the environment

TURN ON THE lights

It's Time to Start Thinking about a Hemispheric Smart-Power Grid for the 21st Century.

by David Jhirad and Alan Poole

How we collectively produce and deliver energy, while coping with the catastrophic threat of climate change, will define our century. The challenges faced by the international community are monumental and multi-faceted. They include stabilizing greenhouse gas emissions, enhancing energy security through reducing the risk of economic disruption and nuclear weapons proliferation, and eliminating the lack of access to energy for over 3 billion people. An estimated $20 trillion in capital investment will be needed for energy infrastructure by the year 2030, according to the International Energy Agency (IEA). More specifically, to meet the immense challenge of climate change to energy policy, there must be dramatic changes in the historic trends of energy and electricity supply and use.

Our hemisphere can play a key role in addressing that global challenge by building a smart, sustainable, resilient, and secure power grid that stretches across the Americas.

The electric power sector has already assumed new prominence in the transformation of global energy production and delivery. It is a fundamental driver of economic growth and poverty reduction; a key sector for reducing greenhouse gas emissions through expanded renewable power; a strategic replacement for petroleum as the transport sector makes the long odyssey from liquid fuels to electricity; and an essential network whose robustness and resilience will need to be preserved in the face of malicious disruption or extreme weather events.

Building on these essentials will require a combination of innovative technology and enlightened public policy. But the ingredients for a smart grid network lie in the huge diversity of the supply base in different regions.

TABLE 1

ELECTRICITY GENERATION IN THE AMERICAN HEMISPHERE - 2006	TOTAL	SHARE OF GENERATION			
	TWh[e]	Fossil Thermal	Nuclear	Hydro	Other Renewable
Canada	595	23%	16%	59%	1.9%
United States	4,065	71%	19%	7%	2.7%
Latin America & Caribbean	1,187	38%	3%	56%	2.9%
Mexico	*236*	*79%*	*4%*	*13%*	*3.7%*
Caribbean [a]	*77*	*96%*	*0%*	*3%*	*0.8%*
Central America	*36*	*37%*	*0%*	*52%*	*11.2%*
Northern Tier of South America [b]	*163*	*24%*	*0%*	*75%*	*0.4%*
Central Andes [c]	*45*	*36%*	*0%*	*64%*	*0.7%*
Brazil	*412*	*9%*	*3%*	*84%*	*4.2%*
Southern Cone [d]	*218*	*40%*	*3%*	*56%*	*1.1%*
Hemisphere	**5,846**	**59%**	**16%**	**22%**	**2.7%**

A: CARIBBEAN INCLUDES PUERTO RICO AND CUBA; B: NORTHERN TIER INCLUDES COLOMBIA, VENEZUELA AND THE GUYANAS; C: CENTRAL ANDES INCLUDES BOLIVIA, PERU AND ECUADOR; D: SOUTHERN CONE INCLUDES ARGENTINA, CHILE, URUGUAY, AND PARAGUAY. E: TWH, OR TERAWATT HOUR, IS A UNIT OF ENERGY. SOURCE: BASED ON DATABASE OF THE ENERGY INFORMATION ADMINISTRATION OF THE U.S. DEPARTMENT OF ENERGY.

The U.S. power system is dominated by fossil fuels (coal and natural gas) that are responsible for about 70 percent of its electricity generation.[1] Renewable sources, including conventional hydropower, provide about 10 percent and nuclear power supplies the remainder. The Canadian system, in contrast, is dominated by hydro, together with a relatively large share of nuclear power. Less than a quarter of power output is from fossil fuels.

Latin America lies in between. On average, less than 40 percent of energy generation is supplied from fossil fuels. This is due primarily to the large share of hydro, with small contributions from other renewable sources and from nuclear power. However, there are large regional disparities. Mexico and the Caribbean are even more reliant on fossil fuels than the United States. In sharp contrast, less than 10 percent of Brazil's power output comes from fossil fuels, while generation in Colombia, Venezuela and the Guyanas is also dominated by hydro **[SEE TABLE 1]**.

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In the U.S. and Canada, more than 70 percent of the electricity generated from fossil fuels comes from coal. In Latin America roughly 15 percent of electricity generation is from coal, while most of the rest is from natural gas. Indeed, the share of natural gas for the U.S. and Latin America is similar—20 percent versus 18 percent.

