



# IIRSA and Energy Connectivity in the Amazon: Can infrastructure solve energy poverty in the region?

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Senior Thesis Research

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## **INTRODUCTION**

About 85 percent (EIA 2010) of Brazil's electricity comes from hydropower plants. Recent efforts are expanding the use of hydropower throughout the country and across its Amazonian region. Major programs, both private and in the government, are financing expansion of dams, as well as other transportation infrastructure. The largest infrastructure group in South America, the Initiative For the Integration of Regional Infrastructure in South America (IIRSA), defines its purpose as an aim to strengthen transport, energy, and communications infrastructure under a regional prospective (IIRSA 2011). Thus presumptuously expanded and new infrastructure is essential to providing a better quality of life. This may be particularly in beneficial South America, where more infrastructure has the ability to provide greater connectivity throughout areas, and expand sources of energy to those without access. This study will analyze these endeavors to suggest whether expanded development achieves its goal in establishing better connectivity and access to energy.

## **A CULTURE OF ENERGY POVERTY**

Disconnection from the electricity grid makes it difficult, if not impossible to achieve many basic tasks because energy powers tools to work much easier. Refrigerators, computers, lights, stoves, phones, heaters, air conditioners comprise some of the most beneficial appliances. Furthermore, the limitations of existing energy structures relegate Amazonians to a subsistence economy, resulting in people are used to living by means of bartering goods and primary products. Even amid the rainforest's high biodiversity, and an abundance of energy and metal sources – more than 40% of the population lives below the poverty line, according to the IBGE (Gianni et al. 2011)

The United Nations Development Programme defines energy poverty as the impossibility of choosing energy services (in terms of reliability, quality, and security and environmental protection), in economic conditions that provide support for economic and social development of the families and individuals. Therefore, lack of access to reliable and efficient sources of energy perpetuates energy poverty in the region. These systems,

although not direct proponents of development, are inherently linked to ideas of improving quality of life in the Amazon (van Els et al. 2012).

Within the realm of education, energy can power a classroom to extend beyond teaching in the daylight hours, and allow for the ability to use computers and other instructive technologies (Lahl 2005). Energy can improve gender inequality for women in rural communities, who are traditionally limited to cooking with heavy polluting solid fuels. These conditions portray a culture of energy poverty, which Poverty in this sense exists throughout the Amazon (Brew-Hammond & Crole-Rees 2004). At least 607 households have been identified in the Brazilian Amazonian that lack are not attended by the electricity sector through its electricity distribution companies (van Els et al. 2012). Most of them have some form of unreliable decentralized electricity generation that is not registered or regulated in the institutional framework (van Els et al. 2012).

## EXISTING ENERGY NETWORK

Brazil has an extensive interconnected energy infrastructure, and it produces about 88,475 MW (Figure 1). Outside of the interconnected Brazilian network however, numerous isolated systems exists. Isolated systems produce energy that primarily involves burning diesel, light, and heavy oils, which tend to be more individualistic and decentralized. This is seen as cheaper alternative to the costs of transporting or distributing sources across rivers, or by other means.

These systems of energy in the Amazon, as shown in Figure 2, provide electricity that is low in quality, and sometimes not reliable. Within the interconnected system of Brazil, there is significantly less access to energy services compared to the rest of the country. Support has been more explicit in the isolated area of electric systems. In 2002, for example, Peru's Ministry of Energy and Mining introduced a Rural Electrification Law – intended to focus government attention on supplying energy to remote areas.

Several factors hinder the development of electricity distribution in the region. Notably, there is an evident disconnection from the formal economy (Figure 3). People in these communities also exhibit patterns of lower energy consumption, which would not be worth the expensive maintenance costs of travelling to service the structures. In the last decade or so, rural electrification programs have tried to remedy the energy poverty

problem throughout the Amazon. In 1994, Brazil's Ministry for Mines and Energy established Prodeem, an energy development program for states and municipalities. However a lack of management problems and proper training preparation (for new energy structures) caused it to fail. Other programs aim to provide rural areas with electricity, especially through less decentralized mechanisms, such as "Luz no Campo" and "Programa Luz para Todas" (PLPT) (Andrade et al. 2011).

Intensified expansion of transportation infrastructure attempts to make energy sources, such as dams, more connected to communities throughout the Amazon. More than 140 large dams were planned for construction in the Amazon in 2010 (Hance 2010). Roads provide a means to transport the supplies necessary to construct dams, as well as the workers to build them. Expanding distribution of energy access in a power grid or by other means also requires an integrated transportation system in rural areas (Matos et al. 2011). Government initiatives and IIRSA have prioritized the need to stress connectivity in the Amazon and throughout countries in South America.

## ANALYSIS OF IIRSA

IIRSA has identified more than 300 projects as part of its overall budget of \$34.7 billion, and 31 priority projects (at a cost of \$4.3 billion). The initiative is heavily engaged in the construction of dams, with its largest project being the Madeira Hydroelectric Complex – a bi-national dam of both the Santo Antonio and Jirau dams. Three other bi-national dams are planned: Guajar a–Mirim (Bolivia-Brazil), Garabi (Argentina-Brazil), and Corpus Christi (Argentina-Paraguay).

A careful inspection of IIRSA's strategies and motives is necessary, given its ability to expand infrastructure in the Amazon, and thus provide access to electricity for the energy poor. IIRSA frames the necessity for its work in the obvious removal of South American countries from the global network of economies (Moreira 2007). Only 12% of trading occurs within the region, compared to 42% in the EU, and 18% in East Asia (Figure 4). Other clusters of nations made gradual progress in trading amongst themselves, but South America's trading declined from 2000 to 2004. Two gaps are the cause of the dilemma, one being institutional loopholes that don't stress unions of trading, and second is a lack of proper infrastructure to facilitate better trading. Under this

premise, better trading and connectivity will stimulate more economic capital for the region and improve quality of life through other beneficial corollaries.

Since the initiative was created in 2000, its projects have had time to begin to effect changes in South America. Throughout the next 10 years IIRSA will continue its goal of reorganizing the continent's landscape based on the development of a physical infrastructure in land, aerial, and river transport, as well as expanding oil and gas pipelines, waterways, maritime and river ports, and power lines and fiber optic cables (Zibeche 2006).

South America is dissected into 10 development hubs to achieve IIRSA's mission of connectivity among them. Projects involve road infrastructure programs to link within regions (Figure 5). According to the Inter-American Development Bank (IDB), the concept of hubs attempts to fully address the economic, social, and environmental dimensions of physical integration and their interplay in the project development process. IIRSA states that its comprehensive approach places a priority on environmental protection and is responsive to the importance of people in the region (van Dijck 2008). Research on the impacts of roads and electricity supply will test IIRSA's hub concept in the Amazon. This review will reveal ways in which this nexus impacts both forest's environment and indigenous people.

Three quarters of the overall amount of investments budgeted in the initiative's 2005-2010 Consensus Agenda are related to road infrastructure (van Dijck 2008). The scales of impacts are likely to have numerous socio-ecological impacts in Amazonia, specifically IIRSA's major land-use change conversion of the forest area (Figure 6). This development is well intended, but previous studies have shown detrimental impacts of roads in this area. Roads fragment habitats and modifies stream network, which have broader consequences in isolation of certain habitats (Aldrich et al. 2012), avoidance by wildlife (Kerley 2002), and a possibility of introducing foreign diseases (Wolfe 2011). To date however, no research has explored the connection between roads in the Amazon and the necessity for building dams, and other energy sources.

## DAMS IN THE AMAZON

Construction of dams in the Amazon began in the 1970s. Initially, most plants were built with the aim of generating electricity for the Eastern Amazon region to stimulate development (Gianni et al. 2011). The potential for plentiful energy supply however, attracted energy-hungry industries to the region, such as metal manufacturing. Much has not changed since then. Dams in the Amazon sell a majority of their electricity to Brazil, so that the country can feed its extraordinary energy demands (Gianni et al. 2011).

The potential roles of hydroelectricity can be ubiquitous because it can be used for general demand of electricity, which can easily be carried far distances and converted for use. Dams can operate as isolated systems, but many are connected to a larger transmission network to distribute energy (Soito and Vasconcelos 2011).

