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

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Table of Contents

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 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 diverse range of backgrounds were in attendance. Several papers were presented on a very wide range of topics related to the *linkage* between water, energy 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 exemplify the challenges in bringing together researchers from different 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 mutual interests in the Americas. When discussing water supply and sustainability, the policies and political dynamics of water use are discussed, as well as the balance between water use and energy use and our view of the climatic effects they accrue. The current view on climate change, including energy balances, numerical modeling, and scientific trends, are also addressed.

After many scholarly presentations at PASI-2010, the current techniques and results of many 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 expected 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 in the large majority of power production, and political challenges arise such as cross border water rights and treaties on water for power production such as hydroelectric power. In addition, water use for ethanol can have a serious impact on micro-climate, due to the large amount of fresh water required for crop growth, as well as due to its impact on food security, if it replaces food crops. Such issues are raised before a viable solution approach can begin to form.

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 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 the future generation. In summary, a greater understanding of some of the more 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, today's and tomorrow's.

2 OVERVIEW

While our understanding of the relationship between the human race and the environment continues to develop, 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 varying levels of challenges facing the transformation of our industry through a sustainable development, and the policies as well as resources dutifully committed by the various nations suggest that a more cooperative approach is needed to recognize and duplicate the good deeds, and encourage the lagging ones.

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 avoid 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 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. 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. The rate of this growth varies from country to country. 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 solution for the future of sustainable development in the Americas.

3.1.1 Transnational Grids and the Inter-American Energy Market

An electrical grid is a power network which supports all the distinct operations: electricity generation, power transmission, and distribution. A transnational grid may be used to refer to an electrical network belonging to one country or an entire continent. While current transmission networks are controlled in real time, in many American countries they are, by current standards, antiquated 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 modern grid, a smart grid is being recommended (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 an improved system capable of routing power in more optimal way with response to a very wide range of conditions. Such smart grid systems, equipped with smart meters, can be set up to charge a premium to those end users that use energy at peak hours – a demand-driven pricing. Furthermore these new smart grids will have the ability to deliver electricity from suppliers to consumers using two-way digital technology that control appliances at consumers' homes to save energy, reduce cost and increase reliability and transparency (Marks 2008). Such a modernized electricity network is promoted by many governments as a way of addressing energy independence, climate change, and emergency resilience issues.

NORTH SECTOR

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) approves rates for the sale of electricity and transmission in interstate commerce for private utilities, power marketers, power pools, power exchanges and independent system operators. 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 grid relying on a high capacity backbone of electric power transmission lines linking all the nation's local electrical networks, upgraded to smart grids (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. The network, as originally envisioned, 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 will be funded by private investors and built and expanded as demand warrants.

MESOAMERICA AND COLOMBIA

Mesoamerica is located on the isthmus that connects North and South America; it covers the region between Mexico and Panama. 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 make this a reality, the region must overcome the common challenges that affect its competitiveness and the availability of reliable power. Fundamentally, greater emphasis must be placed on the development of an integrated power market and the effectiveness of the two transnational grids, the Electric Integration System for Central America, (SIEPAC, see Figure 3.1) and the Puebla-Panama Plan, (PPP, see Figure 3.2). Together these two projects are also known as Mesoamerican Integration and Development Project. This multi-billion dollar development plan, formally initiated in 2001, is intended to promote the regional integration and development of the nine southern states of Mexico (Puebla, Guerrero, Veracruz and points south) 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 respective participating nation states. The Plan Puebla Panama and SIEPAC consist of transnational production and grid integration. The projects are purportedly intended to remedy a lack of investment and stimulate trade in the region by building or improving large infrastructure projects such as electric and telecommunications grids. Projects are to take place along five principal axes (or corridors):

- Pacific Axis, which bears the majority of trade in the region,
- The Gulf of Honduras Axis, to develop trade between the Pacific and the cities in the Caribbean region,
- The Peten Axis, which runs from Puerto Cortes, Honduras to Villahermosa, Mexico,
- The Mexico Trans-systemic Axis, consisting of the Isthmus of Tehuantepec, and,
- The Guatemala/Yucatán Axis.

According to a study by the US-based nonprofit Interaction, $7.7 billion in funding for the Plan Puebla Panama had been designated as of March 2005; the amount is eventually expected to rise as high as $50 billion. This funding comes from national governments in the region, the Inter-American Development Bank (IDB), the private sector, Central American Bank for Economic Integration (BCIE) and the World Bank (Pickard 2004).

Such cross-national projects can often be controversial, and their economic benefits can attract criticism. For example, SIEPAC and the Plan Puebla Panama are blamed for their adherence to a “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 a follow up or expansion to the Plan Puebla Panama and Trans-Texas Corridor initiatives, linking roadways and reducing barriers to 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. Such an ambitious vision given, the IIRSA however has been dormant since.

Growing demand for electricity throughout the Americas, especially in countries such as Mexico and Brazil, has helped to foster the interconnection of the region's various electricity grids. This trend is expected to continue as a result of further deregulation of the electricity sector, the easing of restrictions to international investment, and the development of cleaner, more efficient power plants. However there is some bottleneck in the continental grid.

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. During the second half of the 20th century, a sizeable integration of Latin American economy was observed. This entailed the creation of regional organizations to promote trade. It was hoped that these developments would favor the creation of transnational grids, which would in turn provide a more balanced slot 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.

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 by thermal (coal, oil, natural gas) plants. The remainder is generated by hydropower (25%), nuclear (16%), geothermal and other renewables (2%). 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 happened in an atmosphere of radical economic transformation. In the early 1990's, Latin American countries, almost en masse, embarked on a series of free market-based economic reforms. These policy reforms have in many cases been almost universal, also covering virtually all the energy markets. The economic reforms have resulted in the privatization of a range of formerly state-owned industries, from phone companies, to electric utilities, to petroleum companies. Legal reform has also been vital to privatization efforts in the region, particularly with regards to treating foreign companies equally with domestic companies under the law (United States Department of Energy, 1996). Argentina has been a leader in the privatization of electric power, as it was in petroleum. Latin American electricity privatization has been primarily driven by a rapid increase in electricity demand, coupled with a shortage of domestic capital to meet future electric power generation investment needs. Privatization has involved the sale of power operations to investors (foreign and domestic) and agreements to allow incremental private investment (also, foreign and domestic) in new power facilities which may include renewable sources.