The U.S. and Canada have dominated power sector expansion in the hemisphere and were responsible for over two-thirds of growth between 1990 and 2006. Today they are responsible for about four-fifths of the power generated. But over the next two decades and beyond, the economic development of Latin America will result in a higher electricity growth rate. Depending on the vigor of economic growth, Latin America may account for between 50 percent and 60 percent or more of the growth in total hemispheric power requirements. As a consequence, how Latin America evolves will be just as important, if not more important, than the performance of the U.S. and Canada combined.

Wind, Sun and Water: Moving Toward a Low-Carbon Power Grid in the Americas

There are sufficient renewable resources of wind, solar and hydro to drive toward a low- to zero-carbon power grid in the Americas. The main candidates in the shorter term are hydro and wind energy. There are substantial undeveloped conventional hydro resources in Latin America and, to a lesser extent, in Canada. **[SEE TABLE 2]**

TABLE 2

REMAINING EXPLOITABLE HYDRO POTENTIAL IN TWH

The high case assumes 60 percent of total technical potential can ultimately be developed, the low case 50 percent. In the U.S. potential sites of larger hydro have already been eliminated.

	LOW	HIGH
CANADA	178	281
U.S.	13	72
LATIN AMERICA	945	1,273
HEMISPHERE	**1,136**	**1,626**

Evaluations of wind-power potential are much less developed than those for hydro, and the gap between theoretical and practical potentials is greater. Many countries do not have systematic evaluations of wind potential at all. The areas with high-quality resources are much smaller than those with more mediocre wind speeds. However, it is important to focus on higher quality wind resources to keep the cost per megawatt hour (MWh) lower: say areas with average wind speeds above 15.7 miles per hour (7 meters per second) at a height of 164 feet (50 meters)—known as Class 4 ("good")—or above 16.8 mph (7.5 m/s)—Class 5. The extractable power from wind increases with the cube of the speed.

High-quality wind resources can be found in sites throughout the hemisphere and their combined potential rivals or exceeds that of hydro. Exploiting just 15 percent of the United States land-based potential above Class 4 would generate more than 1,250 terawatt hours (TWh)/year (a quarter of total projected U.S. generation needs in 2030). Canadian land-based potential may be double that of the United States. In Latin America there are also significant potentials, for example:

- The Isthmus of Tehuantepec in Southern Mexico has a gross potential of over 100 TWh above Class 4 (two-thirds above Class 5).
- Parts of the north coast of Colombia and Venezuela and coastal Peru have excellent, if unquantified, wind resources.
- Brazil has about 600 TWh of gross potential above Class 5 and 1,900 TWh above Class 4 spread in diverse areas from northeastern to southern Brazil.
- Argentina may have the best resources of all—the gross potential of areas in Patagonia with average wind speeds above 19.7 mph (8.8 m/s)—Class 7 or "superb"—probably exceeds 2,000 TWh.

Wind power can therefore make a very significant contribution to the expansion of electricity supply in the hemisphere, taking up where hydro left off.

While clearly more expensive than traditional hydro or conventional gas or coal-fired capacity, wind costs have come down substantially in recent years. In good sites, generation costs are likely to be in the range of $55–$70 per MWh (though costs are higher today in Latin America due to the incipient market). Factoring in carbon credits equivalent to $15–$20 per tonne of CO_2 (tCO_2), about $13–$17/MWh for a coal plant, wind can become quite competitive with coal capacity—especially in Latin America, where thermal generating plants on average operate at 50 percent below capacity.

Thus, wind energy is an emerging "game changer" among renewable options for the next two or three decades. Geothermal and biomass, while commercial and quite competitive in some places, have limited overall potential without technological breakthroughs (such as "hot dry rocks" for geothermal and gasification of biomass). The costs of solar photovoltaics, solar thermal-electric and various forms of ocean energy need to come down substantially for them to be viable options for bulk power supply.

The Pivotal Role of Natural Gas in the Hemisphere

Substantial new reserves of natural gas from shale formations have been discovered in the U.S., and natural gas utilization is expected to expand significantly in the U.S. and Canada. According to a recent Navigant study, domestic shale gas reserves can meet U.S. natural gas demand for the next 100 years. The study predicted that annual production from the seven-largest U.S. shale basins could exceed 10,950 billion cubic feet (bcf) and even reach 14,235 bcf within 10 years.