Intensifying effects from climate change could change how well hydroelectricity is generated. More droughts and flooding from severe storms could have a negative impact on the flow of rivers, and the capability to refill groundwater reservoirs and aquifers in many countries, especially those exposed to water stress (Soito and Vasconcelos 2011). Seasonal changes in climate also ruin a dam's full potential for electricity generation.

Large-scale dams will naturally convert much of the land in the forest for its construction, evicting or flooding natural ecosystems and the rural communities of indigenous people. Expanding construction is bound to increase the number of roads across the forests. The Brazilian government approved construction of one of the largest dams in the world in early 2012, Belo Monte. The dam boasts many human development benefits, some of which are similar and link to IIRSA's mission. More research is necessary to understand how the dam will influence the region.

## **THEORY**

Multidisciplinary approaches are necessary to understand the factors of energy systems and infrastructure development. These actions involve fragmenting the forest use

for transportation infrastructure, which will benefit energy poor rural communities. Issues of economic development and trade are also factors when discussing the greater context of IIRSA's road building throughout South America. Established frameworks in environmental justice, human rights, and land-change science will help navigate the broader role of connectivity to dams, and energy generated from those dams.

A human rights perspective explains the necessity of providing access for connectivity to reliable energy sources, whether through roads or utility distribution of electricity. If rural communities in the Amazon are entitled to the electricity needed for basic tasks and health care, then it becomes imperative that governments provide rural citizens with ways to access that energy. This is because all participating countries, as pursuant to the U.N. Charter and the Universal Declaration of Human Rights, will promote universal respect for and observe human rights and fundamental freedoms (U.N. 1992).

Although great for connectivity, the roads part of more intense development have detrimental effects to the precious ecosystems of the Amazon, and change the forest cover of the region. By understanding the coupled system of land change and the human environment within land-change science (Turner et al. 2007), this study can gauge how road and dam construction impacts rural communities.

Issues of infrastructure development in South America elicit pressing issues of environmental justice (Sneddon & Fox 2010). More specifically, there has been a close relationship between the pursuit of trade in South America and environmental justice, which is recognized by various social and environmental activists in Latin America (Carruthers 2008). The perspective of environmental justice becomes necessary then to analyze the motivations behind establishing more sophisticated transportation infrastructure in South America and throughout the Amazon. Connectivity to energy sources is the major motivation this study examines, but there various reasons for building, which IIRSA and other organizations have detailed (Misoczky 2010). Examples include better trade routes and the expansion of modern communications technology (IIRSA 2010). Incorporating an environmental justice prospective can look into whether



the Amazonian population desires better transportation infrastructure, or if the interests of trade are drowning their voices.

## ACCESS TO ENERGY AS A HUMAN RIGHT

As human right, access to the hydroelectricity generated from dams in the Amazon implies that the dams as well as other electrical facilities are services universally connected without discrimination (Tully 2006).

IIRSA's role in major transportation infrastructure projects may mean connectivity becomes more established in the regions of Amazonian. A human rights orientation requires people not to be disconnected from the essential minimum quality of electricity due to financial inability (Tully 2006). While these expectations are demanding, they are realistic and resonant of recent efforts to establish access to energy as a human right (SELF 2012). Energy has long been unofficially recognized as a fundamental human right, necessary to live and perform basic tasks in the 21<sup>st</sup> century, and several nations have already recognized, or are recognizing that electricity access qualifies as a human right (Tully 2006).

In a broader sense, the paradigm of human rights has been said to have the ability to accelerate the process of liberalizing electricity markets (Tully 2006). These sorts of investments are welcome in the Amazon, especially given that isolated and integrated systems of energy lack necessary infrastructure to deliver electricity (ANEEL / SIEGEL 2007). Thus, it is also important to note that while extending access to human rights benefits poverty, it may also contest issues of land-change science because of more intense development.

## DAM CONNECTIVITY AND LAND-CHANGE SCIENCE

Roads naturally impact the ecosystems of South America, and the effects on communities are well documented in land-change science research (Perz et al. 2010). Furthermore, this transformation of the land effects traditional human-environment interactions (Misoczky 2010). While this study also recognizes specific ecological damage within the forests from roads, the scope of this discussion requires a focus on the

people to appropriately measure the effects of roads on communities and within cultural activities.

Recently, there have been major conflicts in Ecuador and Peru between indigenous organizations and the national state surrounding construction changes to the land, which has displaced indigenous people or further altered their cultures in negative ways (Misoczky 2010).

IIRSA's proposed Madeira River Complex (Madre de Dios-Beni-Mamoré-Itenez-Madeira) in the tri-border region of Peru, Bolivia, and Brazil provides an example of the complexity surrounding increased development of dams and other projects. The complex includes the construction of four hydroelectric dams, which would produce about 6,450 megawatts of electricity (Misoczky 2010). The project has a potential to boost soybean transport by 500 percent, but the expansion of farming has been a major cause for deforestation in the Amazon (Morton 2006).

Research relating to land-change science is plentiful, but few studies focus on the nexus of connectivity and energy sources. Land-change science has traditionally focused on examining land management practices on the structure and function of ecosystems and landscapes (Turner & Robbins 2008). This study uses the understood recognition within land-change science that dams and infrastructure development are drivers of land cover change.

## INFRASTRUCTURE FOR ECONOMIC DEVELOPMENT

Issues of environmental justice are an important part of the conversation of land-change science and human rights within energy connectivity. Environmental justice can provide guidelines for how development should be approached ethically. Competing views over the nature of the relationship between sustainable development and free trade persist, which reflects broad ideological divisions amongst people (Carruthers 2008). Therefore, environmental justice can highlight overpowering interests of major organizations, such as the World Commission on Dams (WCD), the World Bank, and IIRSA (Sneddon & Fox 2010).

Using this perspective takes two facets in this study because justice issues relate to the inaccessibility of energy, and also whether alternative exists to building major dam

complexes for electricity. However the justice outlook also reveals a conflict within the human rights perspective, because it posits energy as a need for rural communities, whereas the environmental justice argues that this need may be forced on the people. Although conflicting, conclusions can be made about the state of connectivity and the need for energy when analyze the rhetoric of environmental justice in this battle is important to making conclusions about the state of connectivity and energy need.

## **METHODOLOGY**

Within the Initiative for the Integration of Regional Infrastructure In South America (IIRSA), major investments and planning in infrastructure may have the potential to ameliorate the energy crisis for rural communities in the Amazon. As it stands, many communities produce electricity from dirty and inefficient diesel-powered generators, which can be part of small local grids or stand-alone systems for the local communities (Gomez and Silveira 2010). Other programs led by NGOs and individual states are working toward the same goal of providing electricity to rural communities (Andrade et al. 2011), but not always through means of expanding infrastructure.

As part of IIRSA's three areas of integration, transportation and communications are fused to the linkage of energy systems throughout South America. Accordingly, over three quarters of the overall amount of investments as budgeted in the IIRSA Consensus Agenda 2005-2010 are related to road infrastructure (van Dijck 2008). However, this research design will examine whether IIRSA will actually solve energy poverty, and at the socio-environmental costs associated with IIRSA projects implementation.

## **RESEARCH DESIGN**

New transportation and energy infrastructure can facilitate the delivery of energy to the isolated regions Amazonia. It should be noted that while there are other private and government programs in place to advance infrastructure development throughout Amazonia, this project focuses primarily on the efforts of IIRSA.

The future IIRSA projects will be considered because of their major potential to impact the availability of access to reliable energy. The projects include two hydroelectric plants – the Belo Monte dam and the Madeira complex. There is also the InterOceanic highway (*Interoceánica Sur*), a project that will create 2,603 more kilometers of roads (Bank Information Center 2005). The most recent construction is located near the southwest portion of the forest on the Peru-Brazil border (Figure 7).

Furthermore, results from a hypothetical model and empirical study will suggest what kinds of changes in development, productivity, and employment are expected with intensified expansion of the Brazilian hydroelectricity plants. The spatial engineering model deduces hydropower dam placement for Brazil with hypothetical maps that show how the electrical grid would have evolved. It uses observations from 1960 to 2000 to track the evolution during this period, had infrastructure investments been based solely on geologic cost considerations and ignoring demand-side concerns (Lipscomb et al. 2011). This model is valuable because it acknowledges that Brazil relies nearly exclusively on hydropower to meet its electricity needs, and the cost of hydropower dam construction depends on geologic factors (mainly water flow and river gradient). Additionally, its results make suggestions about the human impacts expected with the electrification of rural areas. Specifically it measures aspects of the human development index (HDI) – a measuring achievement established by the United Nations Development Programme to track three dimensions of development: (1) a long and healthy life, (2) knowledge and a (3) decent standard of living [income] (UNDP 2011).