Currently, government policies and legislation play a vital role in the development of renewable energy sources. Countries in the Americas are aware of this and have enacted favorable policies to encourage investment in non-conventional 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 3.3).

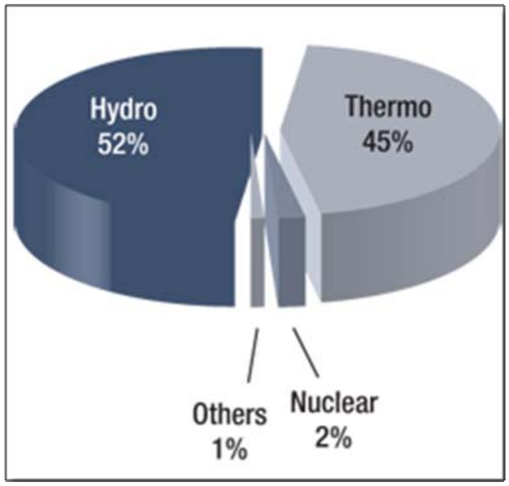

Figure 3.3: Percent of installed capacity energy sources in Latin America and the Caribbean (Source: Energy Tribune, 2008).

For example Honduras, El Salvador, Nicaragua, Argentina, and Chile have set renewable portfolio standards. These countries have targets for the implementation of renewable energy sources. In addition, a number of governments (including Mexico, USA, Costa Rica, and Brazil) also provide indirect subsidies and tax credits to promote renewable energy. These policies and support systems help achieve rapid growth in renewable energy, as the existing programs and legislations bring significant installed capacity to the market.

According to the Economic Commission for Latin America and the Caribbean (ECLAC), countries in this region will require an investment of $572 billion in the energy sector between 2007 and 2030 to meet the energetic demand. According to the United Nations Framework for Climate Change (UNFCC), more than 85% of the energy investment in this region will come from the private sector. In fact international banks including the IDB are financing various power generation projects in this region. Since 2000, the IDB has financed more than $2.1 billion in renewable energy projects in the region, including hydro, wind and geothermal projects. The focus is to develop sustainable energy for the long term through renewable energy sources. The banks also provide financial support for technical assistance programs for sustainable energy and energy efficiency.

A significant challenge facing renewable energy sources is their very 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 they are usually imported from developed countries at very high cost, often outside the economic range of developing countries.

The Clean Development Mechanism (CDM) is an arrangement under the Kyoto Protocol allowing developed countries to invest in projects that reduce greenhouse gas emissions in developing countries. The mechanism, which became operational in 2006, has been one of the key reasons for renewable energy investment in American Countries. Of the total almost 3000 projects that were registered up to April 2010, 461 of them were registered for development in the Latin American region. More than 60% of the total projects relate to the energy segment, especially renewable energy sources. A combination of small hydro, solar, wind and biomass contributes to the majority of this investment. These projects are expected to increase the renewable energy investment in the region. More details regarding the South American Renewable Energy Market to 2020 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 like Costa Rica, El Salvador, Guatemala, Chile and Mexico. The biomass energy industry, however, predicts a level of growth similar to the current state. All these renewable technologies should continue to compete with fossil and hydropower, and perform within the restructuring energy industry.

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

Current trends in energy supply and use are unsustainable, economically, environmentally, and socially. Under the most pessimistic scenarios of anthropic CO_2 emissions and climatic change, the consequences would mean a significant and irreversible change in the natural, social and economic system.

Energy efficiency improvements refer to a reduction in the energy use without affecting the service output quality or activity. The reduction in the energy use is usually associated with technological changes, but not always since it can also result from better organization and management or improved economic conditions in the sector (non-technical factors). To economists, energy efficiency has a broader meaning: it encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic activity (e.g. the energy used per unit of GDP or value added).

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 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 this context, energy efficiency and renewable energy technologies could form the core of the solution. For this o happen, a dramatic shift is needed in government policies.

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. This optimism in part derives from the fact that an American country will have its local conditions to take into consideration in crafting progressive policies.

RENEWABLE ENERGY TECHNOLOGIES

The natural energy flows through the Earth's ecosystem are immense, and the capacity potential for human needs exceeds the current level of energy use 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 (including vehicle efficiency, electric/hybrid vehicles, and fuel cell vehicles),
- Bioenergy (including biofuels and biomass combustion for power and heat generation),
- Carbon capture and storage (including storage and use of CO2 from power plants, industrial processes, and fuel transformation),
- energy efficient buildings (commercial and residential),
- Industrial energy efficiency,
- 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 (including transmission and distribution systems, end-use systems, distributed generation, and information management),
- 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 2.1.2.1 shows the status of Renewable Energy Technologies (end 2001), where it is possible to appreciate the potential of these technologies.

The World Energy Council (2009) states that sustainable development requires a concerted effort from international organizations, national governments, the energy community, civil society, the private sector, and individuals. Whatever difficulties are associated with taking appropriate action, they are small compared to what is at stake. For a number of reasons, the technical and economic potential of energy efficiency improvements has been under-accomplished. Numerous technical options and players could be involved in achieving higher end-use efficiency. Improving the energy efficiency of an economy is a decentralized, dispersed activity with limited visibility, making it a less attractive cause for politicians, the media, or individuals looking for recognition and acknowledgement. In addition, significant barriers – primarily market imperfections that could be overcome by targeted policy instruments – prevent the realization of greater end-use efficiencies. The barriers include:

- Lack of adequate information, technical knowledge, and training;
- Uncertainties about the performance of investments in new and energy-efficient technologies;
- Lack of adequate capital or financing possibilities;

- High initial and perceived costs of more efficient technologies;
- High transaction costs (for searching and assessing information and for training);
- Lack of incentives for careful maintenance;
- The differential benefits to the user relative to the investor (for example, when energy bills are paid by the renter, the property owner may have no incentive to invest in technology);
- External costs of energy use not included in energy prices;
- Patterns and habits of consumers, operators, and decision makers, which may be influenced by many factors, including ideas of social prestige and professional norms;
- Lack of attention to R&D investments in energy efficiency improvements.

