panama had been designated. This amount is eventually expected to rise to about $50 billion. The funding comes from regional governments as wells as the Inter-American Development Bank (IDB), Central American Bank for Economic Integration (BCIE), the World Bank, and other private sectors (Pickard, 2004).

Such cross-national projects can often be controversial, and their economic benefits will attract criticism. For example, SIEPAC and the Plan Puebla Panama are blamed for their "neoliberal model" of development, which is said to favor the interests of multinational corporations over those of local communities and the environment. There are also objections to transnational grids on the grounds that privatization of land, water, and public services is not necessarily in the interest of the people, and that the control of the region by foreign interests compromises the independence of the particular nation state.

The transnational grid, even with obvious technical and engineering benefits, is embroiled by political and environmental controversies primarily because of the nature of capital it attracts and negative impacts of power lines on the environment. The grids could impact rain forests and displace people who often have little or no voice in the development effort. Much criticism of Plan Puebla Panama is related to free trade agreements, including the North American Free Trade Agreement (NAFTA), Central America Free Trade Agreement (CAFTA), and the Free Trade Area of the Americas (FTAA) that facilitated this development (Pickard, 2004 and UCIZONI, 2006).

Figure 3.2: Plan Puebla Panama Grid (Source: Plataforma de Solidaridad Chiapas, 2005)

SOUTH AMERICA

The Initiative for the Integration of South American Infrastructure (IIRSA) is conceptually an expansion to the Plan Puebla Panama and Trans-Texas Corridor initiatives, aiming at linking transportation systems and reducing trade barriers to encourage the flow of people and goods throughout much of North and South America.

IIRSA is a project via which countries of the Andean Community attempt to further integrate their economies, especially by creating international grids connecting from Panama City in the north to major cities in South America. In September 2005, the Energy sector ministers, political leaders, and corporations convinced on the importance of energy integration agreed to advance the cooperation and administrative networking necessary to eliminate asymmetries in regional energy distributions. After such ambitious visions, however, the IIRSA project has been dormant since its original inception.

Growing demand for electricity throughout the Americas, especially in countries where the economy has exhibited relative growth over the last few decades, such as Brazil and Mexico, has helped to foster the interconnection of the region's electric grids. This growth trend is expected to continue as a result of increased trade links, and further deregulation of the electricity sector. Ease of restrictions to international investment and the development of cleaner, more efficient power plants will only bolster this trend.

However there are some political and infrastructural bottlenecks in the advancement of continental grids – mostly resulting from lack of uniformity in environmental impact analyses.

POSSIBLE GRID IMPROVEMENTS

The main projects for energy grid integrations are located in the border sectors of Mexico-Guatemala, Panama-Colombia, Colombia-Venezuela, and others South America countries. As of now, there seems to be sufficient political will to proceed with these projects. The main idea is to integrate the energy market of the Americas by interconnecting the power distribution systems in order to benefit from economies of scale and increase the reliability of the regional energy supply. The recent growth of the Latin American economies has created incentive to expand trade and develop international business agreements in these developing nations. It is hoped that these developments would favor the creation of transnational grids, which would in turn provide a more balanced position for these countries in the global economy. As economic cooperative and free trade agreements continue to increase among Latin American countries, for example the Latin American Free Trade Association (LAFTA), the Central American Common Market (CACM), and the IIRSA, it is likely that these international agreements will benefit the electric market, facilitating economic justification as well as bureaucratic support for transnational grids.

3.1.2 Renewable Energy Sources and the Inter-American Energy Market

RENEWABLE ENERGY TECHNOLOGIES

The natural energy flowing through the Earth's ecosystem is immense, and the capacity potential for human needs exceeds the current level of energy use by many folds. In this context, renewable energy and low carbon emission technology are firm alternatives for the future. Some of these alternatives include:

- Advanced vehicles with high energy efficiency such as hybrid cars,
- Bioenergy - biofuels and biomass combustion for power and thermal outputs,
- Carbon capture and storage - including the use of CO_2 from power plants, industrial processes, and transportation,
- energy efficient buildings (commercial and residential),
- High-efficiency and lower-emission coal technologies (for power and heat generation),
- Marine energy, including wave/tidal energy and ocean thermal energy conversion,
- Smart grids for transmission and distribution systems as well as end-user systems,
- Efficient systems such as distributed generation, and combined heat and power systems,
- Solar energy (including solar photovoltaic power, concentrated solar power, and solar heating and cooling), and
- Wind power (including onshore and offshore installations) (International Energy Agency, 2009). Table 3.1 shows the end 2001 status of Renewable Energy Technologies.

The World Energy Council (2009) states that sustainable development requires a concerted effort from governments, international organizations, utility companies and the energy community, civil society, the private sector, and individuals. The difficulties facing appropriate measures are small compared to what is at stake. For a number of reasons, the technical and economic advances in energy efficiency improvements have fallen short of their potentials. Energy efficiency has captured significant political and media attention only in recent years, mainly as a hauler of climate change. Significant barriers – primarily market imperfections that could be overcome by targeted policy instruments – add to the difficulties of attaining greater conservation and end-use efficiencies. The barriers can be expanded as:

- Lack of adequate information about immerging technologies,
- Lack of adequate capital,
- Uncertainties in investment portfolio on new technologies,
- High upfront initial costs, especially when retrofit is involved,
- Often inadequate information and lack of skilled and trained man-power,
- Lack of, or insufficient incentives to promote new technologies,
- Lack of collective responsibility to promote efficiency, for example, keeping lighting on in public places, and rented apartments,
- Cost of pollution not included in energy prices,
- Affordability and wealth, so that cost of energy is simply not an issue in some communities,
- Accepted norms that are not essential needs, but may provide esthetics,
- Inadequate or lack of R&D investments.

Energy supply in the Americas is heavily dependent on fossil fuel. Only some countries such as Mexico, Venezuela, Colombia, and Brazil have substantial fossil oil resources. The rest of Americas depend on fossil fuel imports. Brazil has significant hydropower resources. Natural gas is also abundant in countries like Argentina, Bolivia, and Peru, but needs significant investment before exploitation.

Among the renewable potentials, wind energy has a great potential in the Americas. Southeast Mexico and most Central American and Caribbean countries are exposed to the so called Trade Winds, while Southern Mexico and Central America are under the *Tehuantepacers*, wind produced by the temperature difference between the waters of the Atlantic and the Pacific oceans. Wind energy exploitation requires a wind energy map, for accurate placement of wind turbines. However, only Brazil and Argentina have developed fairly high density wind maps (Huacuz, 2003). Solar energy is also abundant in the Americas. Solar irradiance maps are available for Brazil, Argentina, Mexico, Colombia, and a few other countries.

For the first time in 2008 the United States added more capacity from renewable energy than from conventional sources. At the end of 2008, renewable energy made up just 6.2% of the world's total energy capacity and 4.4% of generation not including large hydropower. The new installations of renewable energy in 2008 made up about 25% of the total new capacity compared to just 10% in 2004. The total global investment in renewable energy was $120 billion in 2008, about four times more than that of 2004. The United States contributed around 20% of this total. The total new investment in developed countries during 2008 was $82.3 billion, compared to $36.6 billion in developing countries. According to the United Nations Environment Program (UNEP), if large hydropower investment is included, investment in renewable energy exceeded the investment in fossil-fuel technology, by about $10 billion, (UNEP, 2009).

New laws and policy provisions favoring renewable energy portfolio were adopted in many American countries including USA, Brazil, Chile, and Mexico. Several cities and local governments are actively planning and implementing renewable energy policies. The drivers of these policies are climate change, energy insecurity, fossil fuel depletion, and the economy, which means renewable energy will continue to grow for years to come (Figure 3.3).

Table 3.1: Status of Renewable Energy Technologies

SELECTED INDICATORS	**2007**	**2008**	**2009**
Investment in new renewable capacity (annual)	104	130	150 billion USD
Renewable power capacity (including only small hydro)	210	250	305 GW
Renewable power capacity (including all hydro)	1,085	1,150	1,230 GW
Hydropower capacity (existing, all sizes)	920	950	980 GW
Wind power capacity (existing)	94	121	159 GW
Solar PV capacity, grid-connected (existing)	7.6	13.5	21 GW
Solar PV production (annual)	3.7	6.9	10.7 GW
Solar hot water capacity (existing)	125	149	180 GWth
Ethanol production (annual)	53	69	76 billion liters
Biodiesel production (annual)	10	15	17 billion liters
Countries with policy targets	68	75	85
States/provinces/countries with feed-in policies2	51	64	75
States/provinces/countries with RPS policies	50	55	56
States/provinces/countries with biofuel mandates	53	55	65

Source: United Nations and World Energy Council, 2010

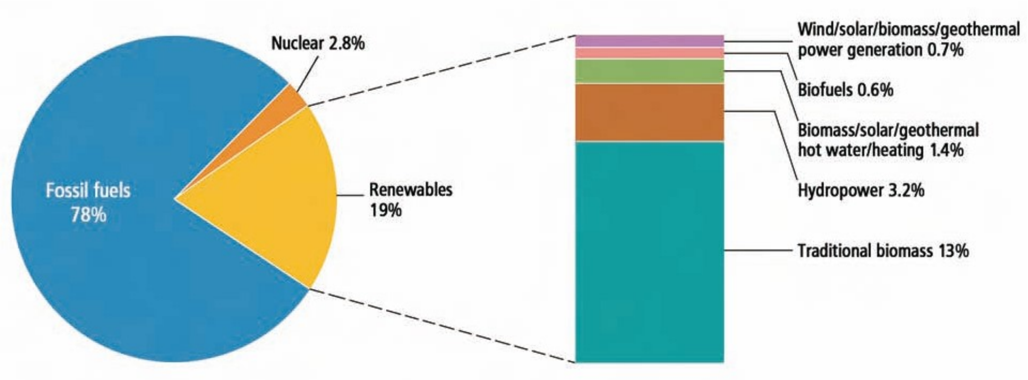

Figure 3.3: Global renewable energy share (United Nations and World Energy Council, 2010)

AMERICAN ENERGY MARKETS

The two largest Energy market capacities in the Americas belong to the United States and Canada. Combined, these two countries account for 80% of the total power generating capacity in the hemisphere. Brazil, Mexico, Argentina, and Venezuela also have significant amounts of power generating capacity. More than 50% of power in the Americas is generated thermally, i.e., from coal, oil, and natural gas plants, while the remaining amount comes from hydropower (25%), nuclear (16%), geothermal and other renewables. To understand the evolution of energy market in the Americas it is essential to understand the role of, and changes from public to private participation.

Privatization of the energy market in Latin America developed during a radical economic transformation of the early 1990's. Latin American electricity privatization grew in tandem with the growth of global energy demand, driven by a rapid increase in electricity demand. However, this rapid demand increase was often coupled with a shortage of domestic capital to meet the growing power needs. The economic reforms that resulted in the privatization of state-owned industries such as telephone companies, electric utilities, and petroleum plants came amidst such turbulent transformation of the economy and the energy market. Reforms of the legal system dealing with foreign companies have also played an important role in the privatization process. Thus, the rising demand for energy, combined with economic reforms favoring privatization, and changes in the legal platform to allow foreign investments to build new power generating facilities, have created a new dynamic for the energy market, including renewable sources.

Currently, government policies and legislation play an important role in the development of renewable energy sources. Many countries in the Americas have enacted favorable policies to encourage investment in renewable and sustainable energy sources such as geothermal, wind, solar, and biomass. Most countries have formulated progressive legislation to promote renewable energy and the portfolio in the continent has increased over the last few years (Figure 3.4).

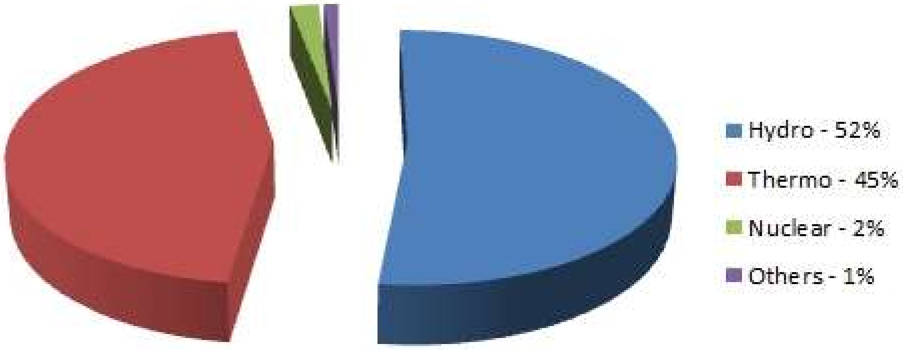

Figure 3.4: Percent of installed capacity energy sources in Latin America and the Caribbean (Source: Energy Tribune, 2008).

Currently, there are targeted renewable portfolio standards in countries such as Honduras, El Salvador, Nicaragua, Argentina, and Chile. This is in addition to other, more developed nations, who provide subsidies and tax credits to promote renewable energy (such as Mexico, USA, Costa Rica and Brazil). Such standards and policies help propel a real growth in the renewable energy market of the Americas.

A significant challenge facing renewable energy sources is their high implementation cost relative to conventional plants. Without government incentives, many of these technologies cannot compete with conventional power plants, even in highly developed countries. Implementation cost becomes a more serious barrier for developing countries because renewable energy components are usually imported from developed countries at very high cost, often outside the economic range of these countries.

The Clean Development Mechanism (CDM) allows developed countries to invest in greenhouse gas reducing projects in developing countries. Defined in the Kyoto Protocol (IPCC, 2007) this mechanism has been one of the most successful renewable energy investment modes in the Western Hemisphere. Of almost 3000 projects registered by April 2010, 461 were registered in the Latin American Region (GBI Research, 2010). In all, the CDM has overseen 60% of its registered investments going towards the energy sector, with special interests in small hydro, solar, wind and biomass technologies. More details can be found in: Favorable policies and Regulations Drive Growth in The Region (GBI Research, 2010).

In Latin America, the energy market segments have achieved profitability. The industries of wind and solar power offer, in the short term, a more optimistic future. The geothermal industry has great potential in countries with underground thermal resource such as Costa Rica, El Salvador, Guatemala, Chile and Mexico. The biomass energy industry, however, is expected to maintain the current rate of growth. All these renewable technologies should continue to compete with fossil and hydropower, and perform within the restructuring energy industry.

3.1.3 Energy Efficiency, Energy Policies, and Mutual Interests in the Americas

Energy efficiency improvements refer to a reduction in the energy use without affecting the service output quality or activity. The reduction in energy use is usually associated with technological innovations, organizational skills, management, improved economic conditions, and tradition. From an economic point of view, energy efficiency could have a broader meaning encompassing the impacts of efficiency in reference to wealth - for example, the energy used per unit of GDP.

Energy efficiency is associated with economic efficiency and includes technological, behavioral and economic changes (World Energy Council, 2009). Most notably, government decision makers must enforce policies which will yield a higher level of certainty for the long term demand for low carbon technologies going into the future.

This will give the industry's decision makers projections for such technologies on which they can rely. In short, the global energy economy will need to be transformed over the coming decades (International Energy Agency, 2009) in order to accommodate for an expansion in the energy sector portfolio. In this context, energy efficiency and renewable energy technologies could form the core of the solution if policies are written to mandate changes in renewable energy and carbon emission requirements.

In general, the mix of set targets and proposed actions, supported by reciprocal will of government and industry for collaboration in drafting policies and regulations, are realistic and attainable.

During the second half of 20th century, the emerging American economic and social integration and the creation of regional organizations to promote regional trade were expected to promote industrialization. On the other hand, the weak link between existing national infrastructures in the energy area remains the major barrier against intensification of the regional economic integration. This condition hampers the growth of regional trade and consolidation of the regional economic integration process. The strong demand from Asia for commodities, the core of the Americas exports, opens positive prospects for sustained growth by the regional economies. For these reason, an important number of projects are in progress or being structured to create conditions for the energy exchange in the continent (World Energy Council, 2009).

The World Energy Council issued in 2007 stated that in order to meet increased demand by 2050, today's level of energy supply needs to double. More primary energy will be needed initially, by 2020, although some regions will moderate this need by more energy efficient technologies. In particular, the extraction and consumption of fossil fuels will remain steadfast even in a low carbon economy, accompanied by efficient GreenHouse Gas (GHG) management technologies.

Analyses of energy efficiency in 26 Latin American and Caribbean countries show that there are variations among these countries in levels as well as regulatory frameworks. However, there is a trend in all cases towards creating energy efficiency programs and reinforcing these programs with regulatory support. With the exception of Chile, which recently provided large increase for energy efficiency programs, such policy support is not usually backed by financial resources to promote energy efficiency. Chile has in fact boosted its international role in contributing to energy efficiency. In May 2010 Chile became the member of the Organization for Economic Co-operation and Development, the first from South America. In October of 2010, the International Energy Agency (IEA) started discussions with Chile with a view of inviting Chile to become members of the Agency, which would also make it the first from South America.