Following this model of hypothetical dam allotment is an empirical study conducted by economist Dr. Taryn Dinkelman. Dinkelman measured the effects of rural electrification within the KwaZulu-Natal (KZN) province of South Africa following the post-apartheid era. Around 1993 one year before the end of apartheid, about two-thirds of South Africans had access to electricity. Dinkelman focuses on changes in women's employment and home efficiency due to electrification of rural homes (Dinkelman 2011). These observations are applicable to similar rural communities of the Brazilian Amazon, which remain disconnected from the country's integrated transmission system.

The hypothetical dam allotment model and Dinkelman's research provide evidence for reasonable predictions about the future implications of IIRSA's approach to intensifying dams and electrification within Amazonia. Most of the research, and the subsequent analysis will focus on the Brazilian Amazon because Brazilian energy systems are better understood compared to other Amazonian countries.

This research design is practical in that it looks at the largest program place to address energy and connectivity concerns in Amazonia. It will be important to examine where, spatially throughout the region, IIRSA projects are focused, and to what benefit those locations provide. However, some factors will also affect the results of electrification as they are observed. For example, Dinkelman notes, "I cannot rule out a labor demand channel for this employment effect, it is unlikely that electricity-driven increases in labor demand explain all of this response" (Dinkelman 2011). Similarly within the Lipscomb hypothetical dam allotment model, when HDI components are observed, it is not reasonable to assume that all correlations are solely based on exposure to electricity access.

## CURRENT STATE OF IIRSA PLANNING AND STRATEGY

There are currently (as of April 2012) 38 energy IIRSA projects underway in Amazonian countries, 10 in Brazil, six in Peru and Colombia, 10 in Ecuador, five in Bolivia, and seven in Venezuela (IIRSA 2012). The projects include energy interconnection (through pipelines and gasification), electrification, and extending hydroelectricity projects (particularly in Ecuador). Furthermore, dams are planned for construction throughout the Amazonia region, in Peru, Ecuador, Venezuela, Brazil, and Bolivia – but not all of these projects have been led by IIRSA (Figure 8). Many of the planned dams are in near proximity to IIRSA's planned road infrastructure, the most notable project being the InterOceanic highway, which links Peru and Brazil (Figure 9). IIRSA's contribution has been said to produce or improve the cross border linkages between already existing national road systems (van Dijck 2008). Therefore, significant efficiency gains may be realized with relatively small investments (van Dijck 2008).

According to the IIRSA website, approximately 71.4% of the 531 projects in the IIRSA portfolio has made significant progress. In September 2011, mobilized investment

of these projects amounted to the sum of 98,696.6 million (measured in U.S. dollars). About 11.9% of the projects (10,408.9 million) have been completed, 29.9% (52,046.6 million) is under implementation, and 29.6% (36241.1 million dollars) is in pre-foreclosure (IIRSA 2011).

As of 2005, IIRSA has been cognizant of the need to analyze the adverse socio-environmental impacts that may result from its projects. To address the problem it established a planning methodology called the Strategic Environmental Assessment (SEA) (IIRSA 2005). IIRSA defines SEA under a broader, Environmental and Social Assessment Strategic Assessment Approach – which aims to “contribute to sustainable infrastructure planning through the implementation of a consolidated tool that allows, on the scale of work area of influence of the project groups of IIRSA” (IIRSA 2005).

There is also a similar methodology that was put into practice in July 2010 to identify specific opportunities for productive development, and the elimination of bottlenecks in logistics flows that develop in the areas of influence of the groups (IIRSA 2010). IIRSA calls this methodology the “Analysis of Potential Production Integration and Logistics Services Development Project Value Added – IPrLg.” IPrLg has four steps – (1) define and characterize the area of influence, (2) prepare and implement analysis of fieldwork, (3) assess impact of projects/actions on development of the area, (4) make recommendations for plan of action (IIRSA–IPrLg).

These two IIRSA strategies provide a cautionary approach to identifying actions necessary to promote the positive effects of projects, and minimize the negative environmental and socio-cultural impacts (IIRSA 2005). However, only a few SEAs related to corridors in the IIRSA agenda are known. Critics claim there is too little systemic knowledge about the appropriate ways to for studies to examine such large-scale corridors (van Dijck 2008). Furthermore, SEAs are seen as merely an obligatory consideration in order to receive funding from the IDB (van Dijck 2008).

## **HYPOTHETICAL MODEL OF BRAZILIAN HYDROELECTRICITY**

Aside from its energy connection for the region, dam construction on the Amazon Basin can have worldwide impacts. The basin plays a fundamental role in the climatic dynamics and hydrological cycle of the planet, representing approximately 16% of the

world's freshwater stocks (Soito & Vasconcelos 2011). Thus, Amazon dams are criticized because of their vulnerabilities to climate change. Droughts and natural phenomena have impacted the hydroelectricity potential of some plants, creating the tendency to create reservoirs with smaller capacities (Soito & Vasconcelos 2011). Smaller reservoirs will leave the region more vulnerable in terms of hydroelectric generation when there are years of water deficiency. Larger dams with bigger reservoirs are then more useful because the large levels of flow ensure that the river does not run dry over parts of the year. Large changes in elevation allow for higher pressure on the turbines with relatively smaller amounts of water (Lipscomb et al. 2011), but most of high-elevation regions are outside of the Amazon.

When evaluating a new location for a dam, engineers consider available head, flow duration, and daily peaking operation to determine the generation cost (Lipscomb et al. 2011). The available head refers to the amount of power that will be produced, and generating a given amount of power is cheaper in locations where the amount is larger. Daily peaking operation is the amount of the flow duration occurring during peak demand hours. Engineers also consider the distance to the existing transmission network (Figure 10) because developing new transmission lines can be expensive, and comprise a large component of the overall budget for the network (Lipscomb et al. 2011).

A model developed on the hypothetical construction of dams and its electricity grid provides relevant statistics on how rural electrification can impact development, and living conditions. The model produces a simulated time series of infrastructure development, based on Brazil's a 40-year history of hydropower expansion (Lipscomb et al. 2011). The modeled electricity grid evolves over time to minimize the engineering costs of dam and transmission line construction, ignoring where people and businesses are located (Lipscomb et al. 2011).

Figure 11 shows the 240 hydroelectric plants predicted based on the 1960s geologic cost considerations (Lipscomb et al. 2011). Red dots on the figure indicate the predicted dams, and yellow dots show the actual plant locations. The color background shows the elevation of the landscape (dark colors are closer to sea level), and blue lines show river locations.

After the allotting of dams, researchers choose to use two types of regression to modeling the recorded effects of electricity. They believe the Ordinary Least Squares regression may have bias because it reports on the development effects of the current (actual) distribution of hydropower dams and sub-stations in Brazil (Lipscomb et al. 2011). This is problematic because many of the existing energy structures may have been placed in rural areas for political and other considerations (Lipscomb et al. 2011). Thus, the instrumental variable (IV) regression does a more thorough job at reporting the efficiencies from electricity and eliminating political bias of the OLS tests. IV estimates were used to observe the returns of the hypothetical electrification model, in which dams were placed solely based on land factors, and where construction costs would be lowest.

The data results from the model are given in tables 1a and 1b. As shown in table 1b, both the IV (instrumental variable) and OLS (ordinary least squares) regressions show a positive relationship between lagged electricity infrastructure (rural electrification) and HDI components – income and education, but not in health. Again, the IV regressions show a stronger relationship between the HDI components and poverty measures. N represents the sample size in the study. The mean of the dependence variable is calculated given the UN’s formula for determining HDI. For example, HDI Longevity at a mean 0.569 according to the formula:  $([\text{Life expectancy at birthday}] - 25) / 60$  – so the mean in this case would be an age of about 60. The remaining means are insignificant given the focus of this study.