Table 3.1: Status of Renewable Energy Technologies, end 2001

Technology	Increase in energy production, 1997–2001 (percent per year)	Operating capacity, end 2001	Capacity factor (percent)	Energy production, 2001	Turnkey investment costs (2001 US$ per kilowatt)	Current energy cost	Potential future energy cost
Biomass energy							
Electricity	~ 2.5	~ 40 GWe	25–80	~ 170 TWh (e)	500–6000	3–12 ¢/kWh	4–10 ¢/kWh
Heat[a]	~ 2	~ 210 GWth	25–80	~ 730 TWh (th)	170–1000	1–6 ¢/kWh	1–5 ¢/kWh
Ethanol	~ 2	~ 18 bln litres		~ 450 PJ		(8–25 $/GJ	(6–10 $/GJ
Bio-diesel	~ 1	~ 1.2 bln litres		~ 45 PJ		15-25 $/GJ)	10-15 $/GJ)
Wind electricity	~ 30	23 GWe	20–40	43 TWh (e)	850–1700	4–8 ¢/kWh	3–10 ¢/kWh
Solar photovoltaic electricity	~ 30	1.1 GWe	6–20	1 TWh (e)	5000–18000	25–160 ¢/kWh	5 or 6–25 ¢/kWh
Solar thermal electricity	~ 2	0.4 GWe	20 – 35	0.9 TWh (e)	2500–6000	12–34 ¢/kWh	4–20 ¢/kWh
Low-temperature solar heat	~ 10	57 GWth (95 million m^2)	8–20	57 TWh (th)	300–1700	2–25 ¢/kWh	2–10 ¢/kWh
Hydro energy							
Large	~ 2	690 GWe	35–60	2600 TWh (e)	1000–3500	2–10 ¢/kWh	2–10 ¢/kWh
Small	~ 3	25 GWe	20–90	100 TWh (e)	700–8000	2–12 ¢/kWh	2–10 ¢/kWh
Geothermal energy							
Electricity	~ 3	8 GWe	45–90	53 TWh (e)	800–3000	2–10 ¢/kWh	1 or 2–8 ¢/kWh
Heat	~ 10	11 GWth	20–70	55 TWh (th)	200–2000	0.5–5 ¢/kWh	0.5–5 ¢/kWh
Marine energy							
Tidal	0	0.3 GWe	20–30	0.6 TWh (e)	1700–2500	8–15 ¢/kWh	8–15 ¢/kWh
Wave	–	exp. phase	20–35	0	2000–5000	10–30 ¢/kWh	5–10 ¢/kWh
Tidal stream/Current	–	exp. phase	25–40	0	2000–5000	10–25 ¢/kWh	4–10 ¢/kWh
OTEC	–	exp. phase	70–80	0	8000–20000	15–40 ¢/kWh	7–20 ¢/kWh

a. Heat embodied in steam (or hot water in district heating), often produced by combined heat and power systems using forest residues, black liquor, or bagasse.

Source: United Nations and World Energy Council, 2004

As stated earlier, 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 GHG management technologies.

3.2 Challenges and Concerns

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.

The up-to-date monitoring data and statistic predictions state a fact of highly intensive use and increasing demand for fresh water resources which goes beyond the principle of sustainability. The present significant consumers, who drastically change the natural water cycle in direct and indirect ways, are the agricultural (71%), municipal (22%) and industrial (7%) sectors (Arizona Department of Water Resources Water Atlas).

In Latin America, although water is generally available, significant water pollution due to irrigation has been reported in Barbados, Mexico, Nicaragua, Panama, Peru, Dominican Republic and Venezuela, FAO (Food and Agriculture Organization of the United Nations, 2004). FAO also points out that the secondary salinity, i.e. induced by irrigation, is a serious constraint in Argentina, Cuba, Mexico and Peru, and to a lesser extent, in the arid regions of north-eastern Brazil, north and central Chile, and some small areas of Central America. Other sources such as OECD (Organization for Economic Development and Cooperation, 2003) refer to water quality impacts induced by subsidies in agriculture, as summarized in Table 3.2.

Table 3.2: Water quality impact caused by agricultural subsidies

Subsidy	Agent of impact	Impact
Agricultural prices support policies	Incentive for water-inefficient crops	Salinisation, water logging, decline in groundwater
Surface water price	Overuse of water	Pollution, salinisation
Electricity price	Substitution of surface water for groundwater	Aquifer depletion, salinisation

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

Source: Biswas, 2006.

Water quality is a problem affecting developed and developing (North, Central and South Americas) countries alike, and the OECD points out that globally farmers rarely pay more than 20% of the real cost of water.

Besides the intensive water consumption (32.5 million gallons per year for the US) the municipal and industrial sectors discharge domestic and industrial wastewaters into the water bodies. Large percentage of sewage is disposed untreated, causing inadequate sanitation of the urban inhabitants.

The reasons for the scarce water treatment are:

- High cost and complexity of treatment facilities are beyond the costs of most communities;
- Priorities - foreign aid agencies and local governments have given priority to water supply project rather than sewage treatment;
- Cost - it is easier to charge for water than for water treatment;
- Partial solutions that removed human waste from towns and cities left the treatment part of the equation for later, and it was often not completed.

There are many other reasons on the national levels depending on geographic, economic, social and political particularities which hamper the regular operation of water treatment plants. However, the most prominent problem, especially for the developing countries of the Americas, remains the high energy use for water treatment relative to water distribution.

