Grand Designs: Assessing the African Energy Security Implications of the Grand Inga Dam

Nathaniel Green, Benjamin K. Sovacool, and Kathleen Hancock

Abstract: In May 2013 the Democratic Republic of the Congo (DRC) announced that construction of the world's largest hydroelectric project will begin in October 2015. Upon completion, according to the DRC, the project will bring electricity to half the African continent. With funding from South Africa, the World Bank, the African Development Bank, and others, the U.S.$80 billion Grand Inga Hydroelectric project will construct a 44,000 megawatt (MW) dam anchored to a new transmission network able to distribute electricity to all four of sub-Saharan Africa's regional electricity power pools. While the dam promises to bring electricity to many millions of Africans who currently lack access, the project also poses risks to the citizens and environment of the DRC. To assess the complex tradeoffs, this article evaluates four dimensions that are part of an energy security framework: availability, affordability, efficiency, and stewardship. In doing so, it explores some of the governance challenges that arise in managing such a "mega-project." The analysis also reveals tensions between national and regional energy security. It presents evidence that, under certain assumptions, the pursuit of enhanced security at the regional

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level may result in a net security loss for the DRC. Finally, the article provides suggestions for enhancing the decision-making process of those designing related national and regional energy strategies.

Résumé: En mai 2013, la République démocratique du Congo (RDC) a annoncé que la construction du plus grand projet hydroélectrique du monde débutera en octobre 2015. Une fois terminé, selon la RDC, le projet apportera de l'électricité à la moitié du continent africain. Grâce au financement de l'Afrique du Sud, la Banque mondiale, la Banque africaine de développement et d'autres, le projet hydroélectrique du Grand Inga, évalué à 80 milliards de dollars, construira un barrage qui produira 44000 mégawatts (MW) et qui sera ancré à un nouveau réseau en mesure de distribuer de l'électricité aux quatre pôles régionaux électriques de l'Afrique subsaharienne. Bien que le barrage promette d'apporter de l'électricité à des millions d'Africains qui n'y ont pas actuellement accès, le projet pose aussi des risques pour les citoyens de la RDC et pour l'environnement. Pour évaluer les compromis complexes en jeu, nous analysons quatre dimensions du projet qui font partie du cadre de la sécurité énergétique: disponibilité, accessibilité, efficacité, et intendance. Ce faisant, nous explorons aussi quelques uns des défis de gouvernance qui se posent dans la gestion d'un tel "méga projet." Notre analyse révèle également des tensions entre la sécurité énergétique nationale et régionale. Nous constatons que, sous certaines hypothèses, la poursuite de l'amélioration de la sécurité énergétique au niveau régional pourrait aboutir à une perte nette de sécurité au niveau national pour la RDC. En conclusion, l'article offre des suggestions à prendre en compte dans le processus de prise de décision de ceux qui conçoivent les stratégies énergétiques connexes au niveau national et régional.

Keywords: Hydroelectricity; energy and development; energy security; Democratic Republic of Congo

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Introduction

In the Katanga Province in the southeastern corner of the Democratic Republic of the Congo (DRC), an unusual sight rises from the forest: the Inga-Kolwezi High Voltage Direct Current (HVDC) transmission line. This is a roughly U.S.$900 million, ±500 kilovolt (kV) electricity transmission corridor traversing some 1,774 kilometers from Bas-Congo Province in the far west of the country, the longest such line in the world when it was built in 1982 (WEC 2010). The HVDC line transmits electricity from the two existing hydropower installations at the Inga Falls near the mouth of the Congo River to the copper and cobalt mines of Katanga (then Shaba) (International Consortium for Africa 2008).