Table 1a shows the effects of development effects of electricity over 1960-2000, with the HDI for each county and corresponding housing values (collected from census question data) as the dependent variables. The data shows about 60% of households for every county were connected to the electricity network, which was determined by the Brazilian Census over this span. Measures of demand, measures of development, and HDI components are also given in the table.

## POST-APARTHEID SOUTH AFRICA: ELECTRIFICATION AND EMPLOYMENT

A South African initiative in 1995 called the National Electrification Programme (NEP) sought to prioritize rural electrification (Dinkelman 2011). An electric utility



electrified over 470,000 households in the KZN province between 1993 and 2003. Households were given a default supply of 2.5 Amps, enough to power a television, radio, two lights, and several kitchen appliances (Dinkelman 2011). Dinkelman compared areas treated with electrification to those without access (control areas) – using statistics to find strong correlations between electrification and employment.

Large numbers of men and women entered the labor market during this period (Banerjee et al. 2006) and on average, female labor participation increased by 10 percent with larger increases in rural areas (Dinkelman 2011). A 28 percent decrease in wood use suggested rural communities that had become less reliant on traditionally cooking methods, and instead using electricity (Dinkelman 2011). Furthermore, treated areas were shown to have higher population growth – 6 percent per year, compared to control areas – 3 percent per year (Dinkelman 2011).

Dinkelman also made relevant conclusions about how communities in the KZN province were selected year (Dinkelman 2011). This can suggest ideas about how electrification of rural areas is more broadly considered rather than having a hypothetical model allocate dams. There was evidence suggesting that poorer areas with more female-headed households were less likely to be treated, but richer areas with more white and Indian adults were also less likely to be treated year (Dinkelman 2011). Instead, treatment was generally assigned to poorer areas because of a strong correlation in community poverty rates and the extent of electrification year (Dinkelman 2011). This was the core mission of the NEP program. Additionally, areas with flatter land gradient were heavily selected for electrification year (Dinkelman 2011). Dinkelman attributes this to the main factors that reduce the cost of distribution lines: proximity to existing power lines, higher density settlements, and land gradient. The less of an incline the land has, the fewer hills and valleys to cross – therefore it will be cheaper to lay power lines and build transmission poles (Eskom 1996 ; West et al. 1997).

## ANALYSIS

The theoretical model discussed earlier provides the evidence to make meaningful evaluations about the reality of energy poverty in the Amazonia region. However, the results primarily focus on the electrification effects and its results on the HDI framework. Other perspectives of development improvement need to be considered outside this because the U.N.'s measurement has been scrutinized due to the tendency to exclude sustainability, as well as the political voice of the poor. For example, the HDI value of Brazil may be “impressive,” but sustainability is not observed since the overexploitation of natural resources is not considered (Sagar & Najam 1998). Therefore, HDI cannot solely be a suitable indicator for planning electrification and grid connectivity because no innovation (providing access to rural areas) is necessary to improve its value.

The hypothetical dam model failed to allocate any dams in the central Amazonian region, a region that can tremendously benefit from the effects of electricity. The model only considers geographic and cost factors for dams, but the allocation mostly congruent with current human decisions. Analysis of the figure 11 suggests that dams are not desired in this region because of lower elevations. Given that water flow is one of the factors engineers consider when making a dam, reliable hydropower is difficult to produce in such conditions.

This explanation elicits broader conclusions about population density in Brazil and other areas throughout the Amazon. Access to energy is more prevalent in areas where people are more density populated. In Brazil's case, the around the southeastern part of the country is heavily populated. Maps in figures 12a and 12b show more cities along the coast and at higher elevations. Coastal cities like Rio de Janeiro, Recife, and Salvador are situated on flatter land, but they are surrounding by higher landscapes. Nearly all of the land in the Amazonian region is flat, and not in proximity to higher lands.

Rural areas in the Brazil Amazonian do not need to be excluded from the benefits of electricity. Although expensive, longer transmissions lines can be built to extend access to the electricity grid. IIRSA's intensified road development also likens the

possibility of better access, however this has not been the case. Imagery from Google Earth shows a distinct lack of electricity at night in the Amazonia portion of Brazil (Figures 13a and 13b). This fact calls for greater scrutiny of IIRSA's implementation, or lack thereof, in energy poor regions.

Some natural resource extraction projects (such as mining and agriculture) are criticized as not beneficial for the poorer people, although it is thought that these expansions will provide employment opportunity and wealth (Bebbington 2009). According to geographer Anthony Bebbington, only the national and international elites believe that accessibility has an important role in the development of Latin America (Bebbington 2009). This critique on expansion is also applicable to the development of energy sources and transportation infrastructure. International banks, Bebbington suggests, are facilitating a new round of infrastructural investment that lends support to the extractive economy with roads, waterways, energy grids, ports and airports (Bebbington 2009).

Other research has determined that there are specific winners and losers, in terms of the benefits and damages that the implementation of IIRSA will generate. For example, Brazil is one of the most industrialized countries in the world, and Bolivia is South America's poorest country. Five IIRSA highway projects (including the InterOceanic Highway) will cross through Bolivia, fracturing its national territory in order to connect trade routes between Peru, Chile, and Brazil. The Brazilian Development Bank (BNDES) is one of the principal financiers of IIRSA (Zibechi 2006). These highways do not galvanize Bolivia's economy, but instead serve to link countries that already have a strong economic presence.

The aforementioned approaches of IIRSA, regarding socio-environmental costs and influence (SEA and IPrLg), were meant to remediate these types of concerns. However, socio-environmental costs and favoritism toward the rich continue. Thus, although acknowledged by IIRSA, these methodologies have not been properly followed.

This evidence suggests IIRSA appears to follow a model for its projects that only favors areas of high population and strong economic presence. It does not seek to innovate by providing to rural locations, the potential beneficial impacts that come from

better road infrastructure and energy systems. The majority of its infrastructure links other major cities and while this is ideal for trade, it only connects the major players of the system. The crisis of energy poverty cannot be solved under this approach. Furthermore, there are multiple reports of violence by the Brazilian government against people who denounce development efforts at major protests (Mendonça 2008). In this sense, infrastructure becomes a tool for political manipulation rather than a benefit for human development. However, this does not ultimately rule out the possibility that electrification can be planned with good motivations and at the best efficiencies for the poor – as evidenced with Dinkelman’s observation of NEP, and the hypothetical model of dam allotment (only considering geographic features).

However, rural communities in the Amazonian are not destined to live without electricity access forever. Multiple studies suggests decentralized energy plans are necessary for rural electrification, instead of waiting for connectivity to large electric grids (van Els et al. 2012 ; Gomez and Silveira 2010). Decentralized programs require more input from the people, which is better because this in this model because citizens are considered part of the electrification process, rather than ultimate beneficiaries of the program (Gomez and Silveira 2010). This can lead to the recognition of needs and actual demand, improving the dimension of the system for successful implementation (Gomez and Silveira 2010). It remains unclear how, and at what possible scale, will Amazonian communities organize to create this decentralized system without guidance from governments.

## **CONCLUSION**

This overview of the energy poverty crisis and the forces attempting to alleviate it through infrastructure development has largely ignored the detrimental impacts of land change to the Amazonian region. The current analysis suggests that many rural communities may have to depend on decentralized methods of energy production, and this may actually be more beneficial for the forest, compared to the effects of building large-scale energy systems. Given this evidence, the assumption of better infrastructure and energy access is necessary to achieving a greater standard of living in rural areas is

somewhat debunked. It should be acknowledged that this perspective, although it has good intentions in mind – is often not perspective of a person within a rural area and without access to electricity. In the broader discussion of energy poverty, and motivations to extend infrastructure, groups should be cautious not to impose this view upon others. Forcing this motivation has a particular conflict inherent within the environmental justice scope of this study.

There must be reasonable alternatives to large-scale construction, should energy access become a human right because these structures have a history of displacing local communities and destroyed the land. Small-scale options like micro hydropower and renewables (solar and wind) may be options, and they can be integrated into decentralized transmission systems.