Recent publicity surrounding the water-energy nexus internationally, 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: 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, primarily because of the pumping requirements. In monetary terms, the groundwater prices range from \$20 to \$160 per acre-foot (Arroyo, 2010). From an energetic perspective the water treatment numbers vary from 1.4 to 3.1kWh/kgal for the cities of Patagonia and Benson respectively, and the Central Arizona project averages 5.5kWh/kgal. The highest use is 9.8kWh/kgal for the city of Tucson due to its elevated location. The energy demand for wastewater treatment depends on 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).

The energy-water nexus also incorporates the use of water for power generation. Almost all types of electricity and heat generation require water. In the United States, thermoelectric power plants account for about 40% of all fresh water withdrawals, which totals approximately 190,000 million gallons of water per day. 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 electricity generation.

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 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.

According to a 2006 Pacific Institute study of California plants, the most efficient facilities operating today use around 12kWh to produce 1,000 gallons of desalinated water (Arroyo, 2010). The energy intensity though varies widely depending on the salinity of the source water (seawater or brackish groundwater) among other factors. One of the main environmental considerations of ocean water desalination plants is the impact of the open ocean water intakes, especially when co-located with power plants. Many proposed ocean desalination plants' initial plans relied on these intakes despite perpetuating ongoing impacts on marine life. In the United States, due to a recent court ruling under the Clean Water Act, these intakes are no longer viable without reducing mortality, by 90%, of the life in the ocean; the plankton, fish eggs and fish larvae. The transportation of water is another important factor: costs range anywhere from $45 to $1,800 per acre-foot.

The implementation of desalination project has to be accurately assessed before it is put in practice. In this case, the basic principles of cost-benefit analysis can be employed to evaluate the project feasibility. Among the evaluation criteria, the most evident are:

- Absence or remoteness of fresh water sources;
- The benefits and damages for local water ecosystems;
- Energy sources availability;

- Land availability for salt residues storage;
- Acceptance of final tariff by supplied communities;
- The scope of distribution net.

As an upshot of the 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. 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 leader in the bioethanol and biodiesel production. In this economically growing sector of transportation fuels, the production chain requires significant amount of water for the irrigation of crops and further for the process of crop fermentation. This makes this particular fuel a considerable player in the water allocation management. The available data show that the gallon of ethanol derived from irrigated crop consumes between 190 and 2,260 gallons of water, while for the biodiesel the number rises to 9,040 gallons of water. This will be discussed in more detail shortly.

As clean energy technologies mature and fossil fuel drops out of fashion, the quick replacement of the fossil liquid fuel for the automobile industry calls for another liquid fuel, which for now happen to be 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 as shifting from fossil fuels to nuclear power, hydropower and concentrating solar power means more intensive water consumption. Biofuels are less damaging from a GreenHouse Gas (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 cannot actually control with what water footprint their energy is created. In the developing countries of Central and South America the governmental 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, and leads to more stringent regulations and quantitatively extensive or intensive technologies to solve the water-energy puzzle.

3.2.2 Viable Regional Solutions to replace the use of Fossil Fuels for Transportation, Inter-American Biofuel and Ethanol Market

Currently, biofuels are the only renewable energy source commercially available that can be used to replace fossil fuels in the transportation sector. In the case of stationary generation there are alternatives such as wind, solar, geothermal etc.

Considering that the transportation sector is responsible for 13% (Intergovernmental Panel on Climate Change, 2007) of global GHG anthropogenic emissions, and that the projections of the International Energy Agency (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. The alternatives being studied comprise hydrogen, fuel cells, electricity and other biofuels feedstock, such as cellulosic material and algae.

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. Mainly produced in the United States from corn, it is also produced in Brazil and the European Union (from sugar cane and sugar beets, 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. 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 learnt from the experience of 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 (voluntary)
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 by 2022 (36 billion gallons): 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 by 2017 (0.9 billion gallons)
Uruguay	E5 by 2014; B2 from 2008-11 and B5 by 2012

Source: 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.

The bioenergy crops should be grown in a sustainable way, not leading to environmental destruction. The use of degraded lands instead of clearing lands is highly desirable. Also protection of surface and underground water and application of less water-intensive technologies must be observed. The problems concerning biodiversity and air quality should also be noted. The decision for adopting a biofuels program must consider not only environmental and policy aspects but also the social and economic dimensions.

Brazil is today the most important ethanol exporter, selling the product mostly to the United States and Europe. According to the Agro-environmental zoning published by the Federal Government, the country has 64 million hectares of land suitable to the production of sugarcane. However, not all of this area will be devoted to sugarcane crops. So far, the aim of Brazilian producers is to supply the internal market and, at an international level that ethanol becomes a worldwide commodity. In order to do so, a larger number of producing countries is required. So, more important than exporting ethanol, Brazil wishes to export technology and expertise to Latin American and Caribbean countries.

Nevertheless, as previously mentioned, biofuels would be a part of the solution for GHG emissions reduction and the replacement of fossil fuels; however it will not be able to replace completely world's fossil fuel consumption. There is much ongoing research, the challenge lies in the development of an alternative that could be environmentally friendly and economically competitive. In the case of Latin America, research activities on biofuel conversion technologies include (BIOTOP, 2010): ethanol production by biochemical conversion technology of lignocellulosic materials, new lignocellulosic feedstocks to ethanol production, conversion of waste feedstocks, algae cultivation, harvesting and processing for biofuels, biogas and biomethane; waste feedstocks for biodiesel production and technical solutions to Biomass to Liquid (BTL) process. In the long term, the alternative for transportation sector should be a new technology, not based in combustion engines, but in more efficient and less pollutant options.

3.3 Future target areas

3.3.1 Technical and engineering issues that form a common 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 way;
- Import and export renewable resources transnationally for the reason stated above;
- Balance domestic concerns of energy independence with the need for free flow of renewable resources;
- Improve and integrate climate, economic and quality of life models;
- Collecting and disseminating climate, energy and water data;
- Form common metrics that can be used to gauge the effectiveness of climate, energy and water policies and projects;
- Implement technology transfer;
- Encourage innovation;
- Educate the next generation of scientists and engineers.