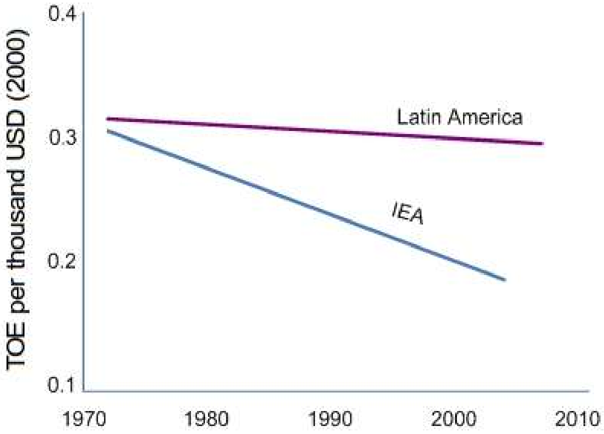

Figure 3.5: Energy intensity (Tons of Oil Equivalent, or TOE), Latin America versus IEA (adopted from IEA, 2010)

In spite of increasing regulatory supports for energy efficiency in the Americas as acknowledged above, research budget allocated to energy efficiency is meager. Energy intensity in Latin America is been nearly stagnant over the last four decades, compared to a significant drop in IEA countries, Fig. 3.5. As a result, the quality of statistical data to assess energy efficiency and performance indicators in countries of South America and the Caribbean, with the exception of Mexico and Brazil, are below standard. Thus, it is not possible to arrive at some generalized conclusions with some acceptable accuracy regarding energy efficiency. The mere presence of energy efficiency legislation, without field feedbacks and raw data for research input, doesn't guarantee implementation of energy efficiency measures. Based on scattered data, overall, up to 25% energy savings could be achieved in the Americas through measures with short payback. New technologies such as refrigerators, lighting bulbs, combined heat and power systems can easily penetrate the market through incentives. These new technologies in many cases are twice as efficient as those currently in the market (Carpio, 2010).

3.2 Challenges and Concerns

The conference has reached a consensus that the energy sector in the Americas, and elsewhere for that matter, is in a critical condition. Acute crisis could erupt at any time from any number of factors, triggered by a simple accident or a political revolt in a major oil-producing country. Such crisis would have a global consequence – both economic and political. Oil prices in the US have doubled in just few decades, and this increase in price has essentially a global trend. Chances of oil supply disruption come against the backdrop of severe energy infrastructure constraints across the Americas. As these constraints are felt at the demand level, they force further increase in energy costs, a prelude for sustained energy crisis approaching at a slow pace. The solution to this problem requires a comprehensive, integrated strategic energy policy for the Americas.

The ongoing rapid growth in the Americas could crash into structural supply and distribution deficiency brought about by long-term under-investment in energy infrastructure. Limited oil refinery capacity versus their high cost of environmental compliance and historically low return on investment, little enthusiasm for nuclear power plants, a growing surge in demand in much of the developing world, and slow progress with renewable energy, mark a gloomy future, especially given the low level of attention given to addressing the crisis as a common, collective responsibility. A unique area of concern is the nexus between water and power generation. This nexus is significant because it merges two critical resources, energy and water, both in short supply at the same time in many parts of the world.

3.2.1 Energy use projections for water treatment and distribution

> *"Climate change is expected to exacerbate the current stresses on water resources... Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate throughout the 21st century, reducing water availability, hydropower potential, and changing seasonality of flows…"*
>
> -Intergovernmental Panel on Climate Change, 2007.

In many cases, particularly in desert environments, the up-to-date data and statistic predictions suggest the prevalence of highly intensive use and increasing demand for fresh water resources which goes beyond the principles of sustainability. This increasing need is compounded by competing interests to address critical needs of the society. For example, the present significant consumers, who drastically change the natural water cycle in direct and indirect ways for the US Southwest, are agricultural (71%), municipal (22%) and industrial (7%) sectors (Arizona Water Atlas, 2009). It is unpractical to expect or demand flat reduction in water use for agriculture, without qualitative or quantitative penalty to agricultural products. Such measure requires innovative irrigation technologies to reduce the rate of evaporation loss, as well as solid research to determine the optimum water amount required.

Although water is available in most of the Americas, there are still concerns of water pollution incurred by irrigation. Secondary salinity, as a result of irrigation, is also a serious problem (Biswas, 2006). Furthermore, the Organization for Economic Development and Cooperation (OECD) states that some of the water quality impacts are caused by subsidies in agriculture, as summarized in Table 3.2. The cost in assured water quality is a problem affecting developed and developing (North, Central and South American) countries alike, and the OECD points out (Biswas, 2006) that globally, farmers rarely pay more than 20% of the real cost of water.

Table 3.2: Water quality impact caused by agricultural subsidies

Subsidy	Agent of impact	Impact
Agricultural prices support policies	Incentive for water-inefficient crops	Salinization, water logging, decline in groundwater
Surface water price	Overuse of water	Pollution, salinization

Electricity price	Substitution of surface water for groundwater	Aquifer depletion, salinization
Pesticide price	Overuse and inefficient use of pesticides	Surface water and groundwater contamination
Fertilizer price	Overuse and inefficient use of fertilizers	Surface water and groundwater contamination

Modified from Biswas, 2006.

In addition to agricultural wastes, in many cities of South America, municipal and industrial sectors discharge domestic and industrial wastewater into the water bodies. In fact, a large percentage of sewage is discharged untreated, creating inadequate sanitation in many urban areas. The reasons for the scarce water treatment are:

- The high cost of treatment facilities are beyond the capacity of most communities,
- Complexity of the treatment plants exceeds engineering and technical capacity of some communities,
- Foreign aid agencies and local governments have given priority to water supply rather than sewage treatment projects,
- It is more acceptable to charge just for water than for water treatment,
- Initial solutions often remove human waste from towns and cities, leaving the treatment part for later, which is often never completed.

There are many other reasons, both at local and national levels, as to why water treatment is rare. These reasons depend on geographic, economic, social, and political particularities that affect the regular operation of water treatment plants. However, the most prominent problem, especially for the developing countries of the Americas, remains to be the high energy use for water treatment relative to water distribution.

Based on recent international publicity surrounding the water-energy nexus, there is a growing attention paid to the subject by local governments, with more and more favorable policies that help shed more light on this nexus. It is argued that about 80% of the cost of water is related to energy, and the delivery of potable water requires electricity for extraction, conveyance, treatment, distribution, use, wastewater collection, reuse and discharge (Arroyo, 2010). For instance, extraction of groundwater for potable use, on average, uses 30% more electricity than diversions from surface water sources, mainly because of the pumping requirements. In monetary terms, the groundwater prices range from $20 to $160 per acre-foot (Arroyo, 2010). The energy used for water treatment varies from place to place. For example, power used for water treatment for the cities of Patagonia and Benson are 1.4 to 3.1 kWh/kgal respectively. For Central Arizona, the energy use averages about 5.5 kWh/kgal, much higher than the other two cities. In fact, in some cases, these costs can be much higher. For example, the city of Tucson has a cost of 9.8kWh/kgal. This high cost is due to its elevation, requiring higher pump work. The energy demand for wastewater treatment depends on many factors, the level of purity expected as well as the technology available in any particular region. Collecting and treating wastewater in Tucson requires about 1 kWh/kgal, while in small rural areas as

Benson and Patagonia these stages use 7.3kWh/kgal and 13.5 kWh/kgal, respectively (Arroyo, 2010).

Considering water and energy as highly related and interdependent sectors, the energy-water nexus also incorporates the use of water for power generation. Nearly almost all types of electricity and heat generation systems require water. In the United States, thermoelectric power plants use about 40% of all fresh water withdrawals, which totals approximately 190 billion gallons of water per day. However, only about 3% of the fresh water is consumed, with the rest being reused or discharged back into the environment. Table 3.3 shows the ratio of water requirements for the most common types of power generation (Arroyo, 2010).

Table 3.3: The water costs of electricity generation

Fuel Type	U.S. DOE [2006, Gal/MWh]	Arizona Public Service [2007, Gal/MWh]
Solar (concentrating solar power, CSP)	750-920	---
Nuclear	400-720	775
Coal	200-480	67-610
Natural gas	100-180*	20-550
Solar (PV)	---	---
*Combined cycle only		

Source: Arroyo, 2010.

ENERGY AND WATER SYNERGY IN DESALINATION

There is a serious mismatch between clean water sites and regions of high water demand in most of the Americas. According UNEP, the Gulf of Mexico Basin, the South Atlantic Basin and the La Plata basin, covering about 25% of the region's territory are home to about 40% of the population, with only 10% of the region's water resources. For example, the Rio de Janeiro plant, the biggest drinking water plant in the world, produces 3.7 billion liters of water per day (EIU, 2010). And yet, it still cannot keep up with population increase, and has recently undergone expansions. As a result, water has either to be transported over long distances to areas of high demand, or it has to be cleaned from nearby saline sources. These measures both require high energy, creating an energy-water synergy. Even Brazil, a country with the largest fresh water source in the Southern hemisphere, has to cope with severe water shortage in the Northeastern part of the country.

According to a 2006 Pacific Institute study of California plants, the most efficient facilities operating today use around 3.17kWh/m^3 (0.012kWh/gallon) of desalinated water (Arroyo, 2010). The energy intensity varies widely depending on the salinity of the source water (seawater or brackish groundwater) and other factors. One of the main environmental considerations of ocean water desalination plants is its impact on salt concentration at a local level. Its impact on the open ocean water intakes, especially when co-located with power plants, has also been a concern. In the United States, due to a recent court ruling under the Clean Water Act, these intakes are no longer viable without proven and significant reduction in mortality rates of marine life. The transportation of water is another important factor: costs range anywhere from $45 to $1,800 per acre-foot (Arroyo, 2010).

The feasibility of a desalination project has to be thoroughly assessed before it is put in practice, with emphasis on cost analysis. Among the evaluation criteria, the most evident are:

- Availability of alternative fresh water sources,
- The impact on ecosystems,
- Energy sources availability,
- Land availability for storage of salt residues,
- Acceptance of the final tariff by communities,
- The scope of distribution network.

As an upshot of linking resource exploitation and climate change, in addition to evaluating the simple cost benefit analysis of energy systems, newer concepts such as extended exergy analysis are strongly recommended. Exergy is the maximum useful work possible during a process that brings a system into thermal equilibrium with its surroundings. This approach allows evaluation of the heterogeneous parameters on homogenous bases of exergy embodied into materials, energy, labor, and capital inflows. The results of both analyses could be of significant addition to the decision making process for every particular national condition. Despite its disputable economy, desalination remains a viable alternative to other sources of water treatment.

TRANSPORTATION FUEL

The Americas are the world leaders in the bioethanol and biodiesel production. In these economically growing sectors of transportation fuels, the production chain requires a significant amount of water for the irrigation of crops and further for the process of crop fermentation. This makes these particular fuels considerable players in the water allocation management. The available data show that one gallon of ethanol derived from irrigated crops consumes between 190 and 2,260 gallons of water, while for biodiesel this number rises to 9,040 gallons (Arroyo, 2010). This paradox of replacing a fuel source to be more renewable while adding further stress to water is central to the energy water nexus.

As clean energy technologies mature and fossil fuel drops out of the picture, one of the major, quick and convenient replacements of fossil liquid fuel, especially for the automobile industry, seems to be another liquid fuel, which many American countries have already identified as biofuels. This replacement is convenient due to existing automobile designs, fuel transportation systems, as well as delivery and metering equipment that require little or no retrofit. However, the competition over water and replacement of food crops by cash crops dictate the need for national and local policies and regulations to recognize the importance of the water-energy nexus for future, sustainable development. There are some obstacles that challenge this symbiosis. The modern trend for alternative energy sources creates difficulties for water resources conservation. This is because shifting from fossil fuels to nuclear power, hydropower and concentrating solar power is followed by more intensive water consumption. Biofuels are less damaging from a GHG perspective, but require more water for the production chain. Public participation is limited to domestic water and energy conservation due to imposed monopolistic regulations on the utilities' generation and consumption. Consumers are not able to actually control how their water footprint and energy source are connected. In the developing countries of Central and South America, the government control of private energy providers is not sufficient to guarantee its environmentally friendly generation and security. Furthermore, the rate of growth of consumers brings a more intensive use of water and energy, which in turn increases the environmental burden, likely leading to more stringent regulations, and hopefully improved technologies to address the growing challenges.

3.2.2 Viable Regional Solutions to replace the use of Fossil Fuels

The most immediate replacement for fossil fuel in the electric power generation industry is likely nuclear power. This is because, the pace at which such replacement is needed, the urgency facing human kind to reduce GHG emissions, is much faster than the pace at which technological innovations are likely to come and allow an economically feasible transition to non-GHG emitting fuel resources. This is especially true in the transportation sector.

Currently, biofuels are the only renewable energy source commercially available that can be used to replace fossil fuels in the transportation sector. This assumes that electric cars are charged by power from plants that primarily operate using fossil fuel. For most parts, the alternatives such as wind, solar, geothermal etc. are still less than significant parts of the energy supply portfolio. Considering that the transportation sector is responsible for 13% of global GHG anthropogenic emissions (Intergovernmental Panel on Climate Change, 2007), and that the projections of the IEA to the year 2030 indicate that the transportation sector will be responsible for 56% of world's energy use, it is important to develop alternative options to minimize reliance on a single fuel source. The alternatives currently being studied on a small-scale include hydrogen, fuel cells, electricity and other biofuel feedstock, such as cellulosic material and algae.

In fact, a more rapid transition to nuclear power plant dominant energy supply could also push innovations in electric cars, mainly in batteries with extended charge cycles and shorter charge periods, reduced weight, longer life time, extended driving range, etc. This is a scenario under which electric cars could be equally or more conventional than biofuel cars.

Presently, the volume of ethanol as a fuel is around 500,000 barrels of oil equivalent per day – 0.7% of the world's consumption or 3% of the gasoline use. Although it is mainly produced in the United States from corn, it is also produced from sugar cane and sugar beets in Brazil and the European Union, respectively. In 2008, the total production from the United States (51%), Brazil (34%) and the European Union (4%) accounted for the vast majority of the 65.6 billion liters of annual world production (Goldemberg, 2010).

In addition to being used as a successful replacement of cleaner transportation energy, biofuels can also increase energy security and help the job market since many developing countries are highly dependent on imported oil. Delivery and cost of imported oil is impacted by security factors at the source countries or en route to destinations. The local production of biofuels can reduce these imports, creating jobs and promoting more uniform domestic development. For example, the Brazilian ethanol program, which started in 1975, is responsible for savings of US$52.1 billion in oil imports from 1975 to 2002 (Goldemberg 2006).

The introduction of biofuels into a country's utility depends on mandates in order to have a captive market. Tax incentives and subsidies have been used as tools to promote biofuels, as can be learned from the experiences of the USA and Brazil. The table below gives an overview of such mandates adopted.

Table 3.4: Biofuels blending mandates in the Americas

Country	Mandate
Argentina	E5 and B5 by 2010
Bolivia	B2.5 by 2007 and B20 by 2015
Brazil	E22 to E25 existing (slight variation over time); B5 by 2010.
Canada	E5 by 2010 and B2 by 2012; E7.5 in Saskatchewan and Manitoba; E5 by 2007 in Ontario
Chile	E5 and B5 by 2008
Colombia	E10 and B10 existing
Dominican Republic	E15 and B2 by 2015
Jamaica	E10 by 2009
Paraguay	B1 by 2007; B3 by 2008, and B5 by 2009; E18 (or higher) existing
Peru	B2 in 2009; B5 by 2011; E7.8 by 2010
United States	Nationally, 130 billion liters/year (36 billion gallons/yr) by 2022: E10 in Iowa, Missouri and Montana; E20 in Minnesota; B5 in New Mexico: E2 and B2 in Louisiana and Washington State; Pennsylvania 3.4 billion liters/year (0.9 billion gallons/yr) by 2017
Uruguay	E5 by 2014; B2 from 2008-11 and B5 by 2012

Modified from REN21 (2009). Note - some mandates may be delayed by market issues. Mandates in some US states take effect in future years or under certain conditions, or apply only to portions of gasoline sold. In Tab. 3.4, E stands for ethanol, B for biodiesel, and the numbers following these letters represent percent volume. For example, E5 stands for 5 vol% ethanol content, B5 stands for 5 vol% biodiesel, etc.,

Emerging biofuel crops should be grown without adding to the existing level of environmental destruction. The use of degraded lands, instead of clearing vegetated lands, is highly desirable. Protection of surface and sub-surface water and application of less water-intensive technologies must be considered. Current production of biofuel does not address these issues. The problems concerning biodiversity and air quality should also be noted. The decision for adopting a biofuel program must consider not only environmental and policy aspects, but also the social and economic dimensions.

Today Brazil is the largest ethanol exporter, selling the product mostly to the United States and Europe. According to the Agro-environmental zoning published by the Brazilian government, the country has 64 million hectares of land suitable to the production of sugarcane (IEA, 2010). In addition to exporting ethanol, there is also a market to export biofuel technologies and expertise to the Americas.

As noted above, as a replacement for fossil fuels, biofuel is part of the solution for GHG emission reduction. However, it will not be able to completely replace the world's fossil fuel consumption and ease the stress on fresh water supply as a quick fix. This requires a protracted policy and research input. In the case of the Americas, such research activities include ethanol production by biochemical conversion of lignocellulosic materials, new lignocellulosic feedstock for ethanol production, conversion of waste feedstocks, algae cultivation, innovative processes for biofuel, biogas and biomethane harvesting, waste feedstock for biodiesel production, and technical solutions to biomass to liquid process (BIOTOP, 2010). In the long term, the alternative for transportation sector should be a new technology, not necessarily based in combustion engines, with emphasis on increasing efficiency and reducing pollution.