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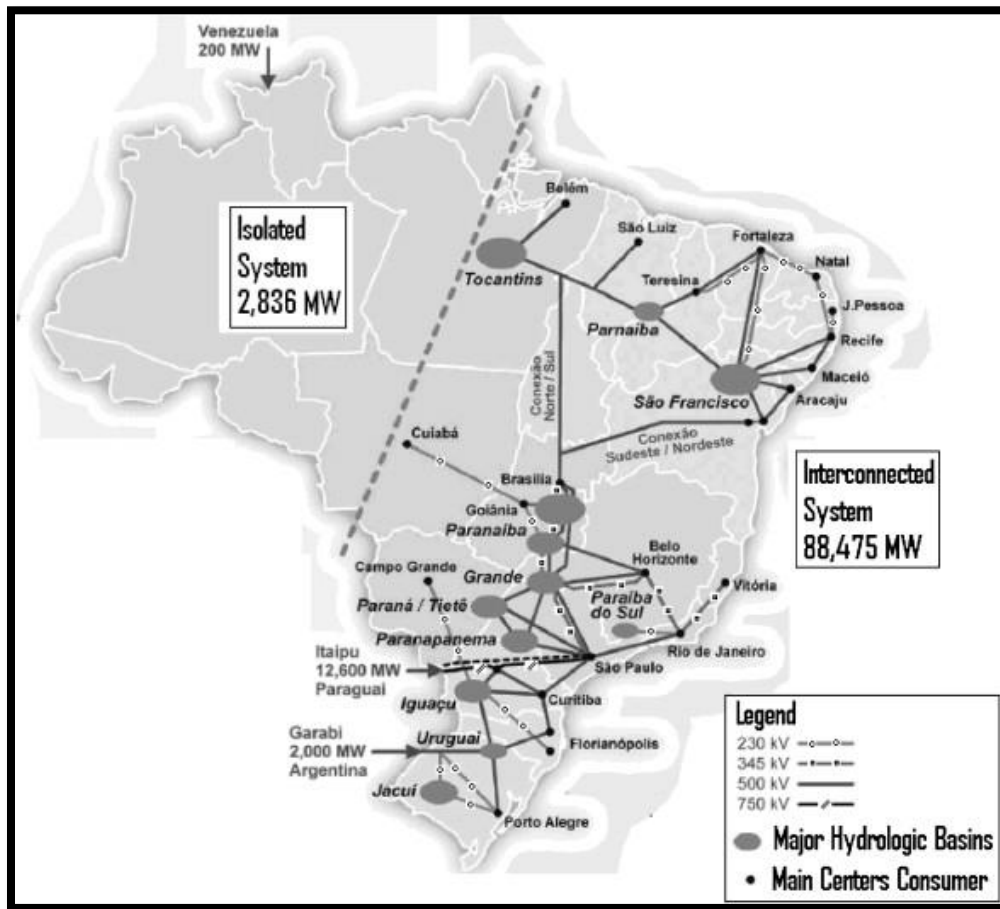
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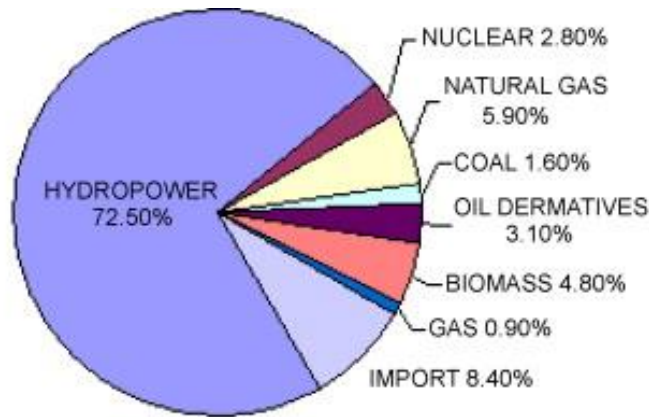
## DIAGRAMS

FIGURE 1. The Brazilian energy system (interconnected and isolated).



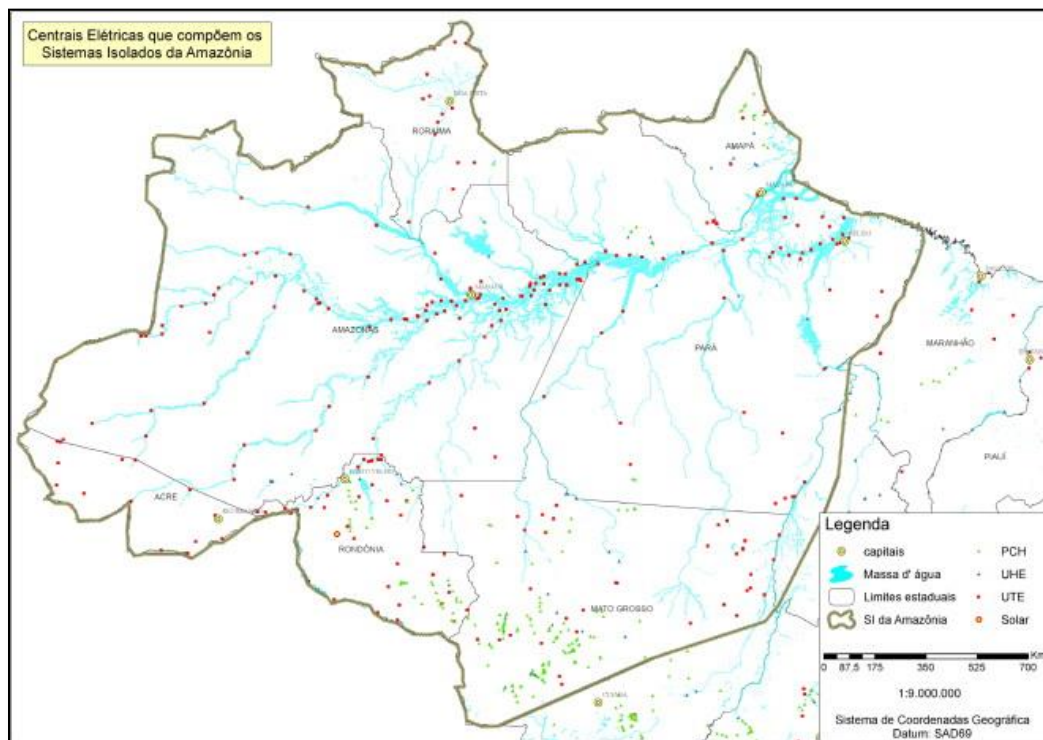
Source: Brazilian Energy Atlas

FIGURE 2. Matrix of energy supply – Brazil – 2008.



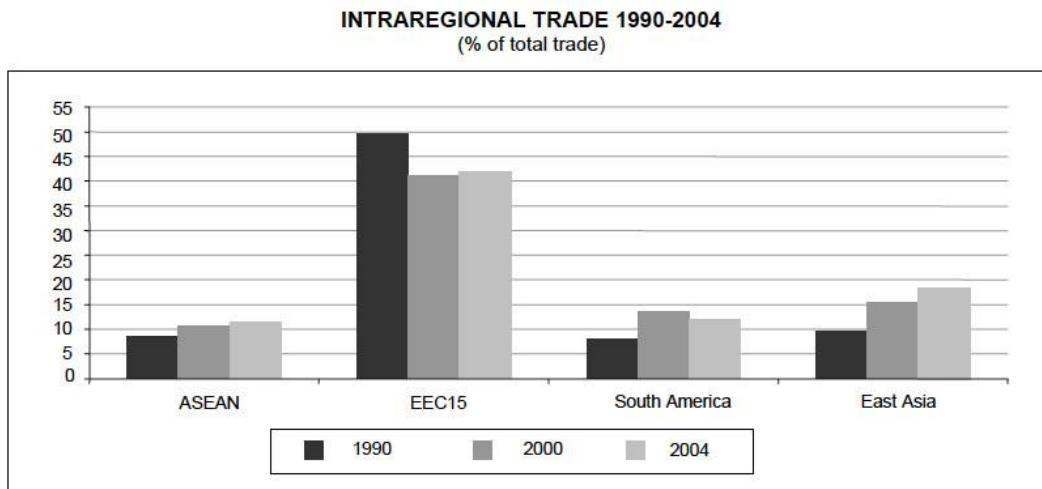
Source: MME, *Resenha Energética – Exercício de 2008 – Preliminar – Março 2009*

FIGURE 3. Electricity systems that make up the Isolated Systems.