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 transfers, innovation and forming common metrics may be placed in either category.

IMPLEMENTATION

As we attempt to move toward more sustainable energy and water management and generation, a great deal of international cooperation will be required. Current renewable sources of electricity using up-to-date technologies (solar and wind) are often of an intermittent nature. To get the most out of these energy sources we require smart grids – as defined previously – that allow for the transfer of power from where it is currently being generated to where it is currently required. The greater geographic area these grids cover, the more useful these grids become. This suggests that smart grid technologies and standards be developed and implemented across the Americas, and that transnational grids be built to these standards.

In similar ways, transfer mechanisms for other sustainable energy sources that can be produced in one region, but may be most usefully used 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 can also be considered in this context.

It is generally agreed that in order to implement a move toward sustainability in free market societies, incentives must be presented by governments to encourage the use of sustainable technologies and behaviors. These incentives can take on a variety of forms, including but not limited to, mandates, carbon tax, cap and trade schemes, etc. Different governments may find it favorable to implement a different mixture of incentives based on a variety of different local issues. While individual governments may be best suited to choose which incentives will be most beneficial for their region, a general framework for these incentives should be formed internationally rather than each country acting unilaterally.

SCIENTIFIC DISCOVERY

Collaboration in scientific discovery 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 understanding of how human behavior is expected to adapt to a changing environment. This may include migration patterns and land use changes as well as changes in economic activity. Economist and academicians in each country are best suited to create models of how their country might react to a changing environment.

Data collection is essential in order to improve models to take stock of current conditions. These data can include both direct observation and remote sensing, such as satellite data. In addition to sharing data, nations must agree on international standards of data collection and maintenance. It is important that how data is collected and interpreted be internationally agreed upon and understood by the various actors in the international scientific community. Thus, when comparing data collected in several countries a researcher can be sure they are, ‘comparing apples to apples.’

Improvement in the understanding of our changing environment and how our societies must 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 proposed metrics include:

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

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. Further the accounting system can be used to form policy road maps that will lead us to a more sustainable future.

OTHER FORMS OF COLLABORATION

Innovation in the area of sustainable energy and water supply continues to accelerate. This is being encouraged by direct support and incentives by the various governmental actors in the Americas. These programs, which include tax incentives, direct government funding of research institutions, grants, loan guarantees, etc. should continue and be accelerated. Care must be taken in evaluating new 'sustainable' technologies to verify that said new technology does in fact provide a net benefit to sustainability. As new technologies become ready for market, it is important that technology transfers are permitted so as to speed up the spread of technology to where it can best be implemented.

The various countries in the Americas have made great strides in different areas of sustainable energy. 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 supply. In order to spread scientific and engineering knowledge and to help train the next generation of scientist 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 collective society. However, no discussion of such cooperation would be complete without mentioning some of the barriers that 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 transfers for security and economic reasons.

Despite these concerns, the Americas have made great strides 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 insufficient, are positive signs.

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

THE ROLE OF ENERGY POLICIES

All countries in the world have some sort of energy and water policies, albeit not as a nexus. Such policies are documents, and also an action plan ratified and executed by government entities. The energy policy addresses the urgent issues of energy development and management (production, distribution and consumption) dealing with legislative, economic, public and environmental issues, and it is more and more associated with developments in climate change, water as a component of the change. Nevertheless, the prime goal of these policies remains to be national supply security.

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 yet to come 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.

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 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.

Unfortunately, quit 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.

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 regarding grid-tied power and off-grid energy services are largely driven by rate of return for private power projects. Many countries in Latin America have converted their state-owned monopolies into privatized systems with emphasis on 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 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 levels (towns, cities), 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 and improved coordination between stored and other water supplies;
- Developing conjunctive use management plans;
- Exercising of recycling;
- Developing alternative local resources;
- Better demand characterization.

Examples of long term strategies may include:

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

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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. The impact of water use on energy and climate change is well observed; water is used in most areas of energy (electricity) 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 areas, and desalinization of salt water is becoming more viable as our technology advances.

In the Americas, water supply can create political rifts between neighboring countries as they vie to divert river basis for agricultural and civilian use. Water policies play an extremely important role in any area with a fresh water supply. 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. 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.

4.1 Current state in the Americas

The Americas are a very diverse region containing arid, temperate and tropical regions, and as such the policies governing water use is becoming very important. In a time when climate change is being felt all over the world, policies that are outdated are still in place, and in some cases this can lead to cross border issues between countries.

Large amounts of fresh water are being used in the Americas for agricultural and power generation purposes, among others. The use of such resources should be closely monitored, but the regional and global impacts of its use are not yet well understood. Agriculture and power generation are two of the most apparent 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, 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 the two biggest freshwater uses in the Americas, Biofuel and Power Generation.

4.1.1 Policies and the Political Dynamics of Water Distribution in the Americas

Water distribution and availability differs greatly among the Pan-American countries and regions. In general, Latin America has relatively good water availability, due in large part to the Amazon Basin. Approximately 30% of the world supply of superficial 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 49% of fresh water is used for agriculture. 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 is in Belize (47%), Bolivia (45%), Haiti (34%), and the Dominican Republic (57%) (Solanes e Joulavlev 2005).

CASE EXAMPLES

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. Brazil has adopted new water legislation and a national water management policy (Solanes and Jouravlev 2006). 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, it 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).

It can be said privatization of the economic sectors in South American countries, despite support from many economists and international stakeholders, was not universally expedient at 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 surface area under 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.

Water management institutes have different structures in different countries. The primary subject of water management in Mexico is river basins. As a consequence, river basin councils dictate management courses. 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 federal government and the states. 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. The U.S. partnership between federal and states, and federal government establish patterns for pollution reduction. States governments implement and comply with the determinations (Veiga e Magrini 2009). Canada has an integrated watershed management approach. 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).

Some important points to reflect upon regarding water resource management are: integration considering various sectors including energy, sanitation, agriculture, etc.; promoting stakeholders participation in the decision-making; and taking a river basin approach, since territory delimitation does not coincide with natural resources delimitation.