3.3 Future target areas

3.3.1 Technical and engineering issues as a platform for collaboration

Facing our collective energy, water and sustainability challenges will require a great deal of international cooperation and collaboration. A variety of technical and engineering issues is of an international nature, and thus forms a common platform for such collaboration. Examples of such issue include the need to:

- Transport renewable resources from where they are produced to where they are needed in a sustainable manner,
- Import and export renewable resources trans-nationally to share responsibilities and address global issues as a common agenda,
- Balance domestic concerns of energy independence with the need for free trade, with a special credit to renewable resources,
- Improve and integrate climate models, with economic and quality of life as inputs,
- Collecting and disseminating energy, water, and climate change data,
- Form common metrics that can be used to gauge the effectiveness of climate, energy, and water policies and projects,
- Promote technology transfer, with credit to those that help the environment,
- Education and training to promote innovations.

These various issues generally fall into one of two main categories that offer opportunities for collaboration; **implementation** and **scientific discovery**. Implementation includes cooperation in engineering projects and political structures, such as smart grids, pipe lines, international agreements and import and export regimes. Collaboration in scientific discovery involves improved climate economic and quality of life modeling, sharing data and tools to obtain data (for example, satellite data) and scientific conferences such as PASI. Other forms of cooperation, such as technology transfer and defining common metrics may be placed in either category.

IMPLEMENTATION

As we attempt to move towards more sustainable energy supply and abundant water supply with tenable environment impact, a great deal of international cooperation will be required. Current renewable sources of electricity using up-to-date technologies (solar and wind) are often intermittent in nature. To get the most out of these energy sources we require smart grids – as defined above – that allow for the transfer of power from where it is generated to where it is required. The greater geographic area these grids cover, the more useful these grids become to shed peak demands. Peak demands are often caused by weather conditions and social events which are fairly regional or even local. This temporally localized peak can be easily shed if energy can be transported from excess areas to high demand areas. This suggests that smart grid technologies and energy distribution standards be developed and implemented across the Americas.

In similar ways, transfer mechanisms for other sustainable energy sources that can be produced in one region, but may be more useful in another, such as biofuels, must be implemented. These mechanisms include pipelines and other transport systems as well as international agreements, treaties and import export regimes. Water management should also be assessed in this context.

Experience in many countries, including the USA, shows that in order to implement new technologies and promote a move toward sustainability in free market societies, incentives must be offered by governments to compensate for the initial high coast of sustainable technologies and behaviors. These incentives can take on a variety of forms, including regulatory mandates, financial support, tax and tariff discounts - as a combination of local and national measures. While individual governments may be best suited to choose which incentives will be most beneficial for their countries, a general framework for these incentives should be formed regionally, such as, for example, a comprehensive incentive architecture for the Americas.

SCIENTIFIC INNOVATION

Collaboration in scientific innovations is necessary in order to maximize our understanding of climate and environmental changes. Future climate models will be linked with economic models to increase our ability to mitigate or adapt to a changing environment and fathom the depth of changes expected. This may include migration patterns and land use modifications as well as changes in socio-economic activities. Only interdisciplinary efforts are best suited to address these complex models and understand how a particular country of the Americas might react to a changing environment. Such research need not be an autonomous agenda of any country, but it should be addressed as a trans-national issue.

Data collection is essential in order to improve models to take stock of current conditions. These data can include both direct observations and remote sensing, such as satellite records. In addition to sharing data, nations must agree on international standards and benchmarks of data collection and maintenance. It is important that data collection and interpretation be internationally agreed upon and understood by the various actors in the scientific community. This allows 'comparison of apples to apples' for data collected from several sources, regardless of geographic location. Several organizations, such as the Open Geospatial Consortium and the Consortium of Universities for the Advancement of Hydrologic Science, Inc. provide international data encoding standards and tools for semantic and syntactic mediation of data. This approach can be expanded across various other fields and countries.

Improvement in the understanding of our changing environment and how our societies must mitigate or adapt can only be done by bringing together researchers from a variety of fields and expertise. International conferences, which bring together scientists, engineers, economists and policy making officials from a variety of countries, such as PASI, should be encouraged.

In order to accurately estimate how policy decisions effect climate change and water resources, common metrics must be used. Examples of some proposed metrics include:

- Changes in temperature,
- Radiative forcing,
- Changes in rate of evaporation,
- Carbon footprints,
- Exergy metrics.

Such metrics should be developed in order to form an accounting system that can be used to determine the sustainability of policies and projects that will have an effect on the environment. The agreement of such a metric and bookkeeping system that takes into account all the various feedback mechanisms involving climate change, energy and water management, will go a long way toward making the problems of global climate change and sustainability seem more tenable to policy makers and the public, who often feel the situation is hopeless. Furthermore, the accounting system can be used to form policy road maps that will lead us to a more sustainable future.

OTHER FORMS OF COLLABORATIONS

Innovation in the areas of sustainable energy and water supply continue to increase, supported by incentives from the various governmental actors in the Americas. This support, which includes tax incentives, direct government funding of research institutions, grants, loan guarantees, etc. should continue being endorsed as a viable policy serving public interest. At the same time, new sustainable technologies deserving such support must be tested adequately to justify public support. As new technologies become ready for market, it is important that technology transfer is given sufficient advocacy to speed up implementation.

Generally, the Americas have made great strides in expanding their sustainable energy portfolio. Some have taken the lead in some specific sectors. In the western hemisphere most research in photovoltaic cells has been done by the United States. Mexico and Costa

Rica as well as the United States have a great deal of experience with geothermal energy. Brazil has successfully made ethanol a major component of its transportation energy sector. In order to spread scientific and engineering knowledge and to help train the next generation of scientists and engineers, universities and research institutions should engage academia and attract qualified students from other countries in the Americas, to study as part of programs specifically designed to encourage the advancement of sustainable energy and technology transfer.

International cooperation is essential in order to reach our sustainable energy and water supply goals as a united society. There are a number of barriers that challenge or impede such cooperation. Regional conflicts and international rivalries still exist in the Americas and can easily derail the advancement in what otherwise should be common interests. Various 'sustainable energy' proposals have been suggested and in some cases implemented, which in fact provide limited or no net positive sustainable effect, but rather forward other intra-national goals in the name of sustainability. The desire for individual countries to either maintain or achieve energy independence may make such countries hesitant to rely on their neighbors for part of their energy and water supply. For similar reasons, more developed countries may be hesitant to encourage technology transfer for security and economic reasons.

Despite these concerns, the Americas have made significant progress in bridging international boundaries. While we are only at the very beginning of the path toward sustainability, we are beginning to set up the frame work for a sustainable future. There is ample evidence that our understanding of how our actions affect our environment continues to mature, and the first steps taken towards shaping this impact, though arguably currently insufficient, present positive signs.

3.3.2 The Impact of Energy Policies and Upcoming Technologies on Water Supply

Great majority of nations in the world have a set of energy and water policies, albeit not as a nexus. Such policies are documents, and also action plans ratified and executed by government entities. The energy policy generally addresses the urgent issues of energy development and management (production, distribution and consumption) dealing with legislative, economic, public and environmental issues. More recently, the policy is associated with developments in climate change, with water as a component of the change. Nevertheless, the prime goal of these policies remains to be security of national energy supply.

We believe that energy policies are the most convenient, if not the only tools for executive and legislative authorities to improve clean water distribution and supply. Energy policy is a vital managerial instrument that also impacts development of efficient and state-of-the-art technologies that benefit water resources as well as energy sectors. Future growth and improvement of clean water supply depend on future creative ideas, scientific and engineering solutions, and a support system to motivate the transfer of these technologies to the end-users. The fundamental challenge of such policies lies in embracing the wide range of stakeholders and their competing interests, to promote guiding principles needed to strike a dynamic equilibrium between development and sustainability. International relationships could certainly complicate the decision making process and the decision itself. The prevailing energy scenarios primarily aim at predicting and avoiding adverse consequences of energy policies while keeping it in check with stated goals. Policies that deal with energy and water as a combined unit resource policy are still not well developed.

Complex relationships between energy and water supply, and the variety of stakeholders involved, create a field of uncertainties and at times acute disputes. The technological progress both in energy generation and water supply, and the appropriate support system such as financial incentives, would decidedly contribute to shifting the path towards sustainable growth and rational consumption. The interdependent character of the relationship between energy and water supply, and the variety of stakeholders involved all create a field for uncertainties and at times contentious debates.

The Americas have a great variety of economic, political, and social backgrounds with access to abundant sources of renewable energy, including solar, wind, geothermal, and biomass. These resources should be catered and mobilized for the supply of clean water. Without key changes to the current renewable technology supply production and deployment, based on the current advances in these technologies, it is not feasible to cover present and future demands for electricity in short enough period without continued significant share of fossil fuels, which have been accepted as the main culprits in global climate change.

Utility investment decisions in both grid-tied and off-grid energy services are largely driven by rate of return. In many Latin American countries state-owned monopolies have been replaced by private investors. The business emphasis as a result has shifted to short term “spot prices” and conventional power generation with low capital costs. Thus, the more expensive clean and alternative sources of energy are inherently at a disadvantage. This is compounded by factors that contribute to energy and water policy failures, which include:

- The mismatch between demand for energy and water resources vis-à-vis local population growth,
- Absence of appropriate infrastructure facilities for energy and water distribution,
- The monopoly character of “open-based” markets,
- The scarcity of stakeholder negotiation practices.

Solutions to many of the prevailing challenges of the energy and water nexus emerge from the same problems. Some of them are short term tactics, others are long term strategies, but all can be equally applied at individual (single household) or community (town, city) levels, either through public institutes or private plants including power generators, biofuels industries, etc.

The following actions can be taken as short term actions:

- Sever water conservation and increase in use efficiency,

- Expanding water storage,
- Improved balance of use between stored and running water supplies,
- Developing conjunctive use management plans,
- Recycling,
- Developing alternative local resources,
- Better demand characterization.

Examples of long term strategies may include:

- Research and development,
- Monitoring, modeling and evaluation activities.

Unfortunately, quite often, accepted policies fail to impart and enforce mechanisms of execution and implementation, and the slow growth in addition of alternative energy sources is not a match for the acute increase in GHG emissions.

4 WATER SUPPLY, CROSS BORDER ISSUES AND SUSTAINABILITY

As perhaps the most essential requirement for life on earth, water supply and in particular, clean water supply, is lagging behind demand in many parts of the world including the Americas. The impact of water use on energy and climate change, at least locally, is well observed; water is used in most areas of power production, and climate change is inevitable when waterways are diverted to feed a specific purpose, for example ethanol production, agriculture, or power generation. Currently, there are many strategies in place to curb the impact our need for water has on our surroundings. Water reuse is a viable solution in many cases, and desalinization of salt water is becoming more viable as technology advances.

In the Americas, water supply can create political rifts between neighboring countries as they vie to divert river basins for agricultural and civilian use. Water policies play an extremely important role in any area with a fresh water supply and in those stressed about clean water sources. For example, the Amazon basin, the largest freshwater basin in the world, is shared between many countries in South America, and its use is subject to the policies created to control its use. Whether it is used for ethanol production, power generation, biodiesel, or other uses, care must be taken to ensure that the delicate balance of life is not disturbed, and that water is not wasted.

Greenhouse effects continue to dominate the world's science and policy agenda on global climate change. One underlying concern is the impact of this change on water supply. The impacts of rapid population growth and continued economic development, the qualitative and quantitative influences of society, on the state of the terrestrial water cycle are still not very well understood.

4.1 Current state in the Americas

The Americas are a very diverse region containing arid, temperate, and tropical regions. Water availability is diverse, ranging from high access in Canada to very low in Mexico (Table 3.5).

Table 3.5: Water availability, per capita of fresh water (APWA, 2007)

Country	**m^3x1000/Inhab./Year**
Canada	99.7
Brazil	43.3
Argentina	29.1
USA	9.5
Mexico	4.6

With variations dictated by the need dictated by tradition of use as well as diverse climatic conditions, large amounts of fresh water are used in the Americas for agricultural and power generation purposes. The use of such resources should be closely monitored, as the regional and global impacts of its use are not yet well understood. Agriculture and power generation are two of the most significant uses for fresh water, and the effect of this use on the surrounding region must not be ignored. Brazil is one of the biggest biofuel producers in the world (REN21, 2007) and this practice requires a substantial amount of fresh water. The role of policies and politics is thus very important for the general public wishing to maintain clean, fresh water for various purposes. In this section the dynamic and complicated issue of international policies will be addressed; in particular with respect to two of the significant freshwater uses in the Americas, Biofuel and Power Generation.

4.1.1 Policies and the Political Dynamics of Water Distribution

Water distribution and availability differs greatly among the Pan-American countries and regions. In general, with the exception of, for example, areas west of the Andes, Latin America has relatively good water availability, due in large part to the Amazon Basin. Approximately 30% of the world supply of surface water is in this region and is found in the Amazon, Orinoco, Sao Francisco, Parana, Paraguay, and Magdalena river basins. In spite of this abundance, about 60% of the Pan-American region, for example Argentina, Bolivia, northeast of Brazil, Chile, northern and central Mexico, and Peru are considered arid or semi-arid. Additionally, about 25% of the population in Latin America lives in regions where water demand is greater than water recuperation capacity (IPCDigital, 2006). In contrast, North America has the best water and sanitation access in the world. Virtually all of the North American population has access to water and sanitation services although there are limits and competitions in the south west of the US and north west of Mexico. In the U.S., about 40% of fresh water is used for agricultural irrigation, and if freshwater use for thermoelectric generation is not taken into account, this number jumps to 65% (USGS, 2000). Due to heavy agriculture and fertilizer use, surface water contamination is a concern (IPCDigital). Combined, North and Central America have 15% of the world's fresh water and 8% of the population. South America, on the other hand, has 26% of the world's fresh water and 6% of the population (UNESCO-WWAP, 2003).

Access to water-related public services is very different among the countries of the Americas, and is largely related to socio-economic development. Level of clean water accessibility is the worst in Anguilla (60% of the population) and Haiti (71%), and in the remaining countries, 80-100% of the population has fair access to water although sanitation services are generally less satisfactory than water distribution services. The lowest levels of sewer collection are in Belize (47%), Bolivia (45%), Haiti (34%), and the Dominican Republic (57%) (Solanes e Joulavlev 2005).

CASE EXAMPLES – REGULATION DEVELOPMENT

The differing levels of socio-economic development in the Americas also have repercussions on development on water policies in American countries. Some countries in Latin America and the Caribbean have implemented significant reforms, but others have significant work to be done. Brazil has adopted new water legislation and a national water management policy. Countries like Bolivia, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Peru, and Venezuela are discussing modifications and reforms to their water-related legislations. In Peru, Colombia, Bolivia, Ecuador, El Salvador, Honduras, Nicaragua, Panama, and Paraguay, water policies are mostly organized into less than useful sectors, outdated at that. Chile has reformed its water law and the water supply and sanitation sectors, and privatized all water-related utilities. Between 1985 and 1995, Chile has promoted the contribution of water to the socioeconomic development process, with an export-oriented irrigated agriculture, mining, aquaculture, lumber, and paper processing. Sustainability and access to drinking water supply and sanitation services have also been modernized. The social movements in Chile that gave rise to agrarian reforms of the 60s and 70s imposed a change in water legislation ratified in 1969, later modified in 1981 (Solanes and Jouravlev 2006).

CASE EXAMPLES – PRIVATIZATION AND RELATED ISSUES

It can be said privatization of the economic sectors in South American countries, despite support from many private and public sectors, was not universally beneficial in all fronts of the socio-economic dynamics. For example, Argentina privatized both the hydroelectric sector, water supply, and sanitation utilities in several cities. Between the 1980s and 90s the total surface area attributed to irrigation declined, and the country's drinking water supply and sanitation services suffered to such an extent that some foreign investors withdrew from the country and filed claims with international arbitration tribunals. Peru has made attempts at reforming its legislation since the 1960s, with varying success:

> "*In some cases, the proposed legislation was mainly on political, economic, and financial considerations. The projects proposed the creation of non-regulated water markets, ignoring local conditions, traditional uses, and the nature of the resource itself. These proposals were stopped because of criticisms made by national, regional, and United States professional advisors…*" Solanes and Jouravlev 2006, 73)

In Bolivia, the current water legislation is based on the Ley de Aguas (Water law) of 1906. Although Bolivia has privatized some water-related services, this governing law is very old and outdated - incapable of addressing modern complex issues. For example, the country had a major conflict, the so-called "war for water" in 2000. Key factors responsible for this conflict can be summarized as disputes surrounding cost and feasibility of some major water related projects, low public participation, mistrust of the institutional capacity, and, at least in the opinion of some, corruption. Bolivia has made numerous unsuccessful attempts to reform water supply laws over the last twenty years. The Bolivian practice, together with many other examples, shows the difficulty in securing broad social consensus on water legislation (Solanes e Joulavlev 2005). In some countries, for example Ecuador, water legislation gives priority to the large irrigation sector, and this is a contentious decision, especially when the farms are owned by international conglomerates.