PCH = Productive Uses of Small-Scale Hydropower (“Usos Productivos de la Hidroelectricidad en Pequeña Escala”), UHE = hydroelectric plants (“Usinas Hidroelectricas”) and UTE = heavy-oil fuel plants. *Source: ANEEL/SIEGEL.*

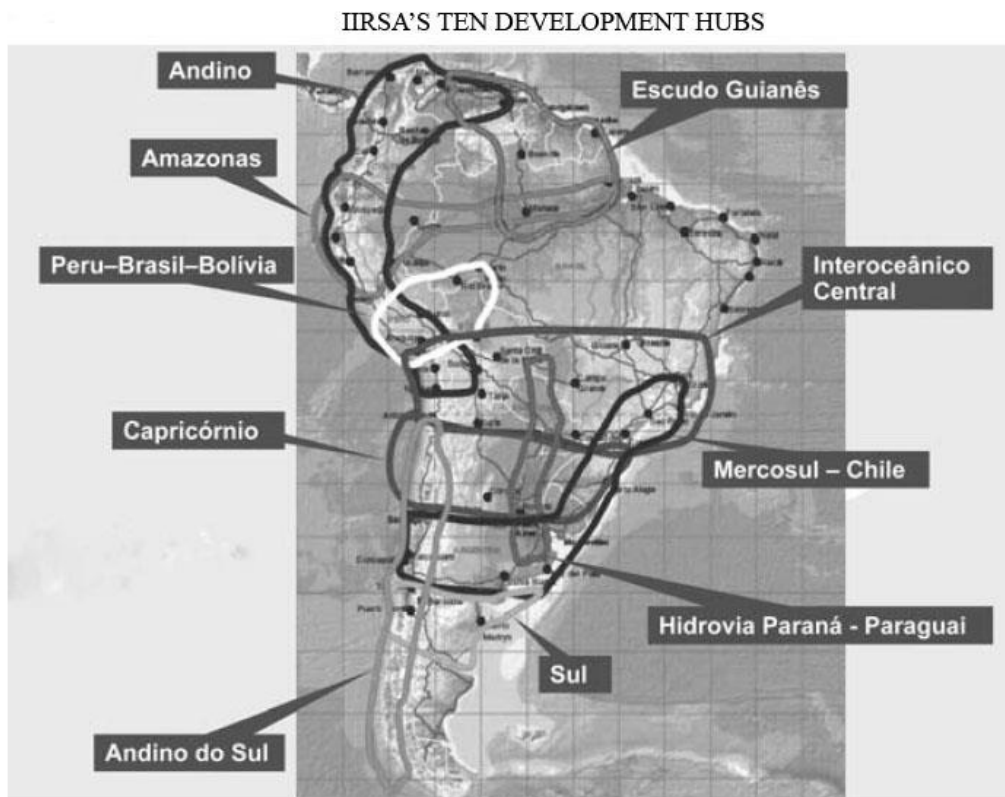
FIGURE 4. Intraregional Trade between 1990-2004



Note: East Asia includes South Korea, Taiwan, Japan and China.

Source: Commodity Trade Statistics (COMTRADE).

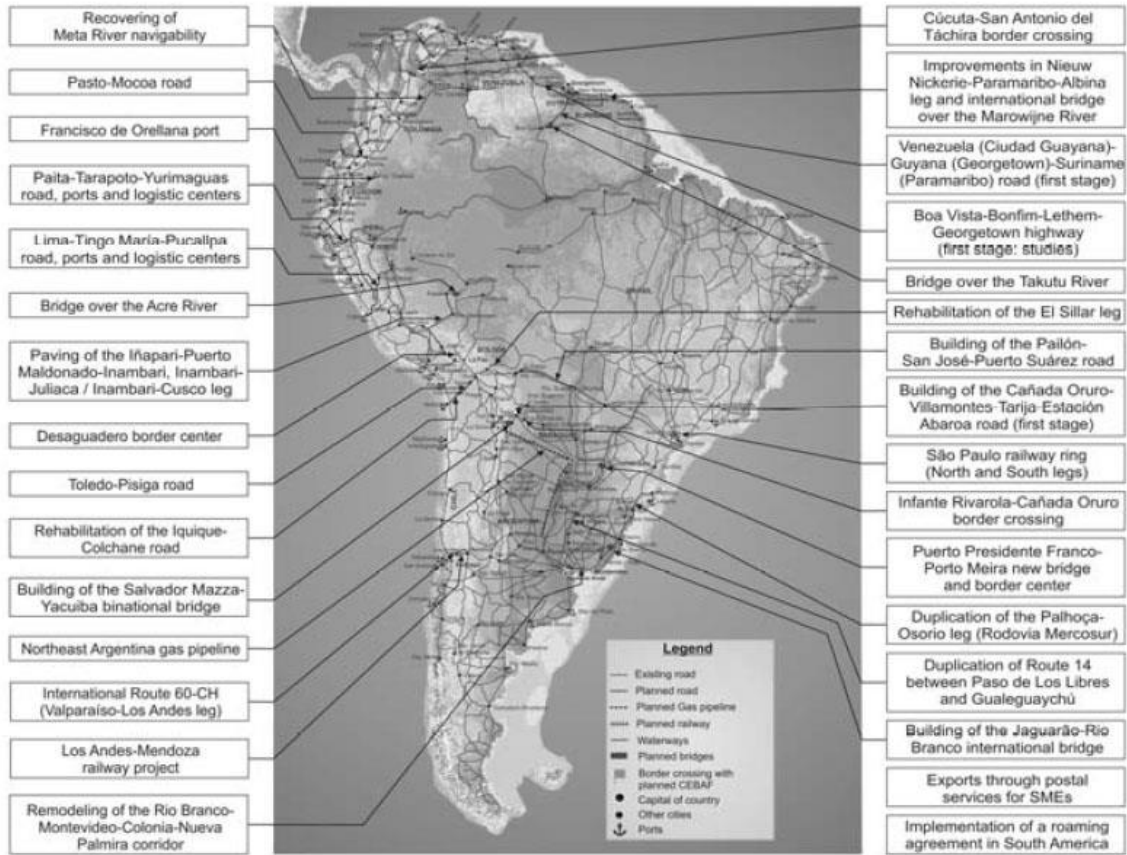
FIGURE 5. The Development Hubs of South America



Source: [www.iirsa.org](http://www.iirsa.org), 2007

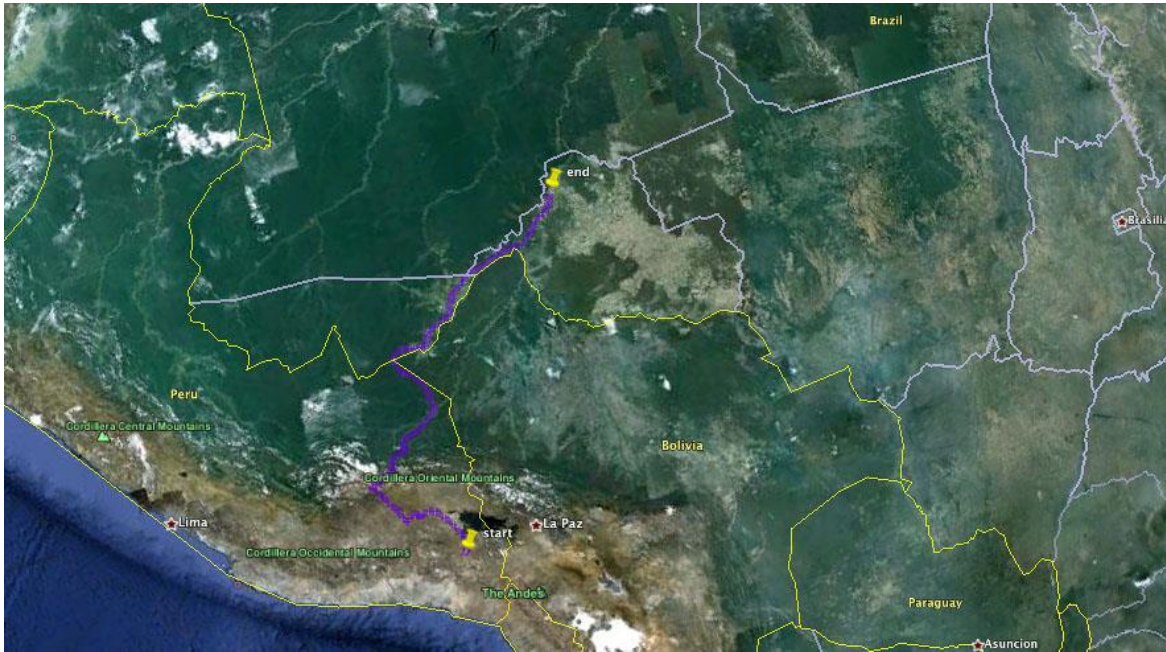
FIGURE 6.