The flow of water across political borders can be a source of conflict, or add to the political dynamics that could aggravate preexisting cold moods. As a case of fierce political conflict, one can mention the recent dispute between the Ecuadorian government and a Brazilian firm, Odebrecht planning 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).

A potentially serious zone of cross-border conflict is the Madeira Basin located in the Amazon region of Brazil and Bolivia involving projected dams. 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. Civil society movements and organizations in both countries have expressed 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 indigenous people are opposed to these schemes for various ecological reasons (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: Lifecycle Water use for Ethanol

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. 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 production will 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 environmental costs: water and air pollution, soil depletion, and habitat loss associated with the conversion of forests to cropland" (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 Withdrawals and Water Use Projections for Power Generation

Water has always been known as a cheap and clean source for generating power. Compared to the combustion of fossil fuels and nuclear power plants it is a clean source since no pollutant is generated by using it. However, there are some restrictions limiting water as the energy source. Damming rivers for example causes some environmental impacts such as obstructing immigrant fish, water temperature change and can significantly change the ecological characteristic of the river. The physical impacts of a dam and reservoir, the operation of the dam, and use of the water can change the environment over a much wider area than that covered by a 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).

Water and energy are two connecting issues; it is virtually impossible to consider one without the other. 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 desired purpose. The total amount of fresh water resources estimated is about 35 million cubic kilometers, 70 percent of which is in the form of ice and permanent snow cover in mountains (UNWater, 2010). Thermoelectric-power generator facilities alone consume 52 percent of the fresh surface water withdrawal (USGS, 2010).

In non-nuclear thermal power plants, typically electricity is generated by converting water into high-pressure steam that drives turbines. Once water has gone through this cycle, it is cooled and condensed back to water. The water is reheated to drive the turbines again, repeating the cycle in closed cycle, or fresh water is pumped instead, as in open cycle. The condenser itself requires a separate cooling water body to absorb the heat of the steam. Closed cycle systems discharge heat through evaporation in cooling towers and water recycles within the power plant. The water required to do this is comparatively small since it is limited to the amount lost through the evaporative process. Open systems use a continual flow of water for cooling purposes. The water demand for these types is between 30 and 50 times that of a closed cycle system (UNWater, 2010).

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 system (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. The Salem Nuclear Generation Station alone takes 3 billion gallons a day from the Delaware Bay (Ottinger, et al. 1990). Steam electric generating plants across the nation draw in more than 200 billion gallons per day. Taking the advantage of renewable energy technologies there will be little or no need for water in cooling systems.

Hydropower plants divert water from the river through turbines in order to generate power. Water is diverted from the river via an intake at the dam. At some hydropower plants, the turbines are located in the dam and thus the water is released directly downstream. At other hydropower plants, the turbines are located in a powerhouse significantly downstream from the dam. This means that the water can be diverted outside of the stream for some distance, sometimes several miles, before being released back in the river.

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). 25% of dams worldwide are used for hydropower, and only 10% have the generation of hydropower as their main purpose. One of the advantageous of hydropower energy generation facilities is the fact that they do not consume water in the process; the only loss is incurred during evaporation when the air temperature is high.

Greenhouse effects continue to dominate the world's science and policy agenda on global climate change. One fundamental concern is the impact of this change on water supply. Despite the rapid population growth and economic development the question of how human society directly influences the state of the terrestrial water cycle is still not answered.

Energy and water demand depend on income. At low income levels, energy and water are used for basic needs, such as drinking, cooking and heating but as income increases other applications such as refrigerating, transportation, cooling systems and swimming become available. The economic and social value of ecosystem services should be integrated into decision making around water, energy and climate change issues. Currently an amount of $1.8 - 4.2 trillion (USD) is lost each year related to ecosystem issues. This value is predicted to increase up to $46 - 133 trillion by 2050, (Braat & Brink, 2008).

4.2 Challenges and concerns

The problem of a finite supply of fresh water in any region is a complicated one, and many popular solution techniques are in place today. 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.

The relationship between ethanol production and food or water supply is also a delicate one, since crop lands which could be used for food production are used to produce organics required for ethanol production. In addition, a substantial amount of water is also needed for ethanol crops. Regardless of the energy production method, political issues between neighboring countries also play a large role, and their policies shape the way water resources are diverted for energy or agricultural purposes.

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) concludes 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."

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.

The biggest 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

As discussed above, biofuels are convenient, renewable, and commercially available replacements for transportation. Due to the high amounts 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 hidden 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 uses about 1.51 billion liters of gasoline every day, 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 could lead to conflicts over water use, as has been identified in the Midwest U.S. Here, water availability is not distributed like 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).

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 complemented by partial ferti-irrigation, carried out mainly to manage water wastes, limiting their 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 (Toasa 2009). Thus, investments should be made to reduce the inputs required for ethanol production while increasing the product quality. 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 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.

The water requirements of ethanol produced from corn vary widely depending on climate (Arroyo, 2010).A consumptive water use plant comes from evaporation during cooling and wastewater discharge. Ethanol plants are designed to recycle water within the plant (Keeney et al., 2006). There is needed high quality of water in the boiler system. Water utilization is 10 gallons per minute for each 1 million gallons of ethanol production in a year (Keeney et al., 2006). Thus, to produce of 50 million gallons per year, an ethanol plant would need 500 gallons per minute of water (Keeney et al., 2006).

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 with livestock facilities; placing a greater economic value on water; and maintaining publicly-available records on water consumption for ethanol production (Keeney et al., 2006).

Ethanol farm will also have 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.

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

Water has become highly politicized 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 Americans, 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 a longstanding treaty and 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 this continent, the use of trans-boundary water resources in South America is more linked to the energy generation, especially over the past few decades. The imposition of higher energy costs by the Organization of Petroleum Exporting Countries in 1973 has 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). 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 tapping more of 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).