CASE EXAMPLES – POLICY AND IMPLEMENTATION

Water management institutes have different structures unique to each country. In Mexico the primary subject of water management is river basins. As a consequence, river basin councils dictate management courses, where the councils operate at four territorial levels: river basin, sub-basin, micro-basin and aquifer. In Brazil, responsibility for water resources management is shared by the states and the federal government. The law determines that river basins committees can act in river basins or river tributary sub-basins. These committees permit social participation on decisions-making, but it needs capacity building of this population to strengthen them to this process (Dourojeanni, 2001). The main federal law governing water in the United States is the Clean Water Act-CWA of 1948, regulated by the Code for Federal Regulation (CFR), Title 40, which focuses on pollution control. This act was updated in 1972 and 1987. These updates contained important amendments about water bodies' preservation, including laws regarding toxic effluents and diffusion pollution. In the U.S. Federal and State governments in partnership define and govern water pollution reduction measures (Veiga e Magrini, 2009). Canada has an integrated watershed management approach such that Canadian legislations are designed to consider interests of different stakeholders in the decision making process on water issues and also consider water quality and health, protection of aquatic ecosystem, and reduction of impacts from floods and droughts (Environment Canada 2010). Other systems can learn from this approach by considering energy, sanitation and agricultural impacts on a river basin before tapping a water supply. By addressing these sectors and including stakeholder participation in decision-making, a holistic perspective can be applied to promote sustainable development.

CASE EXAMPLES – OBSTACLES AND CROSS BORDER CONFLICTS

The flow of water across political borders can be a source of conflict, and can add to the political dynamics that could aggravate preexisting conflicts. As a case of fierce political conflict, one can mention the recent dispute between the Ecuadorian government and a Brazilian firm, Odebrecht, who planned to construct a hydroelectric dam in Ecuador. This contractual dispute has affected relations between Ecuador and Brazil to the extent that the two countries have pooled out each other's diplomats, severing diplomatic ties since January 2008 (Michel 2009).

Another potentially serious zone of cross-border conflict is the Madeira Basin located in the Amazon region of Brazil and Bolivia and involves dam construction. Located on the Madeira River close to the Bolivian border, the system could provide 3330 MW on the Jirau and 3150 MW on the Santo Antonio projects. According to some environmentalists these projects would affect the ecosystem and the population in both countries. The Madeira River has sparked political conflict between Brazil and Bolivia leading to civil society movements and organizations in both countries expressing criticism over the manner in which the environmental permit process was conducted by the Brazilian Government, and the involvement of companies perceived as less than careful about the environment (Ortiz 2007).

Another possible point of conflict regarding the use of hydro resources is the indigenous people's right, as was manifested in the Amazon. The most recent examples are the conflicts over the six dams in the Peruvian Amazon: Inambari with 2,000 MW, Sumabeni with 1074 MW, Paquitzapango 2000 MW, Urubamba 950 MW, Vizcatán 750 MW, and Chuquipampa 800 MW. These six plants would generate over 7000 MW by the start of their operation in 2015. The ecological impact of these schemes remains controversial. For example, the indigenous populations are opposed to the projects (Castro, 2009).

These examples show that sometimes the use of a natural resource such as water can bring many more issues and controversy than simply the engineering design of the dams. In the Americans, cooperative international institutions need to be established to play an important role in preventing or defusing potential water conflicts in transboundary basins. As climate change and frequent droughts render basin-level water management increasingly important, many transboundary river systems would need the necessary institutional structures to avoid or manage conflicts. Such cooperative international institutions can build comprehensive strategies, integrating competing demands across contending goals, and incorporate these strategies with effective climate policy with broad collaboration of interested parties.

4.1.2 The Balance of Biofuel

The biofuel industry in the Americas is growing at an enormous rate. This industry primarily includes the production of ethanol, which is derived either from sugar crops, such as sugarcane, sugar beet, and sweet sorghum, or from starchy crops, such as corn, wheat, and barley. Ethanol currently accounts for about 85% of biofuels worldwide. Biodiesel, another form of biofuel, is derived from oil crops, such as soybeans, sunflower, and rapeseed (Garoma 2010).

In the U.S. alone almost 5 billion gallons of ethanol from corn were produced in 2006, an increase of more than 1 billion gallons over the previous year (Aden, 2007). By 2022, corn ethanol productions are expected to increase to an estimated 15 billion gallons. Reasons behind the U.S.'s ramping up of ethanol production include an effort to move toward energy independence, as well as an attempt to possibly decrease greenhouse gas emissions. Other driving factors for the increased production of ethanol have been favorable economics for ethanol versus gasoline and the need for a performance enhancer to replace the fuel additive Methyl Tertiary-Butyl Ether (MTBE) (Keeney, Fellow and Muller, 2006). However, there is a hidden cost to the increased production of corn: water (Arroyo, 2010). Due to the high amounts of water required for feed crop irrigation and ethanol processing, the consumption of water is one of the most important emerging concerns related to ethanol production (Keeney et al., 2006). In developing countries like Brazil and Colombia biofuel feedstock production and biofuel processing may carry such undesired environmental costs such as air and water pollution, soil depletion, and wildlife habitat loss due to conversion of lands to croplands (Kojima and Johnson, 2006). Related issues to the balance of water and biofuel are discussed below, under "consequences of ethanol production on water and food supply".

4.1.3 Primary Water Use for Power Generation

For low-income populations, energy and water serve basic needs for drinking, cooking and washing. As household incomes increase, other power related applications such as refrigeration, transportation, cooling, and swimming add to the total load. The electric loads add to a collective need for large power plants to address the continuing energy appetite of society.

Compared to the combustion of fossil fuels and nuclear power plants, hydropower is a clean source of energy since no pollutant or hazardous waste is generated in the process. However, there are some restrictions limiting this energy source. Damming rivers for example causes adverse environmental impacts such as obstructing immigrant fish, water temperature change and significant changes in the ecological characteristic of the river. The stored water reservoir of a dam can change the environment over a much wider area than that covered by the reservoir. The energy potential of the dam is also limited by the amount of available fresh water in the area. Based on United Nation's report on 2007, the fresh water withdrawals are predicted to increase by 50% by 2025 in developing countries and 18% in developed countries (UN Water, 2006). On the other hand, the global primary energy demand is predicted to increase by over 50% between now and 2030 (Birol 2007). These predictions further highlight the need to integrate water and energy solutions so as not to drain one resource while working to preserve the other. In this way, water and energy are two connecting issues as water is used to generate energy and energy is used to distribute water. Water treatment contains a series of procedures performed to make water more acceptable for a drinking and irrigation. The total amount of fresh water resources estimated is about 35 million cubic kilometers, 70 % of which is in the form of ice and permanent snow (UNWater, 2010). In 2005, thermoelectric freshwater withdrawals for the US accounted for 41% of all freshwater withdrawals (USGS, 2010).

In non-nuclear thermal power plants, electricity is typically generated by converting water into high-pressure steam that drives turbines (see Fig. 4.1). The partially cooled steam at the turbine exit is cooled and condensed for repeat use. The water is reheated to drive the turbines again, repeating the cycle in a closed cycle, or fresh water is pumped instead, as in an open cycle. The condenser, typically a cooling tower, requires a separate cooling medium, water, to remove the heat from the condensing steam. Such closed cycle systems discharge heat to the ambient in the cooling tower, and reuse water within the power cycle. The water loss in such a power plant is relatively small since it is limited to the amount lost through the evaporative process. However, open systems use a continual flow of water, and i.e., the water demand is between 30 and 50 times that of a closed cycle system (UNWater, 2010).

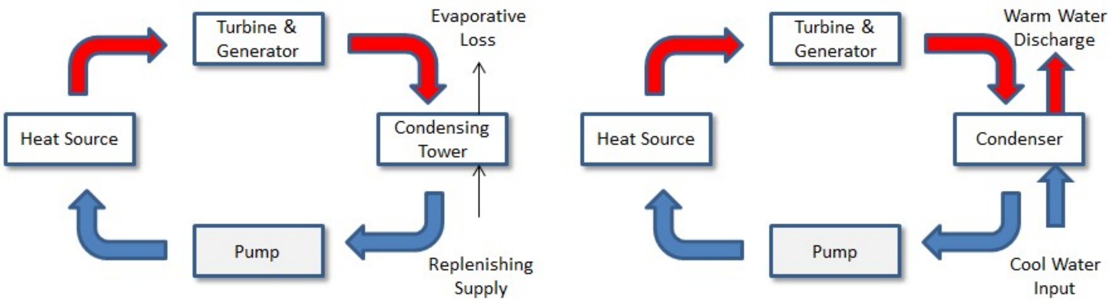

Figure 4.1: Simplified process diagram of a thermal power plant, showing a closed system (left) and an open system (right).

The technology and the size of the power plant define a proper cooling system and the amount of water required. Nuclear reactor plants consume more water than fossil fuel ones and those plants powered by natural gas consume the least amount of water for their cooling systems. For open cooling systems, nuclear plants consume about 400 gallons of water for each megawatt hour of electricity, compared to 250 gallons for fossil fuel plants and just 100 gallons for natural gas plants. These values become 550, 400 and 180 gallons per megawatt hour, respectively, for closed cooling systems (U.S. Department of Energy, 2006). Nuclear reactors require the most water for cooling and fossil fuel power plants require a lesser but still significant amount. For instance, the Salem Nuclear Generation Station in New Jersey takes 3 billion gallons a day from the Delaware Bay (Ottinger, et al. 1990). Steam power plants in the US draw in more than 200 billion gallons of water per day. Taking advantage of most renewable energy technologies means there will be significantly less water needed for cooling.

At some hydropower plants, the turbines are located in the dam, and thus the water is released directly downstream. In other cases, the turbines are located in a powerhouse significantly far from or downstream of the dam. This means the water is diverted from its route for a significant distance, sometimes several miles, before being released back into the river course. There will be an obvious change within the river basin which lost its historical water flow.

Because of availability and its non-toxic and non-hazardous properties, water is also one of the best sources for renewable energy. In hydroelectric power systems, water is the working medium and also the “fuel”. In 2006 hydropower produced 89% of the world’s renewable electricity, and 16.6% of the total electricity generation worldwide (IPCC Working Group III, 2008). In total, 25% of dams worldwide are used for hydropower, and only 10% have the generation of hydropower as their main purpose (WBC, 2009). One of the advantageous of hydropower energy generation facilities is the fact that they do not consume cooling water in the process. However, there is large amount of evaporation loss due to the increase of surface area of reservoirs, especially in arid areas. Therefore, in terms of sustainable options for delivering energy and conserving water, hydropower is high on the list compared with other options currently explored in the Americas.

4.2 Challenges and concerns

The relationship between energy and food or water supply is a delicate matter involving various socio-economic factors. For example, ethanol often competes with crop land which could be used for food production. In addition, a substantial amount of water is needed for ethanol crops. Political issues between neighboring countries also play a large role in shaping policies of water distribution and resource sharing.

The problem of fresh water supply in any region is complicated, especially in naturally arid regions. Desalination is a possible alternative in such extreme environments with limited resources to clean water. Desalinization is becoming a viable strategy for converting salt or brackish water into usable fresh water, and can be done a number of different ways. Regardless of the technology used, the dependence of fresh water production and energy production is very important and will be discussed in further detail below.

4.2.1 Technical and Engineering Challenges to Desalination

With projected increases in water stress on current surface and fresh groundwater supplies, alternative sources of fresh water for energy, domestic, and other sectors will need to be utilized. One such alternative source is desalination, both of brackish groundwater and seawater. Thermal desalination has been used for some time, especially in the desert regions of the Middle East where energy costs are relatively low compared with freshwater supply costs. In the past 40 years, however, membrane desalination technologies, such as reverse osmosis and electrodialysis, have seen much development (Gleick 2006). Greenlee et al. (2009) state that reverse osmosis (RO) desalination accounts for 44% of world desalting capacity and is the leading technology for new desalination plant projects, including those in the Americas. Schiffler (2004) argues that desalination technology, especially RO, has made significant technological gains, "making it significantly cheaper, more reliable, less energy-intensive and more environmentally friendly than it was a few decades ago." As a result, desalination has gained significant attention throughout the Americas.

Several government bodies in Northeast of Brazil had some 2,000 desalination stations installed over the past decade. However, most of these stations have been closed or are not operating properly mainly because of high maintenance cost and lack of trained technicians (IPSNews, 2007).

In Chile, desalination projects are concentrated in the Antofagasta region in the north of the country, primarily targeted to mining communities. In 2010, there are 10 Chilean projects set for desalination. In Pucusana, Peru, an 80,000 m^3/ day seawater desalination plant is planned (UNEP, 2010).

There are 50 to 75 significant desalination projects in the United States, with an average capacity of about 1 million gallons per day. The majority of these plants use membrane processes such as nano-filtration or reverse osmosis (WWD, 2010).

While advancements in membrane RO desalination technology have been substantial, there are still challenges related to wider adoption of desalination as a viable clean water supply in the Americas. The technical challenges of desalination include areas of technological improvement that will hopefully lead to reductions in both energy usage and overall cost of running desalination plants. The engineering challenges of desalination include process improvements, such as colocation with energy supplies, which will also lead to overall reductions in the energy-water system performance and cost.

A major issue with desalination is providing the energy required to desalt the source water. The theoretic minimum amount of energy required to desalt seawater is approximately 0.7kWh/m^3, with current seawater desalination plants requiring 3-12 kWh/m^3 (Schiffler 2004). Relatively speaking, desalination is a rather expensive (both in terms of energy and capital) means of producing drinking water. However, with the technological improvements of the past few decades, the cost of desalination in new membrane RO plants has reached comparable price levels (averaging $0.45/0.7 m3) with conventional forms of supply, such as damming rivers and intra-basin transport) (Schiffler 2004). However, since this cost is an average it hides the localized costs in areas where power production is already at near capacity, or where extensive pumping would be required. As energy becomes more expensive in light of dwindling supplies of fossil fuels and the impacts of climate change, reducing the energy further will become even more crucial. Improving efficiency of the desalination process is central to reducing the fuel and capital costs of desalination.

One of the main target areas for improving RO desalination efficiency is the prevention and/or reduction of membrane fouling (Greenlee, et al. 2009). Membrane fouling is caused by the deposition of a variety of contaminants onto the surface of the membrane. This deposition of foulants is part of the normal operation cycle of membrane desalination. As surface foulant concentration increases, the pressure, and thus energy cost, required to move the source water across the membrane increases. Once the pressure required becomes too high, then a backwash cycle must take place. Pretreatment through chemical or mechanical removal of possible foulants from the feed water increases the time between backwash cleaning cycles, which results in overall less energy required. Additionally, better pretreatment could also lead to longer lifetimes of the RO membranes. As more desalination projects are started with varying qualities of source water, along with new regulations for removal of emerging contaminants (such as pharmaceuticals), researching new and better pretreatment processes will be an important part of progressing desalination (Greenlee, et al. 2009).

Another hurdle for desalination plants is waste brine disposal. Both Schiffler (2004) and Greenlee, et al. (2009) identify brine disposal as an issue with desalination due to both the cost and the ecological impacts. As the feed water is desalted, the rejected salts are concentrated extremely highly in relatively small quantities of waste water. Improving the efficiency of the desalination process (the amount of salts that can be removed) leads to less total volume of waste, but higher concentrations. Disposing of the waste water into surface water or the ocean has adverse ecological effects, and is in many countries regulated against. Another option for disposal is injection into underground aquifers that are already brackish and have no future plans of use. Due to relatively poor understanding of many aquifer systems, injection disposal could also be problematic as high concentration brine could infiltrate into cleaner, in-use aquifers. Evaporating the brine in surface evaporation ponds and storing or disposing of the remaining salts in landfills also presents issues of cost and ecological impacts (Greenlee, et al. 2009).

Desalination plants collocated with power plants have the possibility for synergy and overall reduced water and energy needs. Thermoelectric power plants could use brackish groundwater for cooling purposes, after which the heated waste discharge could be used as the supply water into a desalination plant (U.S. Department of Energy, 2006). This type of energy-water colocation would improve the overall water used than if the plants were located separately and cooling water simply discharged back into the environment. The amount of greenhouse gas emissions resulting from the energy required to desalt water must be taken into account when determining the environmental impacts of a new plant. An even better means of moving forward with desalination projects is the use of renewable energy to supply power when possible. The most likely market for coupling renewable energy with desalination is in small remote communities that are not connected to electrical infrastructure (Schiffler 2004).

With current research and worldwide trends in desalination, it is unlikely that a competing technology will overtake RO for seawater desalination (Schiffler 2004). Communities will have to evaluate the site-specific benefits and costs of desalting water to determine its feasibility. In California, for example, desalination is being examined as an alternative to the long-distance, upgradient transport of water from the water-rich northern region to the dry southern portion of the state. According to Chaudhry (2010), the pumping of water to southern Californian communities' furthest upgradient from the source requires over 5,000kWh/acre-ft. Seawater desalination, on the other hand, is expected to require in the range of 4,000-4,500 kWh/acre-ft of water. Aside from being a possible source of clean water, there are other possible benefits that should be considered when examining desalination projects. Reducing exploitation on coastal aquifers might reduce seawater intrusion, and the long-term environmental impacts of desalination might be less than constructing dams and reservoirs (Schiffler 2004).

4.2.2 Consequences of Ethanol Production on Water and Food Supply

Biofuels are renewable and commercially available replacements for transportation as they can be conveniently stored. Due to the large amount of water required for feed crop irrigation and ethanol processing, the pressure on water use is one of the most important emerging concerns related to ethanol production. Ethanol farms need to be region specific, targeted to areas with high humidity and available water supply. This may also carry inadvertent environmental costs including water and air pollution, farm land and soil depletion, and habitat loss if the land is being converted from forests to cropland (Kojima and Johnson, 2006).