Natural gas repowering of coal power stations in these countries offers a strategic opportunity to significantly reduce carbon emissions for each unit of electricity generated. Furthermore, natural gas power units are superior to coal when used to complement power from variable, renewable resources such as wind and hydro. Though we have not discussed the implications of these new discoveries for a hemispheric grid, it is clear that natural gas will be a game-changing and strategic resource for the remainder of this century.

The Need for New Grid Infrastructure

The accelerated development of renewables on anything like this scale implies substantial new grid infrastructure for more long-distance transmission. An obvious reason is that hydro, wind and geothermal are quite site-specific and can be far from main centers of consumption. Solar is more distributed, but even so is found more abundantly and more continually throughout the year (important for central stations) in certain fairly limited areas. This motive has already led to some important long-distance lines, as for example the line connecting Churchill Falls in Labrador, Canada, to the northeastern U.S., the Pacific transmission line (between the Colombia River hydro complex and southern California) and the new 1,500 mile (2,375 kilometer) lines from the Madeira hydro complex to centers of consumption in southeastern Brazil.

Another reason for long-distance transmission arises from the large potential for complementarity among variable resources like hydro, wind and solar energy on the supply side as well as the variations of consumer demand. The variability of supply should be considered under different time scales: very short (minutes and hours), seasonal and annual (e.g., dry versus wet years).

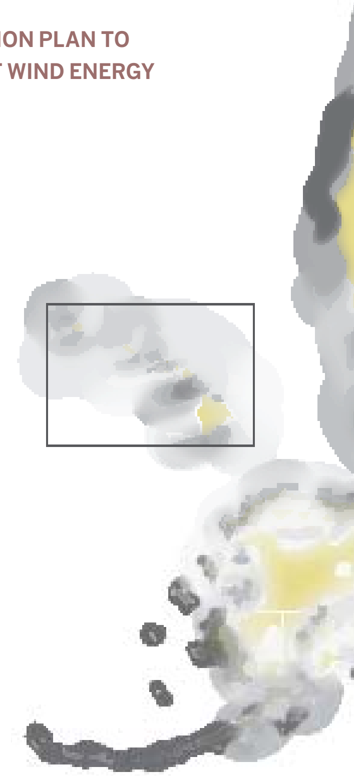
One way to mitigate this variability is to link power generating plants with different patterns of variation. For example, when the river flow in one basin is low, it may be high in another. Exploiting complementarity is traditional in the planning of hydro-dominated systems such as Brazil's. That country's national grid—extending the equivalent of Lisbon to Moscow—is unique in the hemisphere and is perhaps of more general interest to most other countries than the much-talked-about biofuels program.

CONCEPTUAL TRANSMISSION PLAN TO ACCOMMODATE 400GW OF WIND ENERGY
(Aep 2007)

Existing 765 kV
New 765 kV
AC-DC-AC Link

POTENTIAL SOURCES OF WIND POWER
Wind Power Density at 50m
[200–300=GOOD, 800–1600=SUPERB]