IIRSA - IMPLEMENTATION AGENDA BASED ON CONSENSUS 2005-2010



Source: IIRSA 2005.

FIGURE 7.



Purple line shows route of recent InterOceanic highway construction. (Source: Google Earth)

FIGURE 8.



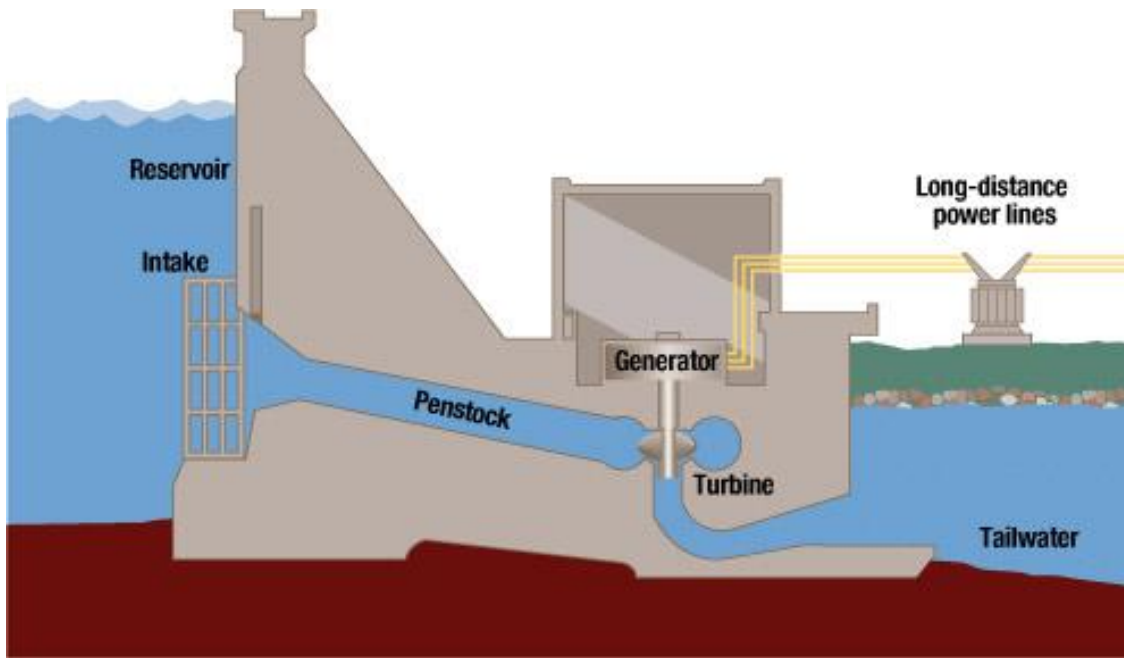
Dams planned, operating, and in construction in Amazonia. (Source: <http://www.dams-info.org/>)

FIGURE 9.



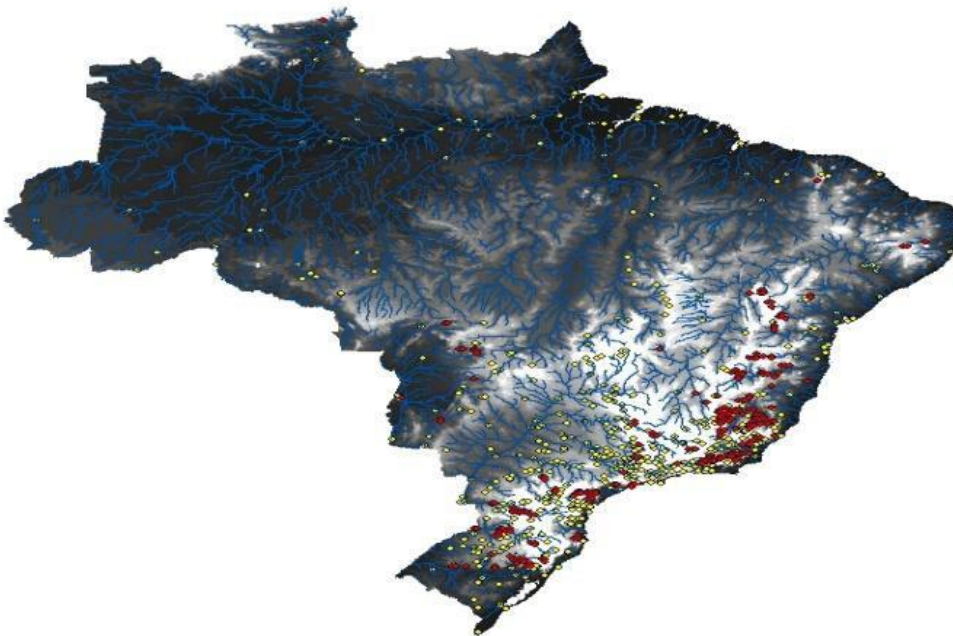
Source: *L.A. Times*

FIGURE 10. Functioning of a hydroelectric dam.



*Source: Tennessee Valley Authority 2010*

FIGURE 11.



Proposed dam sites in Brazil from hypothetical model (*Source: Limpscomb et al. 2011*).



TABLE 1A. Summary Statistics of HDI and Housing Values

Variable		Obs	Mean	Std. Dev.	Min	Max
Electricity	An indicator variable for the presence of electricity infrastructure within a county boundary or within 50km of the centroid of a county which has electricity infrastructure. (From primary data generated from inventories of generation plants and transmission substations by Brazilian Electricity companies).	8730	0.721	0.421	0	1
Percent Electrified	Percent of total households in the county which are connected to the electricity network. (From the Brazilian Census)	8730	0.602	0.328	0	1
Modeled Electricity Instrument	Percent of the evenly spaced grid points which are allocated electricity within a county within a given decade	8730	0.592	0.472	0	1
<b>Measures of Demand</b>						
Population density	Number of people per square kilometer	8730	62.709	292.186	0.041	10097.86
GDP per capita	thousands of R\$ per person, in constant 2000 R\$	8728	3.765	6.057	0.084	252.13
Industrial GDP per capita	Estimated value added in the industrial sector, in thousands of R\$, in constant 2000 R\$	8730	1.196	3.708	0.002	112.18
<b>Summary Measures of Development</b>						
Average value of housing	Thousands of R\$ per household, calculated as the present value of monthly rent in perpetuity, or hedonically estimated values for owned housing.	8730	13.048	8.370	0.428	62.533
Human Development Index*	Index from 0 to 1, the mean of the longevity, education, and income component HDI indices.	8730	0.557	0.169	0.155	0.886
<b>HDI Components</b>						
HDI Longevity	Calculated according to the formula: $(Lifeexpectancyatbirth - 25)/60$	8730	0.569	0.117	0.170	0.881
HDI Salaries	Calculated according to the UNDP formula: $(Log(PPPAdjustedGDPpercapita) - 2)/2.60206$ base changed in 1991, so a ratio of old to new 1991 observations was used to adjust the observations for the year 2000.	8730	0.472	0.287	0.013	1.135
HDI Education	Calculated according to the formula: $(2 * AdultLiteracyRate + GrossEnrollmentRate)/3$ . Where Gross Enrollment Rate is the number of students enrolled in primary, secondary, or tertiary education, regardless of age, as a percentage of the number of people of official school age.	8730	0.515	0.154	0.075	0.877
Gross Monthly Income per capita	Gross monthly income from all sources including formal and informal employment, pensions, transfers, and rents. In thousands of R\$.	8730	0.114	0.085	0.004	0.787
Poverty	Head count ratio: Percentage of people with family income below 50% of the minimum wage	8730	60.469	24.920	3.81	99.88

All R\$ values are given in constant 2000 R\$. \*The calculation of the HDI variables changed in 1991—the HDI variables have been made comparable across decades by multiplying 2000 values by the ratio of old to new 1991 values. The HDI component indices are of the general format: (observed value-minimum value)/(maximum value-minimum value).