4.3 Future Water Treatment, Detection, Recovery, and Reuse Technologies

The 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. Using advanced water treatment, it is possible to achieve high quality water treatment as desired. In California for example the drinking water is provided using various methods since 1968.

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.

Though fresh water 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.

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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). These changes and related forcing correspond with a net change in irradiance of ~2 W/m^2, a small number when comparing to the planet's energy budget (Hansen et al. 2005). The GreenHouse Gas (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. Other feedbacks identified by climatologists relate to phase changes of water (albedo, clouds and water vapor) and are currently not fully represented in climate models (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 Earth's climate is heterogeneous by nature, it is important to understand the temporal and spatial scales of the weather system for numerical application and decision-making. The climate system and its feedbacks interact daily (e.g. regulated diurnally), seasonally (by the inclination of the axis of the Earth) and in century or millennia scales depending on the mechanism or feedback process of interest (e.g., changes in the composition of the atmosphere chemistry or ocean circulation). Researchers need to consider the scope of their more regional work in comparison to the globally scaled systems in order to derive policies appropriate for their area.

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.

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. 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.

Oechel (2010) presents an overview about 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 was revealed that GreenHouse Gas (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.

Climate change models are also a good tool to assess and predict changes in climate. In fact, General Circulation Model (GCM) can be used for climate change prediction, Leung (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 green house 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) presents 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 larger 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, there is expected to be a general decrease in precipitation for the subtropics and increases 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 drying of 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 shortwave 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 the mechanisms described above influence in 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.

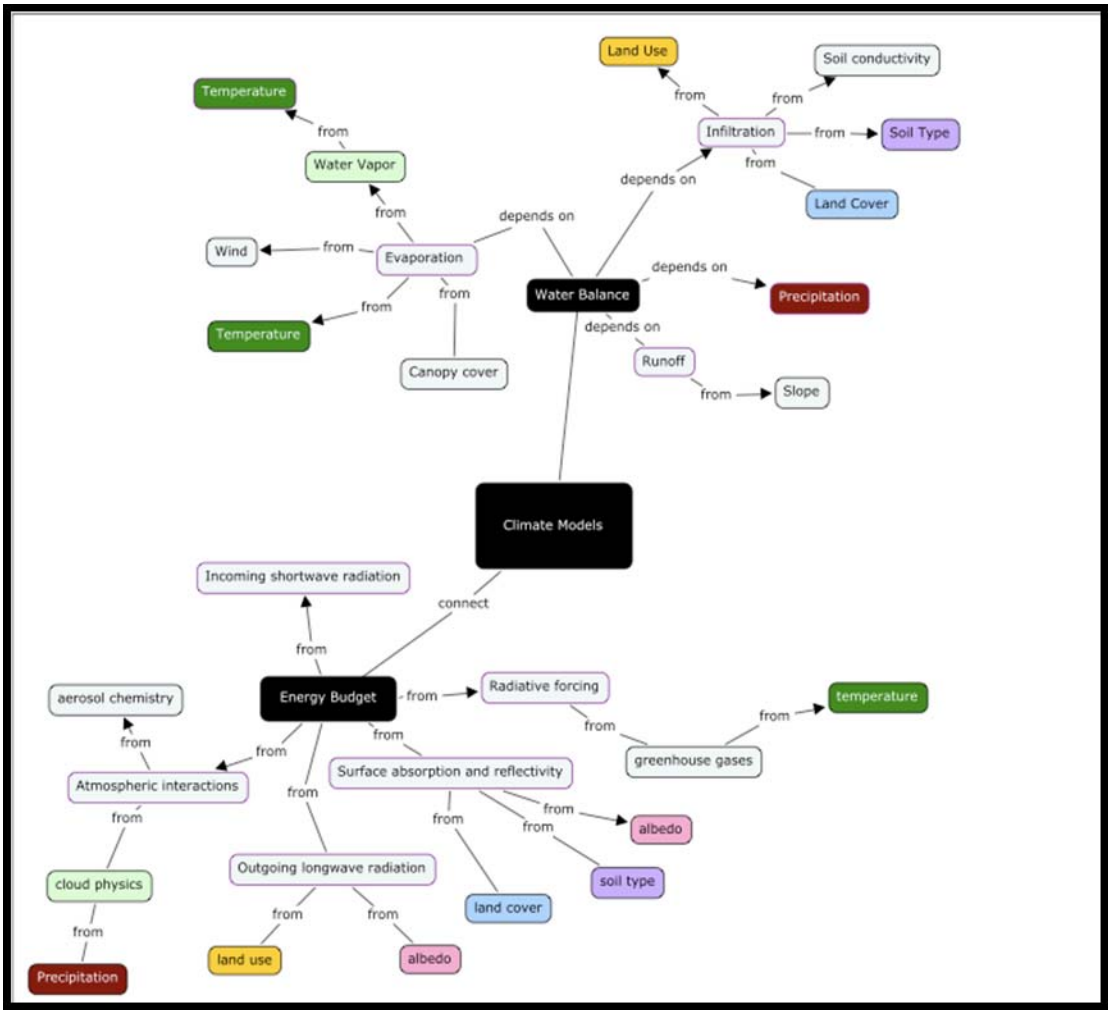

Figure 5.1: Concept map of the linkages between the energy budget and water balance, and the role of climate models in connecting these systems.

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, policies, and global impact analyses

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), 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 and demographic changes, security and energy. 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 is 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	Implication
Principle 7	Businesses should support a precautionary approach to environmental challenges.
Principle 8	Businesses should undertake initiatives to promote greater environmental responsibility.
Principle 9	Businesses should 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 (photovoltaic energy), wind (wind turbine and windmills), 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 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 the 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 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.