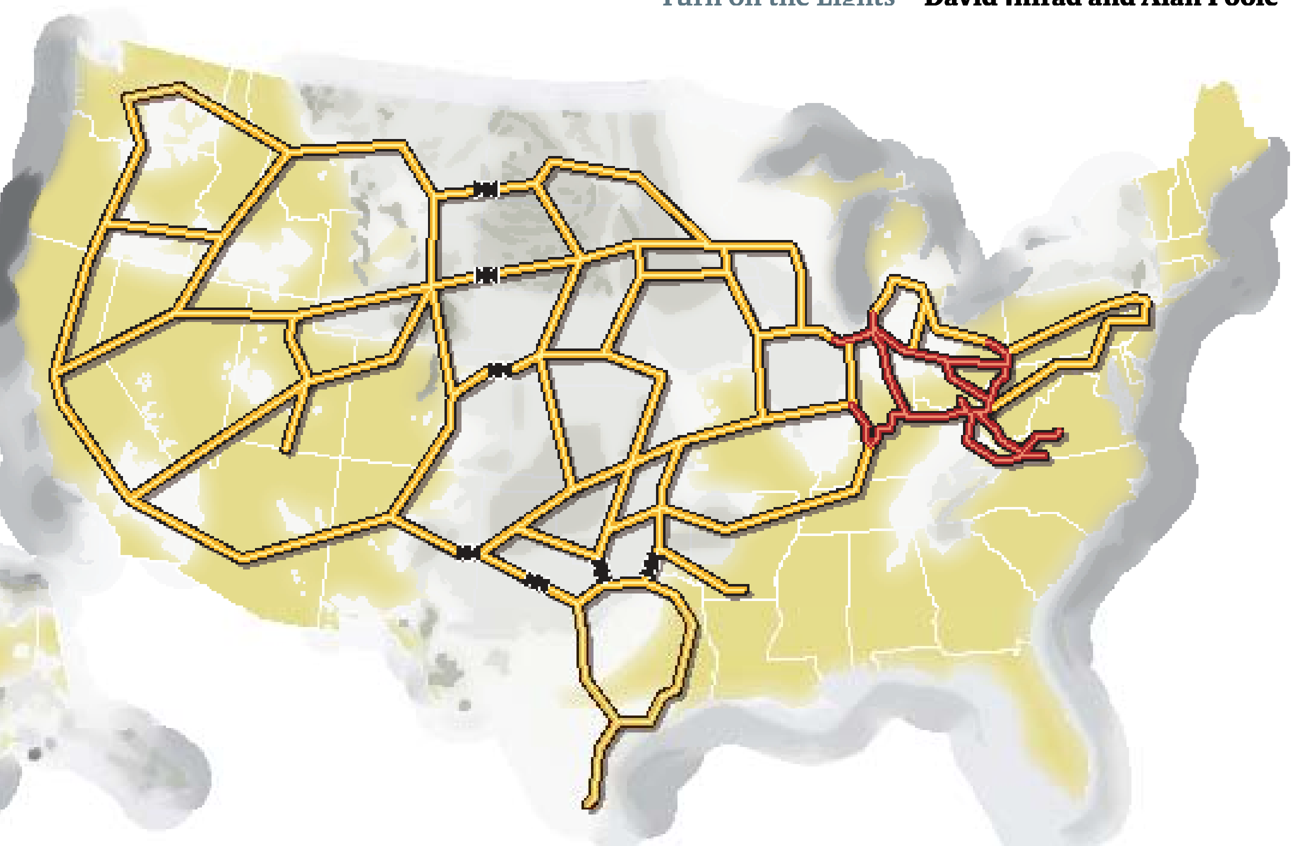
200 - 300
300 - 400
400 - 500
500 - 600
600 - 800
800 - 1600



The key point is that bulk electric power will move back and forth from North to South, and East to West. Power would not be transmitted from Patagonia all the way to Quebec in a hemispheric grid.

The same principle can be applied to wind power. It is generally recognized that by linking plants over a wider area the average variation of output is reduced. Most attention has been paid to smoothing (and predicting) short-term variations (for example, less than 24 hours), but seasonal variability can be reduced as well. This is especially true if mixed hydro-wind systems are considered. Complementarity of natural hydro and wind output has been observed in many places, such as Argentina, northeastern Brazil, Colombia, Central America and Southern Mexico, and Canada. In addition, there are benefits on the demand side, allowing the exploitation of East-West differences in the timing of peak load.

Along these lines, a 2006 Canadian analysis of Sustainable Energy Science and Technology observed that hydro systems might "be more effectively deployed within a 'smarter' electricity system: one which uses storage and grid connectivity jointly to enable more efficient integration of diverse sources of electric-



MAP BY REMIE GEOFFROI

ity, including other forms of renewable energy.”[2] It is worth noting that north of the James Bay hydro complex in Quebec and Churchill Falls in Labrador there are excellent wind resources that are not so far from existing transmission lines and could complement the seasonal variation of hydro.

The need to greatly expand the grid network is not only driven by the expansion of renewable sources of energy. The expansion of nuclear power is also a motivation. One reason is size: not only are individual nuclear plants usually larger than their coal or natural gas counterparts, there is a greater tendency to cluster plants at specific sites. Future expansion is likely to reinforce this tendency: probably almost all new nuclear plants in the United States will be built at existing nuclear sites. The fact that nuclear sites are for all practical purposes permanent is another factor leading to clustering.