Source: Lipscomb et al. 2011

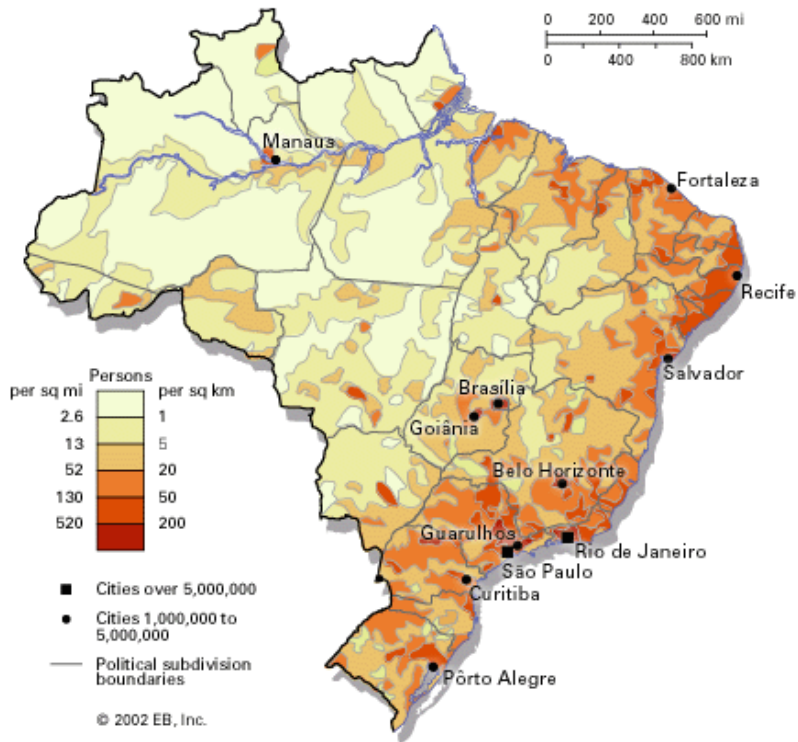
TABLE 1B. Dependent Variables: HDI components and Other Poverty Measures

Dependent variable: Human Development Index Components and other Poverty Measures										
	HDI: Longevity		HDI: Income		HDI: Education		Gross Income pc		Poverty	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Lagged Elect. Infrastructure	-0.004 (0.01)	-0.010 (0.04)	-0.045* (0.02)	0.274** (0.11)	0.029*** (0.01)	0.146*** (0.04)	-0.009 (0.01)	0.073** (0.03)	-1.293 (2.01)	-34.829*** (8.78)
N	8730	8730	8730	8730	8730	8730	8730	8730	8730	8730
Mean of dep var	0.569	0.569	0.472	0.472	0.515	0.515	0.114	0.114	60.469	60.469

Dependent Variables are the component indices of the HDI index and other poverty measures. Year Dummies included in all regressions. All regressions have county size weights and year dummies, errors are clustered by county.

Source: Lipscomb et al. 2011

FIGURE 12A.



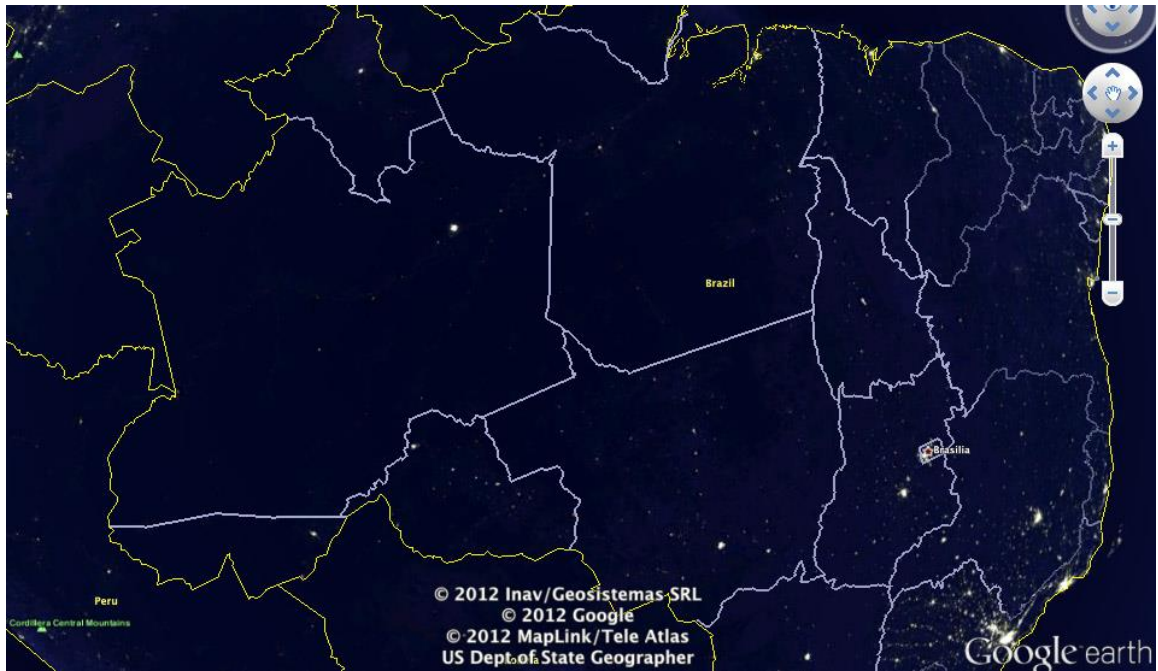
Population map of Brazil [compare with Figure 7b] (Source: *Encyclopedia Britannica* 2002)

FIGURE 12B.



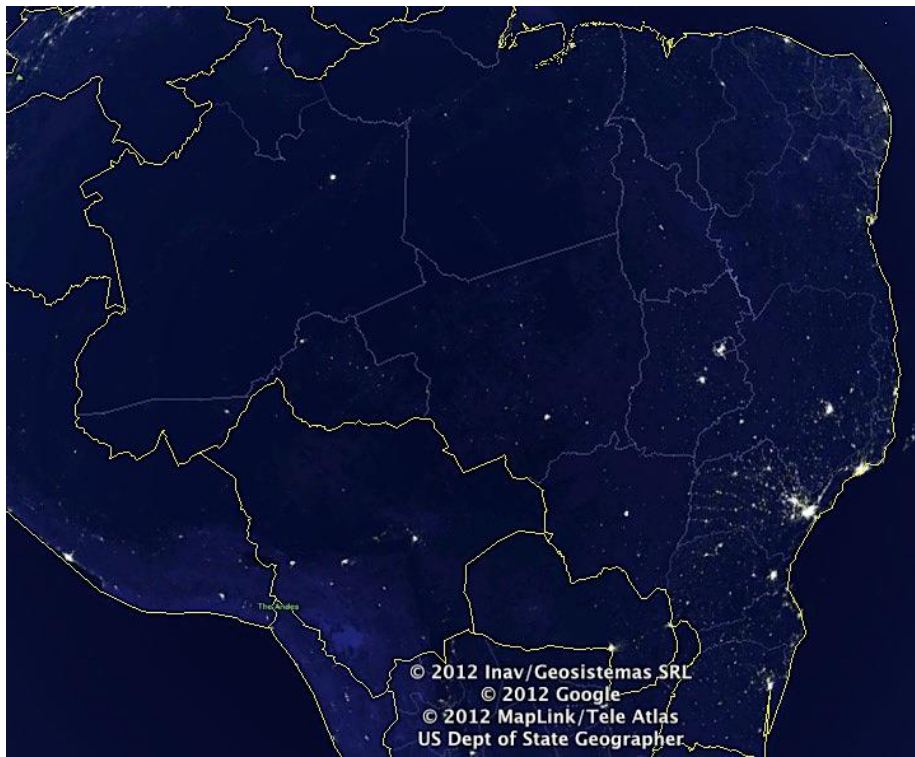
Elevation map of Brazil (Source: *Wikipedia*).

FIGURE 13A.



Night imagery over Brazil with Amazonia region center (Source: Google Earth / NASA Earth Lights).

FIGURE 13B.



Night imagery over the Amazon (Source: Google Earth / NASA Earth Lights).