Considering that the US consumes about 1.51 billion liters of gasoline daily, around 3.6 million gallons of water per second would be needed to replace this with ethanol (Beyene 2010). This is approximately equal to the flow of 22 Colorado Rivers, fully committed to ethanol, excluding production water needed for other uses (Beyene 2010). Water consumption for ethanol production has led to tension regarding water use, as has been identified in the Midwest U.S. Here, water availability is not distributed according to water demand and "large livestock confinements, meat and grain processing plants, and expanding urban regions are all increasing water use" (Keeney et al., 2006). Corn crops use an average of 1.2 acre-feet of water per acre of land (USDA, 2008) and 785 gallons of water are used for every gallon of ethanol produced (Beyene, 2010).

The water requirements for ethanol produced from corn vary widely depending on climate (Arroyo, 2010). Consumptive water use is usually used when assessing water utilization, and refers to the amount of water used that is not returned to the resource. For most ethanol plants, this is made up largely of evaporation during cooling and wastewater discharge. Ethanol plants are designed to recycle water within the plant, although a high quality of water is needed in the boiler system. Water utilization is 10 gallons/minute for each 1 million gallon (3,785,412 liters) of ethanol production in a year. Thus, to produce of 50 million gallon (189,270,589 liters) per year, an ethanol plant would need 500 gallons (1893 liters) per minute of water (Keeney et al., 2006).

Ethanol farms will also have an inevitable impact on world food supply. As the price of gasoline increases, and the support for ethanol grows through government incentives, there would be little reason for farmers not convert their farm lands to ethanol production. Corn, which is traditionally a stock-feed, will be targeted for ethanol, and therefore the consequential food shortage will also impact livestock.

Cane cultivation for ethanol is also quite water-intensive, though in the central-south region of Brazil, nearly all cane fields are rain-fed, in contrast to irrigated sugar production in countries such as Australia and India (Kojima and Johnson, 2006). In Brazil, most of the sugar cane plantations use natural irrigation supplemented by partial ferti-irrigation, mainly to manage waste water, by limiting production to regions where reasonable rainfall occurs. On the other hand, ethanol production from sugar cane crops uses a significant amount of water not only in the agricultural but also in the industrial phases. Water availability is not a problem in most of Brazil, except in some specific regions like the northeast, where the high use of fertilizers leads to issues with the quality of groundwater. Uses of fertilizations and agrochemicals in crops, soil erosion by cane washing are the major water impacts by sugar cane crops (Moreira 2007).

Colombia and Canada also have programs for biofuel production, though they are small in comparison with the U.S. and Brazil. The 2008 production of ethanol in the U.S was 9,000 MG, derived from corn; 6,472 MG in Brazil, derived from sugarcane; 238 MG in Canada, derived from corn; and 79 MG in Colombia, derived from sugarcane (Garoma, 2010). Water requirements for corn ethanol crops vary according to climate zone. Tropical zones like Brazil and Colombia require less water in irrigation than dry and temperate zones. The land preparation in these zones uses the same quantity of water (Garoma, 2010).

Ethanol plants in Colombia use about one-third of the water of Brazilian plants, and about one-half of the energy. This inconsistency is as a result of local technology variations. Most sugarcane plantations in Colombia need irrigation, whereas most Brazilian plantations do not due to consistent rainfall (Toasa 2009). Thus, investments should inevitably account for input variations, and target cost reduction. Ethanol production impacts on groundwater withdrawals vary locally according to factors such as volume used, properties of the aquifer used, and rate of aquifer recharge (Keeney et al., 2006). The production process results in energy use and in releases of carbon dioxide, waste, and residual fertilizers and pesticides (Garoma, 2010). Residual fertilizers, pesticides, and other waste products could lead to contamination of water resources if not treated properly at the point sources.

Options for reducing water consumption during ethanol production include:

- Maintaining and strengthening regulation by state and local governments regarding the placement of ethanol plants, with special emphasis on water supply and availability,
- Where feasible, placing plants adjacent to municipal wastewater facilities,
- Looking for water recycling opportunities in livestock facilities; placing a greater economic value and stewardship on water use, and
- Maintaining publicly-available records on water consumption for ethanol production (Keeney et al., 2006).

4.2.3 Cross Border and International Challenges of Water Supply & Viable Regional Solutions

Water has become highly politicized internationally because it is a trans-boundary resource. The cross-border flow creates appropriation and management challenges, often politicizing water rights, distribution, and pricing among the various states and countries through which a river traverses. The manner in which different stakeholders reconcile their interests is instrumental in resolving water related problems and also in determining responses to climate change (Michel 2009).

Water use is linked to political interests, population density, infrastructure extent, cultural variations, ways of life, and many other issues shared or not shared across the political borders. These issues are also prevalent in many parts of the Americas, pausing serious transnational challenges of water management.

In North America the challenges are mainly dispersed in the Southwest of the US involving USA and Mexico as they pertain to the Colorado River Basin. Under longstanding inter-State and inter-governmental treaties as well as government supervision, the Colorado River irrigates 3 million acres of farmland and supplies water to 30 million people in the United States and Mexico. Due to this high dependence on water in a primarily desert environment, many problems linked to economic development, environmental degradation, and water rationing have emerged. Long lasting and frequent droughts has added to the stress, and additional water supply is high on regional political agendas of the South West US and North West Mexico. This leads to new ideas of water supply which includes purifying and reuse of agricultural runoff (Matalon 2010). There are continuous government level negotiations and deals between the US and Mexico on the fate of the Colorado River. The most recent agreement made in 2010 revisits an old tract signed in 1944. This new treaty stops the flow of wastewater from Arizona's farms into the Cienega, redirecting the wastewater to a desalinating plant in Yuma instead, Arizona (Matalon 2010).

Since hydroelectric power has become a significant source of energy for South America, the use of trans-boundary water resources is more closely linked to energy generation, especially over the past few decades. The imposition of higher energy costs by the Organization of Petroleum Exporting Countries in 1973 profoundly changed the conditions for growth in most of the world's developing countries, especially in Latin America. This in part explains the development of hydroelectric power in Latin America (Goldemberg 1984), and the consequences have been both positive and negative. Examples of positive developments include regulation of flooding, while the negative consequences include rainforest destruction, soil erosion, sanitation, and costly disputes on the right of use.

Perhaps the most outstanding example of cross-border hydroelectric power sector cooperation in the region is the 14GW Itaipu project on the Parana River on the border of Paraguay and Brazil. Operational since 1991, the Itaipu dam is the largest in the Americas, and provides about 19% of power used in Brazil. The success of this project has encouraged Brazil to investigate the possibility of expanding the hydroelectric potential in its borderlands. However, even with the documented output and success, there have been political disputes regarding the distribution of energy from Itaipu (Peixoto 2009). Paraguay wants the right to sell its share to whoever it wants to, at the best market value. However, based on the original contract, due to complexities related to financing the project and debt relief, Paraguay can only sell the power to Brazil (Peixoto 2009). Treaty/contract ratifications would likely improve the efficiency and benefits of the project for both countries although these steps have not yet been taken.

4.3 Future Water Treatment and Related Technologies

The fundamental goal of water treatment is to eliminate the contaminants or reduce the concentration so that it becomes suitable for the desired purpose. The process to achieve water with higher quality than what was achieved by first treatment process can be referred as advanced water treatment. Based on Water Reuse Association definitions (GE, 2010), reusing water is the process of using it more than one time before it passes back to the natural water cycle. Treated waste water can be used for purposes such as agricultural, industrial, toilet flushing or returned to a groundwater basin. Reusing water helps to retrieve the natural water sources and results in less dependency on groundwater and surface water sources.

Water reuse, although a relatively new practice in much of the Western Hemisphere, is becoming more common. Types of wastewater reuse in urban applications include irrigation of parks and public lands, vehicle washing, fire protection and toilet and urinal flushing. Whereas this is simply an example of direct water reuse, these applications do not require additional steps in order to make use of waste or “grey” water.

In terms of active research and development of technology to recapture wastewater for the purpose of producing clean, fresh water, much attention has been devoted in recent years. For example, membrane bioreactors (MBRs) are widely used for wastewater treatment, and plant sizes are large enough to support populations of around 80,000 (Judd, 2006). Plants such as these combine a membrane process with a suspended growth bioreactor to filter out impurities in the water. As wastewater is cleaned, a considerable amount of sludge is produced, which must be removed from the system. Every year, new technologies are created to make these processes more efficient and larger, while producing comparatively less sludge and other byproducts.

Though wastewater treatment is an effective way to replenish water supplies, technology is advancing to allow even more effective treatment. Together with advances in salt water desalinization processes, water treatment leading to a greater availability of fresh water will remain a very important issue, stretching across the political, engineering, economic and ecological sectors of North and South America.

5 CLIMATE AND CLIMATE FEEDBACKS

The world is faced with the dilemma of climate change at a time of increased water security and growing energy demands. Sustainable management of the world's available water and energy resources is essential to meet the needs of the citizens around the globe. While scientists have made notable technological advancements in understanding climate dynamics, there is still concern that the feedbacks involved in Earth's global energy balance are not well understood (Bonan, 2007). In order to develop adaptable and sustainable management solutions to water and energy resource issues, feedbacks and their roles in these systems need to be better accounted for and understood.

Since pre-industrial times, the CO_2 concentration in the atmosphere has increased from 280 parts per million (ppm) to 360 ppm, and the global mean surface temperature has increased by 0.75°C (IPCC 2007a). The increase of CO2 concentration is currently causing a radiative forcing of ~2 W/m2, which corresponds to a relative imbalance of less than 1% with respect to the incoming and outgoing radiative fluxes at the top of the atmosphere (Hansen et al., 2005). Since the system is in a transient state, the observed temperature increase underestimates what would be realized in the long term if the present CO_2 concentration were to be held fixed at the present value. The GHG effect is one well-understood feedback mechanism that contributes to surface warming, whereby increases in greenhouse gases (CO_2, CH_4, e.g.) primarily from anthropogenic sources are trapped in the Earth's atmosphere and deflect upwelling radiation from the ground back down to the surface. Due to the complexity of the involved physics and the presence of multi-scale interactions in time and in space, efforts are still needed to improve the accuracy in the representation of climate feedbacks related to the phase transitions of the water substance - e.g. albedo, clouds and water vapor feedbacks (Rotenberg & Yakir, 2010). Much of the uncertainty in projecting future climate is related to the complexity of these feedbacks and cloud/microphysics interactions.

With technological advances in satellite imaging, supercomputing, large environmental networks that collect near real time information of biophysical processes around the Earth, and climate changes, we are living in an exciting time for studying climate. Since the dynamics of the climate system features occurs throughout a large spectrum of spatial and temporal scales, a great deal of attention has to be set of the understanding of the nonlinear interactions in order to improve the accuracy of the climate prediction and inform accordingly the decision-makers. The multi-scale nature of the climate system is such that, depending on the spatial and temporal domain of interest, we have to refer to a different set of approximations and construct hierarchies of models, rather than adopting a unique modeling framework, as typically done in most physical sciences. When aiming at providing information on smaller scales than those resolved by global climate models, dynamical or statistical downscaling methods must be used in order to inform the decision making process at local scales.

5.1 Climate Feedbacks and Energy Balance

In this section, the energy related topic discussed is not the one needed for electrical or mechanical power for human infrastructures, but the energy provided by the sun to the Earth system. Further, it is noted that the global energy balance cannot be separated from water balance because changes in solar radiation reaching the Earth's surface are the main drivers of the hydrological cycle.

Following the pioneering work of Lorenz (1955), it has become clear that a very efficient way to tackle the fundamental problem of understanding the structural properties of the climate system is to adopt a thermodynamic perspective. The climate can be seen a non-equilibrium system, generating entropy by irreversible processes, transforming potential into mechanical energy like an engine, and keeping a steady state by balancing the input and output of energy and entropy with the surrounding environment (Lucarini, 2009). Such a perspective has recently allowed understanding the properties of large scale climate transitions (Lucarini et al., 2010a) and analyzing the climate response to increasing CO_2 levels in a more physically sensitive way (Lucarini et al., 2010b).

Several case studies related to climate and climate feedbacks have been investigated. These case studies covered multiple aspects of climate feedbacks on the global energy budget. One such study (Beyene, 2010) discusses a need to apply thermodynamic principles to better understand the global energy balance and relate it with the energy uses of human societies. Humans may be able to adapt to meet the energy demands, but the effects on the global energy balance may show a responsive lag because of the size and resilience of the system.

Other studies, (for example, Oechel, 2010) discuss the current perspective of climate change in the context of meeting society's needs with population growth and resource depletion. In relation with the global energy balance, it can be inferred that GHG emissions in the current century can set in motion large-scale, high-impact, non-linear, and potentially abrupt changes over the coming decades and even to future millennia. Further complicating the issue, the outcome of these changes in energy balance and climate change are not isolated, and therefore may have an influence in changes in water runoff, increased drought, increase wildfire intensity and frequency, and an overall increase in climate variability.

Today, General Circulation Models (GCMs) constitute fundamental tools for evaluating future climate scenario under a variety of forcing (Leung, 2010). Therefore, the definition of procedures for the inter-comparison and validation of GCMs has become a central issue in climate science (Held, 2005). Moreover, recently the need for a "quantum leap" in climate modeling, i.e. a qualitative improvement beyond incremental innovations has become apparent (Shukla et al., 2009). Recent analyses show that a good portion of the of the state-of-the-art GCMs included in the 4th assessment report of the IPCC do not feature a physically consistent energy balance, which points at some fundamental flaws in the representation of the physical processes (Lucarini & Ragone, 2010). A critical challenge in GCMs is to reduce uncertainty that is related to complexity of feedback processes associated with water and its phase changes. The global energy budget cannot be separated from the water cycle because energy will be absorbed by water and water vapor can also act as a greenhouse gas influencing the global energy balance. Surface albedo feedback is also important, especially in terms of the snow-albedo feedback. In terms of using GCMs for regional application, large-scale hydrologic modeling may show the challenges in downscaling GCMs to calculate regional and local energy fluxes (Beighley, 2010). Therefore, there is a need to improve our understanding using new tools such as modeling and satellites that provide high spatial and temporal information for solution of the energy and water models.

From a more purely mathematical perspective, Shen et al. (2010) present statistical approaches and challenges to quantify the uncertainty associated to climate change. The main conclusions related with global energy balance are:

- Warming and changes in global energy balance observed since 1861 are reliable,
- A better understanding of cloud dynamics is needed to better understand the global energy balance,
- There are still several mathematical challenges because the climate processes are non-stationary and the response to feedbacks is non-linear.

Research topics to address these challenges include the application of Bayesian approach for model simulations and the investigation of non-stationary and nonlinear annual cycles and anomalies.

Regional climate change studies focusing on the Americas are also currently underway. Sena et al. (2010) examined the Rio Acre basin of Brazil, and discussed the ongoing changes in temperatures, precipitation patterns and forest fires, and the implications of these effects on the communities of Brazil. In terms of energy, all of these phenomena influence the surface albedo, and consequently the amount of solar radiation reflected back to the atmosphere.

Another factor that can affect climate change models is local radiative forcing. By assessing the importance of local radiative forcing footprint, Zevenhoven, Falt and Beyene (2010) showed that replacing fossil combustion by less efficient thermal plants, like nuclear fission, will increase the global heat-up rate and waste heat release to the environment. Furthermore, that a total ban on fossil fuel combustion could lower the rate of global warming by up to 60%, but will not completely stop it.

The use of alternative thermodynamic measurements, i.e., exergy, for the calculation of energy balance and climate change as well as accounting of energy use at different spatial and temporal scales was suggested, Sciubba (2010). It was proposed that sustainability issues can be addressed using classical thermodynamic, exergy analysis in particular. The premise of this analysis is that heat cannot be entirely converted into work; therefore its exergy content is lower than its energy content. This idea can be applied in any natural and man-made system to calculate its energy use and thereby provide a common metric for comparison of unrelated systems.

5.2 Climate Feedbacks and Regional Water Stress

Water stressed regions are those where the demand for water is greater than the amount available. The stress might have been originated by drought conditions, but in most cases it is aggravated by overexploitation of the existing water resources (surface and groundwater reserves). A great example is large-scale agriculture in semi-arid regions, where precipitation is insufficient for crops' water requirements and the production is highly dependent on irrigation. Irrigation depends on groundwater availability, which in turn is threatened by abusive consumption and projections of decreasing precipitation and increasing temperature in the near future. Other example is the rapid growth of urban centers in desert areas, where the demand for water increases exponentially to satisfy the ever-thirsty population (not only for domestic use, but also for energy generation, and industry). Serious groundwater management becomes critical in these cases, and many times it transcends local, state and even national boundaries.

For a future warmer climate, the current generation of models indicates that global precipitation tends to increase (IPCC 2007a). In addition at the global scale, the averaged mean water vapor, and evaporation are projected to increase. The increases in precipitation are expected in areas of regional tropical precipitation maxima (such as the monsoon regimes) and over the tropical Pacific. In contrast, a general decrease in precipitation for the subtropics is expected, accompanied by an increase at high latitudes as a consequence of a general intensification of the global hydrological cycle. Climate models consistently predict the decrease of precipitation in areas that already are under semi-arid and arid conditions. Most of these arid and semi-arid regions are found in the subtropical and lower mid-latitudes, such as the Mediterranean basin, southwest North America, southern Africa and northeast Brazil.