The ABB Group, a global hydroelectric power and automation technologies conglomerate with headquarters in Zurich, is currently upgrading the corridor's carrying capacity to bring it closer to the original design specifications, which called for twice the carrying capacity of the existing line. Current plans for enhancing the Inga-Kolwezi HVDC reflect renewed interest, from both the DRC and the international community, in harnessing more fully the hydroelectric potential of the Congo River's Inga Falls. In March 2013 delegations from the DRC and South African governments met to finalize a treaty for the development of a third hydropower installation, one that will result in the world's largest hydroelectric dam (DRC 2013). Dubbed "Grand Inga," the new facility will support a regionwide, perhaps even continent-wide, transmission network. When completed, the project will boast roughly 40,000 megawatts (MW) of capacity, about twice that of China's Three Gorges Dam and an amount roughly equal to the installed capacity of the Republic of South Africa, the continent's largest electricity supplier (Fall 2010).[1] The construction of the dam will require something on the order of U.S.$40 billion in direct project funding, plus another U.S.$40 billion in transmission extensions and upgrades. As one scholar concluded, to call the Grand Inga Dam a "mega-project" may be understating its scale and potential impacts (Showers 2011).

One key question, then, is what impact the Grand Inga Dam will have on energy security—an inherently difficult notion to quantify. To provide an answer, we assess the energy security implications of the Grand Inga Dam along four dimensions: availability, affordability, efficiency, and stewardship. We find that the Grand Inga scheme may well improve regional energy security, but that under certain scenarios it may also undermine aspects of the DRC's national energy security. This finding reveals the true complexity of energy security aspirations and associated infrastructure development decisions. This analysis considers some of the tradeoffs within a complex decision space that includes aspects as diverse as climate change, social development and poverty, regional cooperation, corruption and governance, and technological innovation.

This study can help inform dialogues on development and energy policy at both the national and regional level. There is yet time to refine critical aspects of design and investment decisions for the Grand Inga—and this has motivated our research. The DRC suffers from one of the world's lowest rates of electrification, with 25 percent access in urban areas and 4 percent in rural areas, for a total of around 11 percent, well below the average sub-Saharan Africa rate of 30 percent in 2009 (IEA 2010; IRN 2011; IFC 2011). We present one perspective on how to evaluate this project, so that national planners and international investors can better assess its costs and benefits. Some laud investments in large-scale hydropower projects for offering opportunities for cross-border investment (Sovacool & Cooper 2013), and the possibility for meeting energy access goals (Sawin et al. 2012). We critically test those claims.

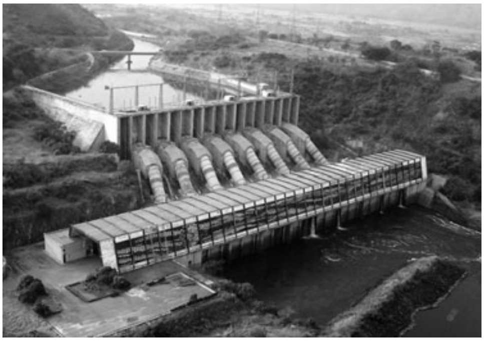
The Grand Inga Dam Proposal

The Grand Inga Dam will be built on the Congo River in the DRC, one of the world's least developed countries and currently ranked 181st in the world (out of 185) for "ease of doing business," 100th for electricity production, 101st for electricity consumption, and last (out of 186) on the United Nations Development Program's (2013) "Human Development Index." The design of the dam has developed gradually under the guidance of numerous regional influences. Thus, before we discuss energy security in an African context and consider its performance under our four basic energy security criteria, we begin with a brief discussion of its geographic scope, the related institutional context, and the international organizations and agreements involved in its evolution.