Smart National Grid Development in the United States

The U.S. provides an important example of the move toward a smart national grid, both for local distribution, as well as for long-distance transmission. President Barack Obama’s administration is committed to economic recovery and infrastructure improvement, is supportive of increased investment in science and technology, and is determined to address the challenge of climate change.

Making the transition to a carbon-free energy system is the foundation that will help achieve those goals, and a smart national power grid is an essential building block in this transition.

A new power grid provides the infrastructure necessary to move the U.S. to an economy with drastically reduced carbon dependence. As personal transport becomes more electrified, as mass-transit systems spread and as alternative and renewable sources of power become a larger part of the U.S. electricity profile, a new backbone grid network with “smart grid” distribution components becomes an absolute necessity. The recent $787 billion stimulus package allocates $11 billion in loans and loan guarantees to the electricity transmission system.

The national “backbone”—or national grid—is the building and expansion of the high voltage transmission grid. The smart grid refers to improvements to the distribution system, which has to be linked to the transmission system and the sources of power generation on one end, and to consumers on the other. The U.S. needs to modernize and expand both distribution and transmission systems to allow the grid to use new sources of low or zero carbon power from wherever it is located. Already, projects representing significant wind generation capacity are waiting to get underway, dependent on the ability to hook into a more robust future grid. The current U.S. grid simply cannot handle a significant amount of new generating capacity from wind, solar and other sources.

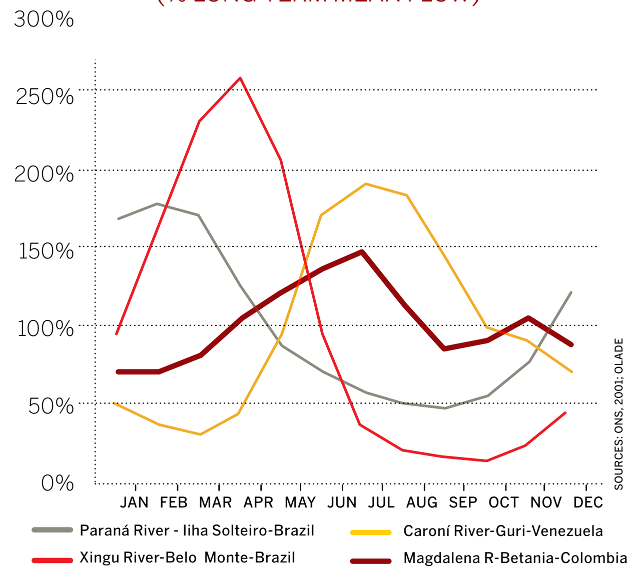
A new grid has the potential to provide much more resiliency, robustness, redundancy, and security to the U.S. electric power system. The U.S. power infrastructure has become more vulnerable to the increased frequency of extreme weather events and the prospect of terror attacks or sabotage. The power blackouts in the Northeast several years ago, traced to a cascading series of transmission shutdowns triggered by a downed tree branch in the Midwest, remains a stark reminder of the fragility, obsolescence and vulnerability of the U.S. power infrastructure, as well as of communications and other systems that depend on reliable power.

The need for massive new capacity to move large quantities of power from new and often remote places to population centers where there is large and increasing demand trumps virtually everything else. Steven Chu, President Obama's secretary of energy, stated in his confirmation hearing that the power grid is "very crucial" to domestic energy strategy, and that the key challenge is the siting of transmission lines, including across state boundaries.

A major obstacle is that the current balkanized regulatory system in the U.S., which is divided among 50 state public utility commissions, offers few incentives for utilities and transmission companies to invest in a smart national grid.

The creation of a new smart national power grid is a necessary part of other initiatives that will help transform U.S. infrastructure and the economy. Without the capacity, resilience, security, and reliability of a smart grid infrastructure, there is great risk that the other components of a new energy system will simply not get implemented. However, the U.S. should not lose sight of the advantages of wider interconnections and exchanges both to the North, with Canada and to the South.