The intensity of precipitation events is also projected to increase (IPCC 2007a). These changes are expected in tropical and high latitude areas that will experience increases in mean precipitation. Even in areas where mean precipitation is expected to decrease, intensity is projected to increase but with changes in frequency with longer drought periods between rainfall events. There is a tendency for decreased humidity in the mid-continental areas during summer, indicating a greater risk of droughts in those regions. Precipitation extremes are expected to increase more than mean precipitation in most tropical and mid and high latitude areas. These changes will not allow for the soil to retain more moisture (i.e., ground water recharge will be limited if most precipitation immediately goes to runoff), thus increasing the risk for desertification.

While the warming effect due to the positive feedback from greenhouse gases is well understood, the cloud feedback effects are not (Leung, 2010). This poses an important challenge because their representation in climate models is not entirely reliable. The basic assumption is that low-level clouds induce a negative feedback, since they decrease the amount of incoming short-wave radiation without affecting the amount of long-wave radiation that leaves the lower atmosphere. The resulting effect is cooling of the surface. High clouds, on the other hand, are not effective in blocking shortwave radiation, but do enhance the greenhouse effect by retaining the outgoing long-wave radiation from the surface, thus warming the atmosphere. The quantification of these processes however is still based on simplified parameterizations.

The impact of aerosols in the climate system is also not entirely understood, and their representation in climate models is somewhat simplified (Leung, 2010). In theory, an increasing concentration of aerosols in the atmosphere due to anthropogenic pollution will increase the availability of hygroscopic particles to serve as cloud condensation nuclei. The effect is a decrease in cloud droplet size, thus decreasing the chances of light precipitation. Precipitation will only occur after a greater accumulation of cloud droplets, leading to more intense events. While this effect might be quite predictable, the parameterization of the influence of aerosols on global and regional energy budget and water cycle (through their interactions with radiation and cloud microphysical processes) has yet to be improved.

Feedback processes through land-surface vegetation might also act to amplify pre-existing drought conditions. Within a dry atmosphere, little water vapor is available so the atmospheric demand for water increases the evapotranspiration rate from plants. With higher air temperatures, the potential rate of evapotranspiration is even higher. This leads to higher ground water consumption by the plants' rooting systems, ultimately lowering the water table depth (Leung, 2010).

All of the mechanisms described above influence the correct prediction of future precipitation patterns. This is critical because precipitation itself is the key challenge in predicting regional climate changes. It links physical, chemical and biological processes, and it is the most important driver of environmental impacts. Finally, from climate perspective, precipitation is the central element of concern when discussing water stress.

5.3 Climate models, energy balance and water cycle

Relationships between the global energy budget and the hydrologic cycle are applied quantitatively via general circulation models (GCMs), which simulate the Earth's physical processes. By solving the primitive equations and using parallel computing, climate models are able to couple land and surface dynamics to atmospheric interactions, and provide links between the past (observations) and the future (predictions) climate. These capabilities infer the importance of GCM outputs in the quest to understand the magnitudes, locations and mechanisms for climate change.

Motivation for modeling the physical processes governing Earth's climate is primarily three-fold: (1) to understand the interactions and feedback mechanisms between the land, ocean and atmosphere in order to accurately represent these dynamic relationships in the global system, (2) to determine how the system will respond to perturbations and forcing—namely from anthropogenic sources, and (3) to investigate how climate change will impact environmental and human health on both a regional and global scale. One way to visualize the connections between climate models, the energy budget and the water cycle is through illustration of a concept map (Figure 5.1). This shows how elements and internal processes of the water cycle and energy budget are inextricably linked and must be considered so in economic, planning and management analyses.

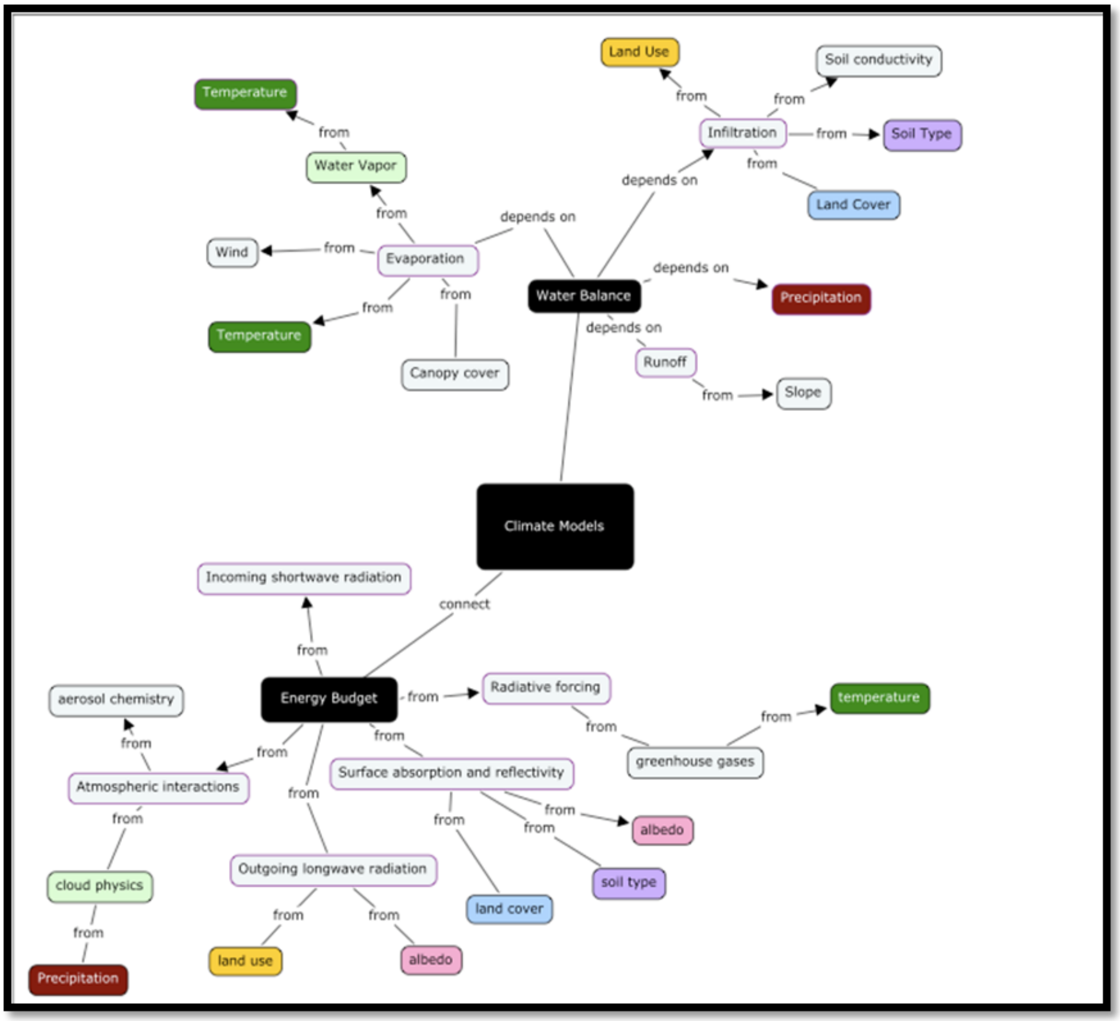

Figure 5.1: Concept map of the linkages between the energy budget and water balance, and the role of climate models in connecting these systems.

Because the Earth's climate system is complex and contains processes that are currently not well understood, there is a significant amount of uncertainty associated with climate prediction from GCMs. Quantifying uncertainty is a vital element in interpreting model outputs for regional planners, thus identifying the areas of greatest uncertainty can direct future research and give policy makers an idea of model limitations (Shackley, Young, Parkinson, & Wynne, 1998). This section will discuss current climate and hydrologic modeling efforts, including those presented at PASI 2010, and make recommendations on how to progress in this area for the immediate future.

GCMs, as tools, can accomplish a task that scientists cannot do – simulate Earth's climate as a dynamic system without use of active experimentation (Leung, 2010). GCMs have improved in the past two decades namely in terms of spatial resolution and computational abilities. These improvements translate to more effective representation of land processes and topography, which allow regions to grapple with impacts of expected changes in temperature and precipitation. Uncertainties in GCM outputs are mainly attributed to limited understanding of cloud microphysics interactions and also land-use to surface albedo feedbacks.

Regional climate models can be used to predict future climate for a smaller area of interest (Leung & Wigmosta, 2007). These regional models differ from GCMs as they can be run at a higher resolution and with model complexity set by the user (able to select level of detail in post-processing). Currently, researchers use regional models as a more accurate alternative to GCMs for predicting short-term weather over an area; and, the next IPCC report will make use of this approach in order for local governments and entities to construct policy mitigations and adaptations. Overall, improving the GCM outputs is a difficult task, as radiative forcing from carbon dioxide corresponds to very small changes in the radiative budget (less than $2W/m^2$), which are difficult to model precisely. Misjudging important parameters in the climate system can perturb the model incorrectly and lead to presenting an inaccurate picture of the future.

5.3.1 Hydrologic modeling

As discussed in the climate and energy section, there is a link between GCMs and hydrologic modeling. Climate change connects hydrologic modeling to GCMs via analysis of different emission scenarios. Temperature and precipitation outputs from GCMs are fed into hydrologic models to produce stream flows for a range of future possibilities. Therefore, climate change introduces an added uncertainty to the future hydrologic state of a river making it even more difficult to produce accurate models sufficient for flood and drought analysis for an area. Since rivers are a main water source for agriculture and municipal use, their sustainability is extremely important for society. Using available satellite and observational data, scientists develop models to determine stream flow estimates for specific river basins. These hydrologic models require inputs of land characteristics, precipitation and temperature to then solve the surface energy balance equation over a given basin.

Beighley (2010) created a Hillslope River Routing Model (HRR) to determine flow for large river basins based on hydrologic and hydraulic parameters. HRR defines irregularly shaped grid areas following the Pfafsetter delineation methodology, and uses climate and land characteristic inputs from satellite data to produce stream flow in each grid section, and thus for the entire basin (Beighley, 2010). The HRR model was applied to the Amazon basin and produced results that varied in accuracy depending on the spatial scale selected; this indicates the heterogeneity of the basin makes it sensitive to parameterizations. The model is useful for developing stream flow regimes in areas that have variable data available, as this approach allows for the data to dictate the complexity of the model.

One way to reconcile the gap between future regional planning and model uncertainty is to use downscaling strategies to develop regional scenarios for a given area. In Baja, California (BC), Cavazos (2010) uses statistical downscaling schemes published by the Lawrence Berkeley-Livermore Lab to develop future climate scenarios for 2000-2100 at 12 km resolution. By selecting the best performing models (as validated with historic observational data), Cavazos (2010) created a realistic ensemble of possible future climate scenarios for BC to implement in their state climate action plan. This improvement in resolution over the GCM outputs allowed for analysis of impacts on the available water supply, wine-making industry and potential sea-level rise. This case study is a great example of how researchers and planners can apply GCM outputs to their unique region and enact policies to adapt and mitigate to expected changes.

5.4 International treaties on climate change

With growing concern and interest in the global effects of climate change, the need for international collaboration and cooperation has become essential to effectively address the adverse consequences associated with this phenomenon. Various entities – the United Nations (UN), Intergovernmental Panel on Climate Change (IPCC), International Monetary Fund (IMF) and the World Bank, Food and Agriculture Organization (FAO) – have begun formulating policies and strategies to minimize the anthropogenic activities associated with climate change, such as the increase of greenhouse gases from burning fossil fuels. Other global strategies have been proposed and enacted to address the climate change issue on a regional or local scale; however, their progress has been hindered by the inability of major stakeholders to reach a consensus as to the most appropriate implementation and intervention measures to be taken. Meanwhile, the adverse effects of climate change have become more evident in the most vulnerable regions of the world. As such, the severity of the situation requires a more aggressive and coordinated response on a global scale in the areas of policies, education and conservation.

In addressing the global climate change issues, several treaties have been established and implemented over the past two decades. In February 1979, the first World Climate Conference was held, where several countries convened in Geneva, Switzerland to discuss the issues raised in regards to climate change. The conference set precedence for future international treaties and protocols, along with the establishment of the IPCC in 1988. In 1994, the Montreal Protocol was ratified, focusing on substances that deplete the ozone layer and on long-range trans-boundary air pollution. The protocol looked to reduce or ban the usage of various chemicals such as chlorofluorocarbons, halons, and tetrachlorides.

In 1997, the Kyoto Protocol was established, five years following the United Nations Framework Convention on Climate Change (UNFCCC) held in Rio in 1992. The aim was to begin evaluating and determining what can be done to reduce global warming and assessing what measures would best address the temperature increases that were projected to occur in the coming future. Under the treaty, countries must meet their targets primarily through national measures which would best fit their respective needs. Additionally, the Kyoto Protocol offered a means for the participating countries to meet their targets by way of three market-based mechanisms: 1) emissions trading (carbon market); 2) clean development mechanism (CDM); and 3) Joint Implementation (JI) (UNFCCC, 1997).

In December 2007, the Treaty of Lisbon was signed, followed by enactment two years later. The treaty provided the European Union (EU) with modern institutions and optimized working methods to tackle the current global issues in an efficient and effective manner. The EU serves as a centralized source of regulations and policies in addressing issues such as globalization, climatic variations, demographic changes, security, and energy supply. One of the objectives of the treaty was for the EU to increase the initiatives and measures taken to address climate change while also looking to increase sustainability and responsibility for resources by EU members.

In December 2009, The Copenhagen Accord was agreed upon by the Conference of Parties (COP) and accepted by over 30 countries as a means of building on the goals previously listed in the Kyoto treaty with certain short and long-term goals. The Accord's main points outlined by the COP UNFCCC's report can be summarized as the following: the need for global reduction of carbon emissions to aim for <2°C increase, cooperation and participation from all parties, leadership and individual policies from top-emitting countries toward mitigation, protection of forests, and financial support and incentives for adaptation strategies from developed nations (UN, 2009). While this endorsed the Kyoto Protocol and conceded that reductions were necessary, it was not legally binding.

The UN Global Compact is an initiative that invites companies to join UN agencies, labor leaders and civil society in supporting ten principles in the areas of human rights, labor, the environment and anti-corruption (UNGC, 2008). Some of the goals of the compact related to the environment and climate change are shown in Table 5.1.

Table 5.1: Environmental Implications of the United Nations Global Compact

Principle	**Implications,** businesses should support:
Principle 7	A precautionary approach to environmental challenges
Principle 8	Undertake initiatives to promote greater environmental responsibility.
Principle 9	Encourage the development and diffusion of environmentally friendly technologies.

Source: UNGC (2008).

Companies from countries around the world voluntarily join the Global Compact in order to seek interdisciplinary solutions that consider the idea of "a successful business" from a holistic perspective.

Global climate change impacts affect both natural and social systems at the policy, environmental and cultural levels. The challenge to policy-makers is to formulate a cohesive, organized approach that cuts across national boundaries but also takes into consideration the unique social, economic and cultural diversity.

The current climate change policies have led to great progression while facing various challenges. Several positive outcomes have occurred as a result of the ratification of these treaties. There has been an increased visibility of climate change issues. In response to the increase visibility, research into the various aspects of climate change has increased. Studies have been made in many areas where the implications of climate change have been assessed: engineering, geography, environmental sciences, political science, economics, anthropology, public health, medicine, and a host of other disciplines. As more research is conducted and evidence produced on the effects of climate change, countries and communities have begun using and looking into alternative and sustainable energy and water options. In areas where applicable, there is potential to take advantage of the sun (both thermal and photovoltaic energy), wind (wind turbine and windmills), and water (desalination, hydroelectricity). In finding the best alternative energy and water sources, the need for increased global collaborations between government, industry, and education has become more evident.

In spite of the numerous strides made by the treaties and policies, several challenges have risen as a result. One of the challenges has been the difficulty in reaching a consensus on resolutions. This has been due to several factors, such as differing opinions on the severity and implications of climate change. While critics have chastised the IPCC for being too conservative in their assessments of the predictions and trends of climate change impacts, other studies and groups have been criticized for their overestimation and sensationalism of climate change impacts. These conflicting schools of thought have led to some countries refusing to sign the international treaties or adhering to different protocols. A second challenge in regards to the treaties and policies is the difficulties associated with implementing the treaties and policies. For example, the Kyoto Protocol calls for the reduction of emissions by industrialized countries by five percent.

A third challenge is the barriers in the communication & understanding of climate change issues by respective governments, policy-makers, and communities. As mentioned before, there has been an influx in data and reports, with many offering varying degrees of severity and significance on the implications of climate change impact. As such, this leads to issues in trying to providing non-technical communication and recommendations. If the language, expectations, guidelines, and data are not clear and accurate, it becomes difficult for the national governments to endorse the policies or implement appropriate and effective measures for their respective countries. In the same way, it becomes difficult for the general public to acknowledge the existence of or understand the importance of climate change impact.

These challenges are evident in addressing the climate change impacts and implications on increasing temperature, sea level rise, water stress, extreme weather events, and environmental health. Global climate change impacts affect both natural and social systems at the policy, environmental and cultural levels. The challenge for policy-makers is to formulate a cohesive, organized approach that cuts across national boundaries but also takes into consideration the unique social, economic and cultural diversity.