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 as presented by 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 green house 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 with dominance switching gradually to carbon effects in the tropics. 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 region (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., in Press, Figure 5.2). With this approach there is interplay between data, model structure, and the model developer. The process detail depends somewhat on whether the problem is focused on state estimation of the system, or on parameter estimation of the model. If state estimation is the goal, then model states are adjusted to generate closer agreement with the observations. If model parameter estimation is the goal, then model parameters are adjusted so that the model state(s) come into closer agreement with the observations. Following the optimization of model parameters, it is critical that further analyses be conducted by the modeler to:

(1) Quantify uncertainties in optimized parameters;
(2) Evaluate the plausibility and temporal stability of optimized parameter values;
(3) Under-stand when and why the model is failing; and
(4) Identify opportunities for model improvement (e.g., re-formulation of structure and process representation). When treated in this manner, it is possible that model data synthesis has relevance to both basic and applied scientific questions (Vargas et al., In Press).

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?

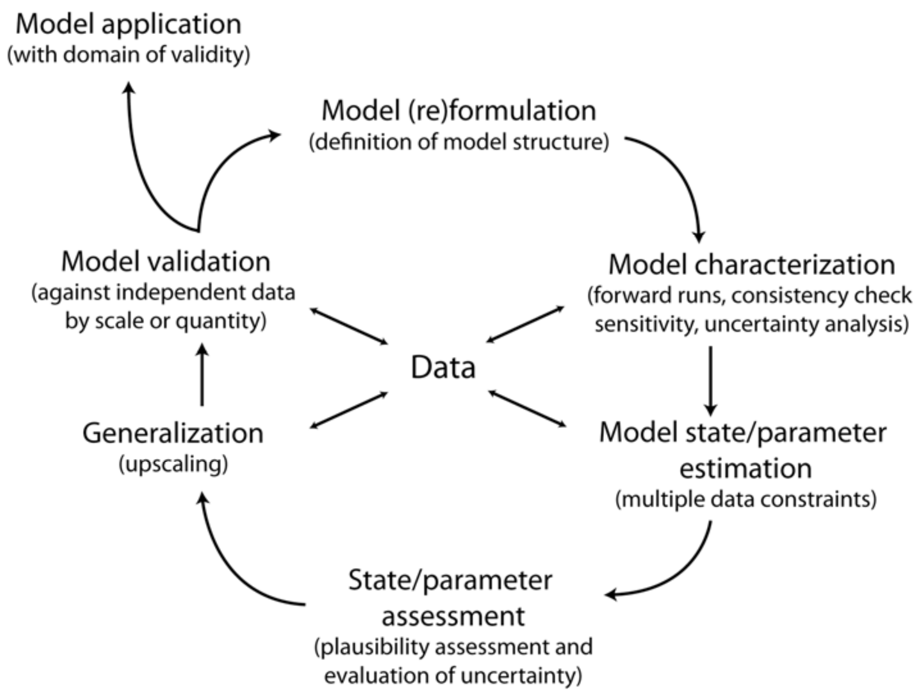

Figure 5.2: The multi-step process for model-data fusion: a conceptual diagram showing the main steps (and the iterative nature of these steps) involved in a comprehensive data-model synthesis (Source: Vargas et al., In Press)

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 impede the development of global change policy 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.

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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 widening.

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 our 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 evident in many sectors.

The U.S. is the largest economy not only in the Pan American region but also in the world, using 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 the environment. 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 hydro-electric ((Sena et al., 2010; Megdal, 2010). The establishment of hydro power generation typically comes at a cost of increased deforestation to make room for dams. This has been particularly an issue in the Amazon region, an area with highly sensitive ecosystem. As a consequence, reduced precipitation and subsequent decline in river levels have been noticed. There is an apparent interlink of the three - in which water used for energy generation threatens the environment. These challenges to renewable energy from global climate change perspective may hinder the drive to become carbon neutral (Rodrigo, 2010).

Several projects in the Pan-American region utilize energy to clean or transport water. There are about 18 water desalination plants in California that use energy to produce clean water. 64MW of power is set aside to pump water in New Orleans for alleviating floods, (Beyene, 2010). There are 14 plants that pump about 1.5 million acre feet of 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 cannot be assumed negligible. 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 for the Americas

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 or 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. and 2 Mexican states. Treaties between U.S. and Mexico determine its flow. 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. Regional population growth in the dry states of Arizona and California is projected 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 the river basin is in Brazil. There are international treaties governing water flow. 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 a fundamentally global problem; 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).

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.

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).

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 response to the threats to energy production and water supplies, there must be increased collaboration on critical resource planning. This collaboration should take place among all actors involved: various levels of government, watershed and other local protective groups, industry, and other stakeholders. Ideally, not only do actors need to work together to monitor availability, quality, and cost of resources, but also to improve energy and water efficiencies.

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. While the Energy-Water Nexus' creation represents a definite step in the right direction, the group's main purpose is 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.

To avoid such problems and 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.

In sum, the threats to energy and water resources are real and present. Without strategic and cooperative natural resource planning, such as the employment of regional natural resource planning groups, our heavy dependence upon energy and water resources will be in continued risk.

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 (ΔT) 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:

- The largest share of historical and current global emissions of greenhouse gases originated in developed countries;
- Per capita emissions in developing countries are 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.

Historically economic trade has been one of the most successful forms of international collaboration and has been a strong opponent to armed conflict and other forms of unrest

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 footprint, 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.

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.

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. costed, in the 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 lead 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 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 (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 Current and Future Research Measures Combining Energy, Water, and Global Change, Targeting Future Needs as Pan-American Solutions

LOW CARBON RESEARCH
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 the 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). There also exist significant research opportunities which 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 hydropower systems;
- 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

World wide fossil fuels contribute about 4.154×10^{14} MJ of energy per year. The current climate models for climate change research by and large do not 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 researches 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 the surrounding (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 of regional requirements

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 CONCLUSION

The thrust 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.

(i) 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 (ΔT) 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.

(ii) 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.

(iii) 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.

(iv) 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 waste heat, traditionally ignored in climate modeling, accounts for a fairly traceable rise in temperature – an appropriate topic for future research.

(v) 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.

(vi) 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.

(vii) 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.

(viii) 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.

(ix) 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.

(x) 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.

(xi) 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.

(xii) 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.

(xiii) 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.

(xiv) 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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