VARIATION IN AVERAGE SEASONAL RIVER FLOW (% LONG-TERM MEAN FLOW)



Implementing a Hemispheric Grid: Next Steps

With the diversity of energy supplies and obvious economy of scale and seasons, a hemispheric energy grid make sense. The question is how it will overcome barriers of border, diplomacy, nationalism, and history. Fortunately there is an incipient network that is beginning to transcend many of these obstacles.

A hemispheric transmission backbone network is likely to be built in segments, so that individual units are economically justifiable. This is possible because there are potential opportunities up-and-down the hemisphere as well as back-and-forth. In some cases, it may be necessary to have the clear goal of dramatically greater interconnection to build a transmission line or segment. In other cases one could allow for more capacity than an isolated "business as usual" analysis, building in "headroom" as proposed by the Canadian Academy of Engineering this year.

An example of the first approach would be an interconnection between two large hydro plants in South America: Belo Monte (11,000 MW, to be built on the Xingú River just south of the Amazon River) and Guri, 10,000 MW on the Caroní River (tributary of the Orinoco River) in Venezuela. This interconnection would cross the Equator and hence exploit the huge potential for complementarity due to the "hydrologic diversity" which exists between the Northern and Southern Hemispheres inside the tropics. Considering the large degree of complementarity, the poles for the interconnection are not that far apart—about 1,900 miles (3,000 kilometers) passing through Manaus.[3]

Obviously, the interconnection would link not only the individual plants, but the wider electrical systems of which they are part. In the case of Brazil the predominant influence is the Paraná basin. The Venezuelan system linked to Guri is much smaller today, but could be augmented by ties with existing capacity and large new potential in the Guyanas and Colombia.

An example of creating "headroom" would be the interconnections being planned between Central America and Mexico on the one hand and Colombia on the other. The new tie with Mexico is small (only about 100 MW of capacity) and motivated by short-term reliability objectives. The line from Colombia is being laid under sea due to the difficulties of the Darien Isthmus and is to have about 300 MW of capacity. In between these proposed new lines is the interconnected system of Central America (Sistema de Interconexión Eléctrica para America Central - SIEPAC), one of the few attempts until now in the Americas to create a multinational grid infrastructure and accompanying market.

Why not rethink these three components in terms of the dimensions for significant exchanges between Colombia and Mexico—not only the small Central American market—and ultimately between the Northern and Southern Hemispheres? Central America is clearly a crucial link for any hemispheric grid. Fortunately, there are strong complementarities close to home—for example between the wind resources of southern Mexico and the hydro of the Isthmus.

Despite its potential benefitis, there are many obstacles to realizing this strategy. International power trade in the hemisphere is very limited overall, especially if a couple of exceptional cases (Itaipú on the Brazil/Paraguay border and Churchill Falls in Labrador) are excluded. In Central America, a pioneer in electric power integration, trade has declined significantly since the 1980s as a share of generation.

Often, the construction of generating capacity that targets a foreign market is viewed with local suspicion. One sees this now with hydro plants being planned in Peru to integrate with Brazil. There is, as well, a lack of confidence, especially in Latin America, that contracts will be respected. For example, Brazil and Chile have depended on Bolivia and Argentina, respectively, for natural gas supplies and have suffered from unilateral breaches of contract. In the U.S., as discussed earlier, there are major unresolved issues regarding transmission line planning, siting and cost allocation among states and regions.

A hemispheric grid based on renewables and natural gas builds relationships characterized by symmetry and interdependence. Commercial relationships are exchanges and not just one-way flows. As the electric power sector in the Americas takes on the new climate and security challenges of the twenty-first century, political leaders can forge new strategic and economic paths to prosperity, sustainability and resilience. A smart resilient grid spanning the Americas offers major leadership opportunities and multifaceted benefits for the hemisphere in addressing global challenges of climate mitigation, climate resilience, economic development, private capital mobilization, and energy security. A successful model could inspire international power grids between Europe and North Africa, and among the nations of South and Central Asia.

There is a pivotal role for private investment and multilateral banks, and for government partnerships along lines discussed at the Summit of the Americas in April 2009 in Port-of-Spain, and for entities such as OLADE (Organización Latinoamericana de Energía). Global and hemispheric leaders can begin to forge policy incentives to address the nexus of climate change, economic development and poverty reduction in all major forums such as the G8, the G8 plus five and the G20. There can be no more important vision on the road to and from Copenhagen.

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