At the regional level, agriculture will likely be severely impacted by increasing temperatures, water stress and extreme weather events as the seasonal precipitation variations become less predictable (Oechel, 2010). This will require a concerted effort by all stakeholders for better water management, particularly in regions that share the same water sources such as the upper and lower basin states on the Colorado River. The Central Arizona Project (CAP) that routes water to higher elevations for agro and other uses in Arizona is an example of such water management schemes. However, the CAP project does not fully address the water-energy balance, and the environmental cost of generating the power to pump the water could possibly outweigh the benefits derivable by moving water over such long distances. For example, the CAP derives 95% of its power from coal-based power sources which contributes to the increase in GHGs. Instead, policy makers should address the ethical sustainable agriculture question by considering if it is prudent to farm in desert lands or if it is better to import foods from areas more suitable to farming.

As the body of knowledge regarding climate change expands and sound data are established, it is necessary to set sight on what the future holds in terms of policy, energy, conservation, and education. The various policy mechanisms to address the global climate change include Hard Instruments and Semi-Hard Instruments. Hard Instruments are set by governments and policy makers, such as command and control (CAC) methods whereby specific targets are set for countries, organizations, and businesses on energy use and emissions. Semi-Hard Instruments utilize market mechanisms where the optimal price/cost for energy and emissions are set and controlled by market forces.

One of the major problems in addressing global climate change is the apparent lack of awareness or understanding of the issue by the large swathes of the world population. According to the different future climate scenarios presented by the IPCC based on GCM predictions, there is little doubt that a need exists for lifestyle changes to reduce the carbon footprint in developed countries, as the US currently has the largest carbon footprint per capita. However, public education in the US has been hindered by a lack of objective reporting on the issue, leaving large parts of the population unsure of whether the issue of global climate change is real, or whether it is man-induced, or what corrective actions can be applied. So while the scientific community has long agreed that the global climate change is man-induced, the general population is still receiving mixed messages on the issue.

The onus is on policy makers to rise above the rhetoric and act in the best interest of the citizens and the earth. There needs to be a concerted effort to start early education on the issue of climate change and sustainability using proven scientific facts rather than political considerations. The uncertainty in GCMs does not remove the startling fact that the earth is experiencing rapid climate change as manifested by the increase in CO_2 concentration levels from 260ppm in the preindustrial period to the current 380ppm. This trend is expected to continue over the foreseeable future as the world population increases unless measures are implemented to significantly reduce the carbon footprint per capita.

5.5 Future Directions and Recommendations

The global energy budget involves the Earth's system, thus perturbation of this budget acts at long temporal scales (Bonan, 2007). A first issue is that changes in the composition of the atmosphere (e.g., changes in concentration of greenhouse gases) have influenced radiative forcing and therefore the Earth's energy balance. A second issue is differences in changes in albedo. Over the high and middle latitudes, climate feedbacks from carbon and albedo work in opposite directions. In general, albedo effects tend to dominate carbon storage effects at high latitudes. Because these processes acting at longer temporal scales, any changes in policies and practices that change radiative forcing will take longer time to see the effects.

The future success of climate models lies in the capability to reduce uncertainties in GCM outputs. Governments and agencies have accepted climate change as a reality and now seek adaptation and mitigation strategies for their specific regions (IPCC, 2007b). Based on the universal concern for water availability, especially in the Americas as highlighted in this PASI meeting, action should precede GCM improvements. Regional models are available with finer resolution and should be utilized by planners and those working on projects in highly dynamic regions.

One area that needs further emphasis is model calibration and validation. Remote sensing datasets have expanded in number and increased in sensitivity such that scientists can rely on satellite data to create models and use that information as input parameters. It is important to recognize that there is an increasing number of land and sea in situ observations (e.g. FLUXNET, the global consortium of eddy covariance towers) that can be used to train, parameterize, and validate models. However, it is critical to identify the temporal and spatial scale at which parameters represent processes. This process can be achieved through 'model-data synthesis' or 'model-data integration' (Vargas et al., 2011, Figure 5.2). With this approach there is interplay between data and model structure. The process detail depends on whether the problem is applied to state evaluation of the system, or on parameter estimation of the model. If state evaluation is the goal, then model states are adjusted to engender closer agreements with observations. If model parameter estimation is the goal, then model parameters are attuned so that the model states are reconciled for better agreement with observations. Following the optimization of model parameters, it is critical that further analyses be conducted in order to (Vargas et al., 2011):

(1) Quantify model uncertainties in optimized parameters,
(2) Evaluate the credibility and temporal stability of optimized parameters,
(3) Understand reasons for model failure, and
(4) Identify opportunities for model improvement.

From this meeting several questions arose:

- Which is the resilience of the global energy budget and how do changes in policies mitigate the Earth's energy budget?
- Do we really understand the mechanisms and feedbacks that regulate the energy budget at multiple temporal and spatial scales? This is important for global climate models to be able to predict changes in the following century.
- Can we use other indicators to evaluate human decision that will have an effect on the global energy budget and therefore climate change?

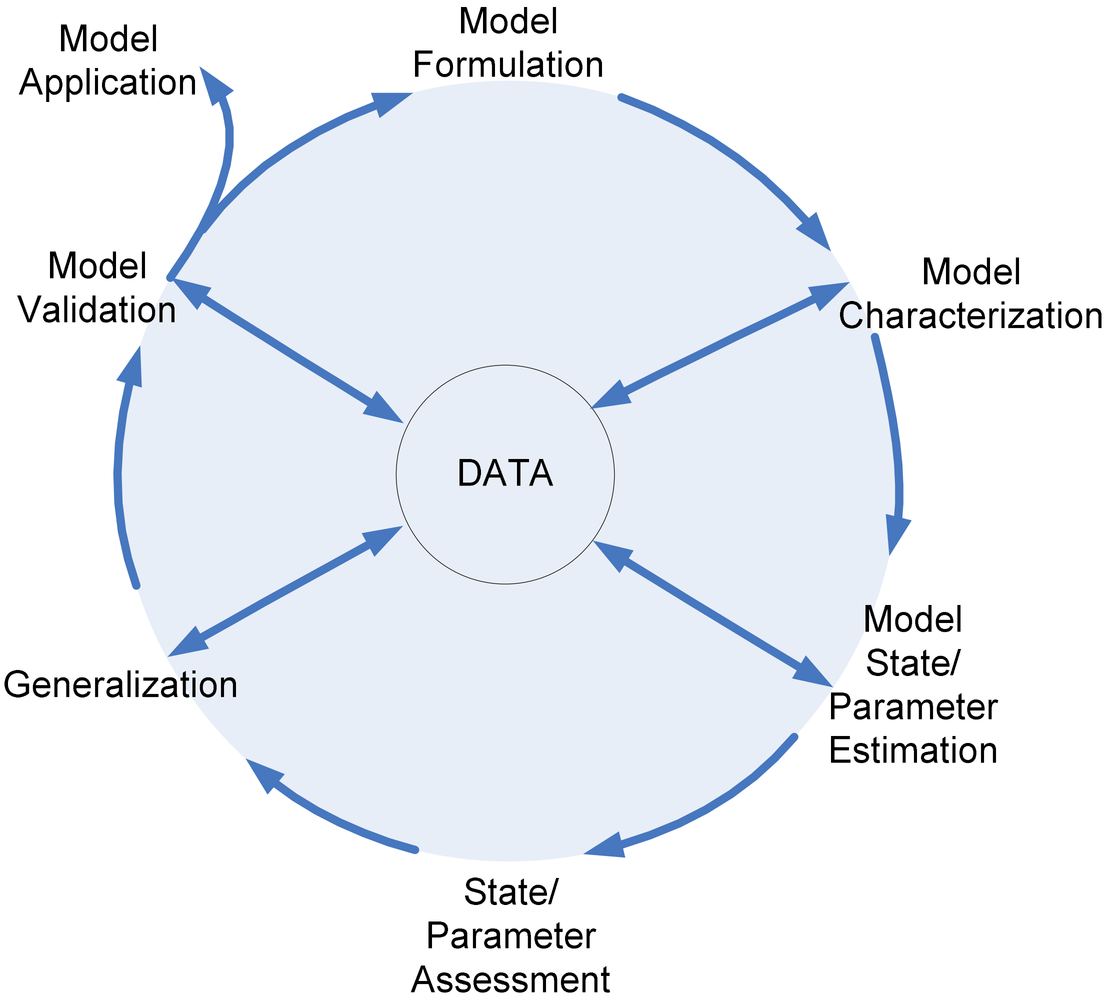

Figure 5.2: The multi-step process for model-data fusion: a conceptual diagram showing the main steps (and the iterative nature of these steps) involved in a comprehensive data-model synthesis (Modified from Vargas et al., 2011)

We believe that although there are many uncertainties in the feedbacks for the global energy balance, water cycle and model parameterization, the uncertainties should not obstruct the development and use of global climate change modeling tools.

In regards to the international treaties and policies, the expected outcomes have not been met. While they have helped to bring attention to the climate change issues, the targets and implementation strategies have not been effective. While it is necessary to have these treaties in place, modifications are necessary to take into account the different needs and dynamics seen regionally. In modifying current treaties and establishing newer ones, it will become necessary to include the different stakeholder in the process- governments, non-governmental organizations (NGOs), education sector representatives, public health sector representatives, scientists, engineers, economists, social scientists, community advocates, and companies. In doing so, a general language can be established and adhered to when discussing climate change, water, and energy. Additionally, it will provide for climate change impacts seen on the various areas to be better understood. Finally, it was pointed out in this PASI meeting that several international treaties are sometimes obsolete (e.g. water treaties in the Colorado River), based on climate conditions, land-use and occupation characteristics that are not realistic anymore and even less representative of future conditions. From this discussion, we propose that current climate information and model predictions should be used for policy making rather than “convenient” past understanding and measurements of climate conditions.

6 LINKING ENERGY, WATER, AND GLOBAL CHANGE STUDIES

Although an extensive amount of research has been devoted to study climate change, energy production and water resource availability, the vast majority of it is done in a disjoint fashion. Synergies linking these areas are of the utmost importance, and this can be seen in current governmental policies recognizing their interdependence. However, many of these policies are currently system-based, and are becoming outdated as our knowledge of the energy, water and climate change sectors is increasing.

The challenges facing the implementation of a long term solution to our many problems is complicated, but the solution most certainly lies in the formation of adequate national and international policies. Information and data exchange, economic based policies and cooperative research will be required to achieve this common goal. As humankind continues to progress, synergies between the energy environmental sectors will become increasingly necessary, with critical resource planning of the utmost importance.

6.1 Current state in the Americas

The North, South and Pan-American regions, and in particular North America, use a substantial amount of energy and water. As this undeniably impacts climate, we are faced with incorporating this into the energy and water infrastructures. This is a troublesome task, as climate change cannot be expressed as quantitatively as water volume or electrical energy. System based natural resource policies are then required, including hydrological, climate and other natural resource systems. As we strive toward the future, collaboration on critical natural resource planning is essential.

6.1.1 Energy, Water, and Environmental Infrastructure Synergies

The Pan-American region utilizes a lot of energy for economic development, and its availability is of critical importance. As such the generation process places a huge stress on water as a working medium in hydro-electricity and as a cooling medium in thermal cycles, which eventually has an impact on climate. Currently synergies between energy, water, and climate change are faintly evident in many sectors.

The U.S. is the largest economy in the world, and uses about 1000GW annually (Beyene, 2010), 80% of which comes from fossil fuels. This load places a toll on water supply which requires water for cooling in these fossil-fuel based power plants. It is also notable that these power plants generate large amounts of GHG emissions which are known to impact climate change. Even hydroelectric power plants, generally regarded as renewable, are not neutral in their impact. For example, in Brazil and Costa Rica a significant part of the energy is hydroelectric (Sena et al., 2010; Megdal, 2010), a fact that has led to increased deforestation to make room for dams. This has been particularly an issue in the Amazon region – an area with a highly sensitive ecosystem – where reduced precipitation and subsequent decline in river levels have been noticed. There is an apparent interlink of the three sectors - in which water used for energy generation threatens the environment. These challenges in increasing renewable energy may hinder the drive to become carbon neutral (Rodrigo, 2010) when considered from global climate change perspective.

Several projects in the United States utilize energy to clean or transport water. For example, there are about 18 water desalination plants in California that use energy to produce clean water. Additionally, in New Orleans alone, 64MW of power is set aside to pump water for alleviating floods (Beyene, 2010). There are 14 plants that pump about 1.5 million acre feet out of the Colorado River water annually for irrigation and household use (Megdal, 2010). The impact of diverting large amount of water from the water path, or even discharging concentrated saline water on local and regional climate is significant. For example, drinking water and wastewater services contribute 45 million tons of greenhouse gas emissions by consuming 3% of the total U.S. energy use (Chaudhry, 2010).

6.1.2 System Based Natural Resource Policies and Regulations

Systems can be considered in terms of geography or in terms of resources. In general, the current state in the Americas is that natural resource policies and components are managed separately, rather than holistically. Integrated systems planning and policies are important for identifying connections between different locations and elements (Gautier, 2010).

HYDROLOGICAL SYSTEMS

Geographically, groundwater basins and river systems are naturally connected. However, current hydrologic planning often lacks dynamic considerations for the consequences in other parts of the basin. Groundwater aquifers are interconnected systems - drawdown or pollution in one region may affect the entire basin. Under water laws in most U.S. and Mexican states, there are few restrictions on groundwater pumping, leading to depletion in several major aquifers (Kretzschmar, 2010), which impacts river flows and aquifers in adjacent and even distance regions.

River systems generally have more stringent laws than those that govern groundwater extraction, but the governing policies often do not consider the river basins as a system. For example, the Colorado River, which is very important to the U.S. Southwest and Mexican Northwest, drains 7 U.S. states and 2 Mexican states. Treaties between U.S. and Mexico regulate flow, where historically the agreements are based on maximizing the water output for individual states, and have not considered the river system as a whole. Currently it is over-allocated, and rarely reaches the Gulf of California, which has led to the loss of the formerly rich delta ecosystem. Projected regional population growth in the dry states of Arizona and California along with extended drought periods are expected to place future demands on the river (Megdal, 2010).

The Amazon River system drains 40% of South America and carries more water than any other river in the world, most of which in Brazil. There are international treaties governing water flow in the Amazon to manage water quality as improper sanitation, chemical pollution from Columbian cocaine production, and fishing in Peru and Bolivia all affect the downstream regions of the Amazon. Conversely, Brazilian forest clearing along the 'arc of deforestation' in the southern part of the basin, is affecting the climate in the upper Amazon basin, decreasing mean precipitation and increasing the frequency of extreme events - floods and droughts. Global climate change is also contributing to these regional hydraulic changes in a noticeable manner (Sena et al., 2010).

CLIMATE SYSTEM

Climate change is fundamentally a global problem, as it encompasses the entire planet. Large impacts are projected in the Americas, especially increases in droughts and extreme precipitations. In particular, northern Mexico and the southwest U.S. are projected to dry significantly over the next few decades, aggravating stresses already caused by growing population and consumption (Leung, 2010).

Climate change impacts are another area which could benefit from system-based planning; for example, how potential changes in precipitation, sea level, and temperature will affect the environment and ecology of a region. Some development has gone into state climate action plans that provide a framework for mitigating and adapting to climate change in different sectors. However, these have only been developed in a couple of U.S. and Mexican states (Cavazos, 2010).

Attempts to internationally address climate change and create a binding treaty to reduce global emissions have been stymied by the gap between the developed and developing world. The developed world is responsible for most of the historical emissions and has much higher present emissions per capita, but much of the future growth is projected from the developing world, a makeup of the entire South America. Part of the challenge in implementing climate mitigation policy is the uncertainty in pricing the projected damages (Bartelmus, 2010), and the share of the developed versus developing countries to pay for the high cost of cleaning the environment.

RESOURCE SYSTEMS

Regardless of the geographical scale or region in consideration, energy, water, land, and climate are all linked. However, most natural resource policies for food, water, the atmosphere, and energy have been managed and developed separately. Currently, energy and water development plans do not take impacts on other sectors into account. Energy and water facilities are not usually co-located or connected on the grid in ways that can take advantage of shared resources (Hightower, 2010).

It has been challenging for regulators to provide incentives for resource users to optimize for several resources. Payment for ecosystem services has been applied on small scales in the Americas to conserve resources and could be used on larger scales in the future (Branca, 2010).

6.1.3 Collaboration on critical resource planning

In the United States, the Department of Energy has created the multi-laboratory Energy-Water Nexus, which has helped to bring the issue of water-energy interdependency into focus (http://water-energy.lbl.gov/node/21). While the Energy-Water Nexus' creation represents a definite step in the right direction, the group's main purpose is limited purely to research.

As investigation continues, plans for integrating management and planning should be written or revisited. Already, the lack of integrated planning has impacted energy production, watersheds and regions across the United States. For example, a number of states including South Dakota, Wisconsin, Tennessee, and Texas are racing to prioritize water use for different sectors due to recent droughts and lacking water resources.

The threats to energy and water resources are real and present. To ensure proper evaluation and valuation of water resources, further collaborative mechanisms must be introduced which foster concerted efforts among such groups as government agencies, regulatory groups, industry, etc. These mechanisms might take the form of natural resource planning groups, organized by region or locale, which would be in continuous multilateral communication with other water-related actors in order to organize, oversee, and manage water use and quality. These regional natural resource planning groups could also help to set standard performance goals, train personnel from a variety of sectors, and help develop and implement plans for such events as droughts, natural disasters, and emergency outages or curtailments.

6.2 Challenges and Concerns

The main goal of any working document, such as this one, is to inform the public and policy makers, and allow making better decisions based on real world data and experiences. This section outlines some of the main concerns and challenges with respect to economics and information exchange with the hope of coordinating policies made across borders.

6.2.1 Policy coordination, economic basis, and information exchange

Policies for climate change and sustainability need to be formulated by focusing on a balance between expected damages and measures required to fix these damages (Meira, 2010). Expressing the information on climate change effects in terms of the induced damages instead of mere change in temperature would improve the understanding of policy makers. With this aspect, there is a need for an alternative global metric for measuring the extent and effects of global climate change. However, most climate change damages are often local (UN, 1992). Therefore, there is the issue of underestimating or missing the local effects if a global metric is used.

There is a divide among developing and developed nations on how to handle the costs of global climate change. The United Nations Framework Convention on Climate Change

(UNFCCC) adopts a principle of "common but differentiated responsibilities" (UN, 1992). The parties agreed that:

- They share of historical and current global emissions of greenhouse gases originated in developed countries,
- They acknowledge that per capita emission in developing countries is still relatively low,
- The share of global emissions originating in developing countries will grow to meet social and development needs.

Objective responsibility and future emissions were discussed as a means for splitting the costs for climate change among nations. Developing economic powers like China and Brazil claim that past emitters should pay for the current pollutions (Meira, 2010). This claim is based on the assumption that the current climate changes are mainly caused by past emissions from the developed nations over the past couple of centuries. In a similar argument, questions were raised and discussed on whether it would be unfair to require developing countries to refrain from pursuing economic development in an effort to reduce future climate change impacts. It is estimated that energy use will increase by 44% over the next 20 years, mainly due to the growing needs in China, India, and Brazil (Garoma, 2010). It is unlikely that developed countries would be willing to sacrifice their current living standards to offset the pollution induced by developing countries. These issues have key policy implications and will need to be addressed if an integrated global climate change policy, accepted and implemented by all nations, were ever to be developed.

In the last decade there have been several attempts to associate an economic price to environmental resources. The representations of environmental capital with carbon credits, carbon footprints, etc., are some of the possible solutions (Bartelmus, 2010). But with any value system that alleges to be globally valid, international acceptance through policymaking and trade agreements is required. To properly assign value, information needs to be exchanged as to the environmental impact of emissions or the loss of environmental resources.

Currently resources such as watersheds, carbon sinks, aquifer recharges etc. have no monetary value, but by considering the importance of these types of environmental capital a value must be assigned in such a way that a resources capital can be left untouched and the interest from this capital exploited (Branca, 2010). For example, this would allow river basin land thought to have low economic value when left untouched, to be assigned a high environmental value and thus a loss of capital becomes associated with its destruction. The flooding of New Orleans in 2008 was partly caused by the loss of flood lands in the river delta because the economic value in developing that land was not countered by an environmental value associated with leaving the land in a natural state.

When the environmental value of a resource does not exist for the country in possession of the resource, but for a neighboring state, as in the case of tributaries for a multinational river system, trade agreements become necessary. This type of monetization is best accomplished through information exchange across borders. The economic and social value of ecosystem services should be integrated into a decision making process around water, energy and climate change issues. Currently an amount between $1.8 and $4.2 trillion (USD) is lost each year related to ecosystem issues. This value is predicted to increase up to between $46 and $133 trillion by 2050, (Braat & Brink, 2008).

6.2.2 Informatics, regional and interdisciplinary data integration

The creation of an information system mirroring ecosystems is useful, as it would allow for a feedback loop for an ecosystem spanning several regions or nations. If the ecosystem is cross border, then the information system too must freely flow between borders in the same way changes in the ecosystem will flow. International scientific collaboration is one form of this type of information exchange, but the systems currently in place are sparse and not sufficient for informed policy making. Raw data could be posted and made available with sufficient resolution to include the complexities of the system.

Systems of validation and risk analysis of data and simulations allows for the (pseudo-) real time monitoring of the environmental state, and testing of the effects of policies. Networks linking satellite data from several countries has begun (e.g. GIOnetCAST). Further development in the analysis and display of this data is necessary for the visualization of these complex systems for nontechnical people involved in policy making. An example of this type of system using UN data is found at Gapminder (www.gapminder.org).

In Brazil simulations of policy negotiations have allowed to work through conflicts between settlements in environmentally sensitive areas (Barban & Ducrot, 2010). Several states in Mexico have begun to produce action plans using shared data and simulations relating to climate change (Cavazos, 2010). These action plans are hoped to be the basis for new laws to mitigate the effects of climate change.

Aquifer depletion and other water shortage data needs to be combined with power and fuel generation to not cause new problems in one area with solutions in the other (Hightower, 2010). The true costs of power and water production technologies must be readily available to find locally viable solutions. Ethanol production in Brazil and the USA do not have the same viability since corn and sugar cane based production have different yield and resource requirements (Garoma, 2010).

Examples of information integration and validation are becoming more prevalent in web technologies with examples found in Wikipedia (www.wikipedia.org) where errors in open collaboration are mineralized through crowd-sourcing and other techniques. NASA and other scientific institutes have found how to use these technologies for the analysis of remote sensing, and show the power of these techniques which can be adopted for the purposes of regional interdisciplinary data integration.

6.2.3 On the economics of climate change

Climate change effects include concerns of overuse of exhaustible resources of energy, water and forests, as well as pollution of the atmosphere by greenhouse gas emissions. Environmental economists consider these non-market effects as 'externalities' that need to be 'internalized', i.e. included in the cost plans and budgets of governments, corporations and households. The objective is to re-gain the efficient (optimal) and sustainable economic performance, lost by environmental depletion and degradation. Models of cost internalization by means of optimal carbon prices and taxes are inconclusive, however, due to differences in modelling techniques and assumptions. A wide range of estimates of future damage and damage mitigation costs is the result (Bartelmus 2010).

A more realistic alternative to optimal pricing and taxing is to assess actually incurred environmental costs in environmental accounts. These costs could be used to set the initial level of market instruments such as an eco-tax for tackling climate change, rather than leaving it to the common practice of political negotiation. Environmental accounts also define depletion and pollution costs as the cost of maintaining natural capital. Making an allowance for restoring or replacing lost natural capital, brought about by climate change, contributes to the environmental sustainability of economic growth and development.

6.3 Future target areas

The Pan-American continent is experiencing drastic changes in energy and water use, which has led to changes in the climate. Energy, water, and climate change are naturally interlinked. However, little research work has been done to address the topic as an interdisciplinary field. Some of the works to date address two of the three areas, at most. It is essential to address such complex and interlinked topics as such if a desired and comprehensive sustainable solution is to be obtained. Such a solution requires complex tools that can be understood and used by policy makers.

There are existing parameters that can be used to create such tools. Some additional, possibly useful parameters have been proposed at this PASI meeting. These parameters transform the effect of human interactions and the environment into a set of simple numbers that quantify our impact on climate change (Sciubba, 2010).

In a similar manner, an educational tool is proposed to present a complex system, of, for example, energy, water, and climate with a conceptual map visualizing the couplings between the different areas of interest, Gautier (2010).

Other specific research ideas are listed below.

6.3.1 Research Measures Combining Energy, Water, and Global Change

LOW CARBON TECHNOLOGIES

Fossil fuel based power will continue to be used as major source of energy in the medium term until alternative sources of energy are large enough to become primary sources. It is therefore necessary to manage the transition period to ensure sustainability of society. In this respect research on efficient carbon capture and storage systems is essential (Ndiritu et al., 2010) to reduce emission of greenhouse gases to the environment. It is thus an opportunity for the Pan American region to participate in design of carbon capture mediums. Many opportunities are available, including fuel cells to supply energy at reduced carbon emission (Milewski, 2010). Significant research opportunities also exist that offer very low or negligible emissions in the areas on renewable energy in particular:

- Design of efficient solar power systems,
- Wind mapping systems to locate the most appropriate location of wind farms,
- Exploring use of hybrid solar wind energy systems (Muralikrishna1 & Lakshminarayana, 2008) to take advantage of fluctuating weather patterns,
- Exploring use of secondary cycle for geothermal power systems that ensure stability of the underground water.

MANAGING WATER DEMAND

Certain measures could be undertaken to reduce water demands during energy generation processes (Hightower, 2010). These include:

- Development of systems that utilize both wet and dry cooling with a view to wiping out the former,
- Ensure efficient cooling of power plants,
- Research on appropriate materials carrying cooling water,
- Search for ways of reducing cooling water used in power systems,
- There is a need to find ways of reducing water for biofuel cooling and for processing,
- Undertake research on use of algae and cellulose for biofuel generation

MORE ACCURATE MODELING

Worldwide, fossil fuels contribute about 4.154×10^{14} MJ of energy per year. The current climate models for climate change research do not truly account for this large amount of energy discharge into the atmosphere, which could be accounted for using the control volume approach widely used in thermodynamics (Beyene, 2010). This also allows a better energy balance of the atmosphere, accounting for enthalpy of vaporization which is not necessarily accounted for with a rise in temperature. This provides a background for further work to establish a more accurate climate model (Beyene, 2010). In these numerical models the key challenge is validation, so that subsequent predictions are accurate and more reliable.

Some ongoing researchers have established the influence of radiative forcing on global warming (Myhre et al., 1998). This model has shown that waste heat accounts for a rise in global temperature such that a total ban on fossil fuel use may reduce global warming by 60%. However, if the replacement is another thermal power plant, the resulting waste heat will sustain the heating effect by a large proportion (Zevenhoven, Falt, and Beyene, 2010). There is a need to improve efficiency of power plants, to operate at efficiencies of 50% or better, using systems such dual cycles or combined heat and power. A comparative study of efficiencies and emissions for California and Finland reveals interesting scenarios that can be a source of action as well as research initiatives that can be extended to other Pan American regions (Zevenhoven, Falt, and Beyene, 2010).

Use of extended exergy accounting to assess the state of the environment has also received PASI-2010 attention. Exergy is the maximum useful work possible during a process required to bring a system into equilibrium with its surroundings (Perrot, 1998). Exergy could serve as a better quantifying parameter for climate change – an area that could be explored further in order to prioritize resource utilization and understand the physics of climate change (Sciubba, 2010).

6.3.2 Guidelines and Framework for Development

Guidelines for requirements for regional development are determined in consultation with all stakeholders, combining all interested parties including representatives of all regions that share the ecosystems of the region. The framework for finding these guidelines must include the history and culture of the region combined with internationally acceptable norms of human rights. Any changes in usage of the resources of a region will affect the culture of the people; thus, culture as well as the environment can be considered to have a capital value, and changes could imply a capital loss or gain.

Guidelines for requirements for regional development should include resource need and balance of area, - water and energy needs in particular, combined with environmental impacts of resource exploitation. The outputs of the region are mediated by international treaties. One of the most difficult tasks is to define baseline values of the environment, which is made more difficult by the ever-changing environment and population density.

It was observed that future research and action target areas must focus not only on mere research on the singular topics of energy, water, or climate change, but also, and perhaps primarily, on their combined effects on society as well as their interactions.

7 CONCLUSIONS AND RECOMMENDATIONS

The bulk of this paper is a shared consensus, that there is a relentless drive of humanity for continued economic growth, with an accompanying need for energy and water as fundamental resources, and yet we have failed as a society to strive for comfort without polluting the environment. This dichotomy can conveniently be addressed linking energy, water, and climate change as a research agenda. In summary, the workshop found the following to be relevant issues requiring more research and institutional focus. This list should be considered partial, i.e., incomplete inventory of the major points with no particular order.

- The need to formulate policies for climate change and sustainability in terms of a balance between actions and expected damages. Expressing the information on climate change effects in terms of the induced damages instead of mere change in temperature would improve the public understanding as well as that of policy makers. In this respect, there is a need for an alternative global metrics for measuring the extent and effects of global climate change.
- Geographic settings, cultural predispositions, and variables driving regional economic growth in a globalized market, i.e., policy formulations, cross-border flow of resources, and migration of the impacts of industrialization, make the need for transnational discussions an essential component of agenda for a sustainable future. These cross-border socio-political conditions are superimposed as aggravating factors on complex and multi-disciplinary subjects affecting our relationship with the environment, which is contributing to our understanding of the consequences of ill-equipped resource exploitation on climate. There is a need for more international discussions.
- It was concluded, that in order to provide a universally acceptable and valid sustainable use strategy for energy and water, steps must be taken to improve efficiency, deploy a larger number of “clean” technologies, and design more creative ways to use finite and limited resources. Mapping interlinks of energy, water, and climate change for regionally diverse conditions is spatially and temporally variable; a multi-dimensional problem requiring gross mobilization of resources and talents. The entwined nature of these issues must be strategized with clarity that sifts through ideas and avoid flawed solutions.
- The need for advanced tools and mechanisms to more accurately model and forecast climate change instigated by human activities. Current research on climate change uses long term temperature data as an input, and uses statistical approach to estimate deviations. The current climate models for climate change research by and large do not account for the large amount of energy discharge into the atmosphere, which could be accounted for using the control volume approach, widely used in thermodynamics. This allows a better balance of environmental energy flux, accounting for enthalpy of vaporization which is not necessarily credited for with a rise in temperature. Furthermore, ongoing research has established the influence of radiative forcing on global warming. Application of this model suggests that anthropogenic heat, traditionally ignored in climate modeling, accounts for a fairly traceable rise in climate change – an appropriate topic for future research.
- Some additional, possibly useful parameters to quantify climate change have been proposed at PASI-2010. These parameters transform the effect of human interactions and the environment into a set of simple numbers that quantify our impact on climate change. In a similar manner, an educational tool is proposed to present a complex system, of, for example, energy, water, and climate with a conceptual map visualizing the

couplings between the different areas of interest. Use of extended exergy accounting to assess the state of the environment is proposed as a strategy that should receive more research attention.

- There is a divide among developing and developed nations on handling the costs of global climate change. The United Nations Framework Convention on Climate Change adopts a principle of "common but differentiated responsibilities." Objective responsibility and future emissions were discussed as a means for splitting the costs for climate change among nations. It is unlikely that developed countries would be willing to sacrifice their current living standards to offset the pollution induced by developing countries. These issues have key policy implications and will need to be addressed if an integrated global climate change policy, accepted and implemented by all nations, were ever to be developed.
- Historically, economic trade has been one of the most successful forms of international collaboration. In the last decade, there have been discussions to associate an economic price to environmental resources. Defining environmental capital with carbon credits, carbon footprint, etc., are some of the proposed solutions to mitigate climate change. For example, currently resources such as watersheds, aquifer recharges, etc. have no monetary value. If environmental capital value could be assigned to them in such a way that a resource capital can be saved, then the interest from this capital could be used to raise their cost. This increases river basin values, and the loss of its capital would be associated with its destruction. The challenge is, such value system with inevitable international impact, needs to be accepted globally by policymakers and ratified through trade agreements. Furthermore, to properly assign such values and promote it as a global tool, data and detailed information, including environmental impact of emissions and the depletion of resources need to be known.
- The creation of an information system mirroring ecosystems was introduced, as it would allow for a feedback loop for an ecosystem spanning several regions or nations. If the ecosystem is cross border, then the information and mitigation system too must freely flow between borders in the same way changes in the ecosystem flow. International scientific collaboration is one form of this type of information exchange, but the systems currently in place are sparse and not sufficient for informed policy making at the global level.
- Systems of validation and risk analysis of data and simulations allow for the (pseudo-) real time monitoring of the environmental state, and testing of the effects of policies. Networks linking satellite data from several countries has begun. Further development in the analysis and display of these data is necessary for the visualization of these complex systems for nontechnical people involved in policy making. An example of this type of system using UN data is found at Gapminder.
- Aquifer depletion and other water shortage data need to be combined with fuel and power generation to not cause new problems in one area with

solutions in the other. The true costs of power and water production technologies must be readily available to find locally viable solutions. For example, ethanol production in Brazil and the USA do not have the same viability since corn and sugar cane based production have different yield and resource requirements.

- Examples of information integration and validation are becoming more prevalent in web technologies with examples found in Wikipedia (www.wikipedia.org) where errors in open collaboration are mineralized through crowd-sourcing and other techniques. NASA and other scientific institutes have found how to use these technologies for the analysis of remote sensing, and show the power of these techniques which could be adopted in energy and water nexus, linked with climate change.
- Fossil fuel based power will continue to be used as major source of energy in the medium term until replaced by other clean sources of energy. It is therefore necessary to manage the transition period to ensure maximum sustainability. In this respect research on efficient carbon capture and storage systems is useful, to ensure less release of greenhouse gases to the environment. This offers an opportunity for the Pan American region to participate and promote research addressing such medium term solutions. Some of the promising research opportunities on renewable energy include: design of efficient solar power systems, wind mapping systems to identify the most appropriate location of wind farms, hybrid solar - wind energy systems to take advantage of fluctuating weather patterns, secondary cycles to boost cycle efficiencies of thermal plants, and other energy harvesting systems at the nano levels. The use of algae and cellulose for biofuel generation also offers an optimistic research topic.
- Increased population continues to put stress on water, which has become a critical issue in many arid areas of the region and the globe. There is a need to reduce the kW/liter of water treatment to reduce the cost of treatment and desalination technologies.
- Water demand during power generation processes also imposes research topics that include: reducing cooling water used in power production as well as in biofuel processing plants.

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