The Congo River is the deepest river in the world, the second-longest in Africa (at 4,700 kilometers), the second most powerful in the world (with a flow rate of 42,000 cubic meters per second), and the most powerful in Africa. Hydropower developers have long targeted it for development, particularly at the Inga Rapids in Bas-Congo Province, where operators commissioned the 350 MW Inga 1 Dam in 1972 (see figure 1) and the 1,750 MW Inga 2 Dam in 1982, the same year the Inga-Kolwezi HVDC corridor was finalized (Showers 2009; IRN 2011). Rather than attempt to dam the river, engineers built a canal that takes advantage of its sharp bend, bypassing the falls and returning water back to the river after driving the turbines at the dams. In 2009 BHP Billiton, the world's largest mining company, signed an agreement for a U.S.$5 billion Inga 3 Dam to provide 2,500 MW of electricity to an aluminum smelter, but the deal was scuttled in late 2012 (BBC World News 2012).

For some time the Inga-Kolwezi HVDC corridor has symbolized the potential of a regional electricity system, even as the Inga I and Inga II facilities have suffered from inadequate maintenance. In 1995, with the encouragement of the World Bank, the members of the Southern African Development Community (SADC) formed the Southern African Power Pool (SAPP), bringing the region closer to its goal of a market-driven integrated electricity market. In 2001 plans for a Grand Inga Dam became a priority project under the African Union's New Partnership for African

Figure 1. The 350 MW Inga Dam I in the DRC



Source: Authors

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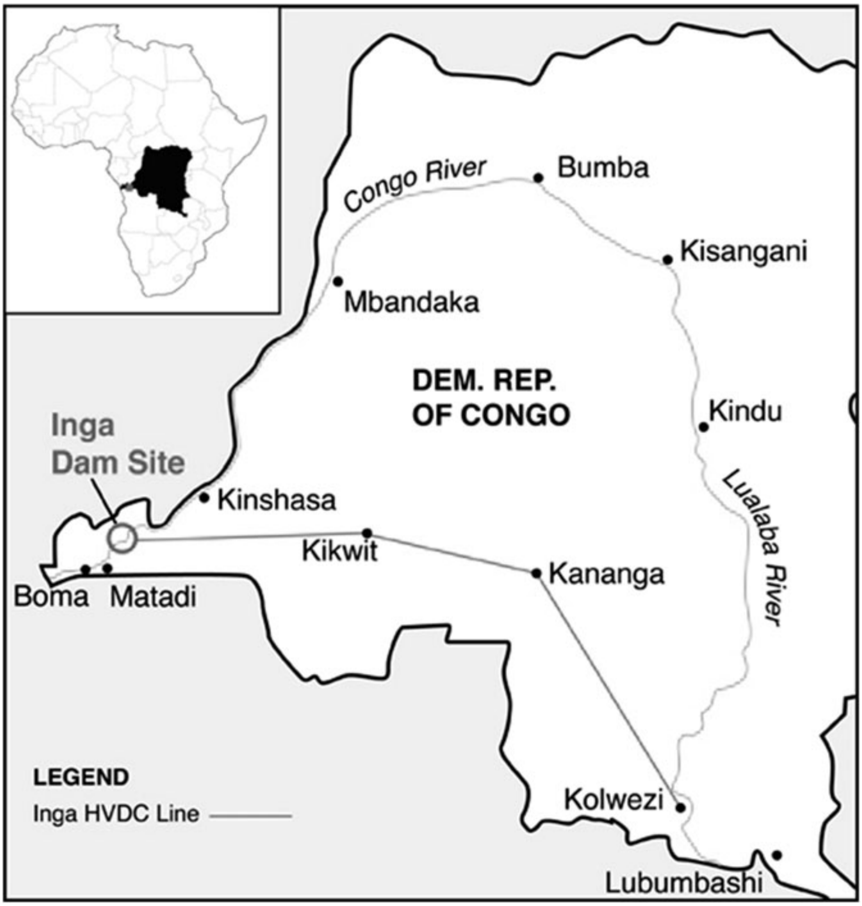
Development (NEPAD). South Africa's Eskom Enterprises, the largest electric utility in Africa, formed a consortium to build Grand Inga, and in 2007 the Africa–E.U. Strategic Partnership Agreement and the E.U. Renewable Energy Policy established plans for greater electricity interconnection between the E.U. and Africa. At the same time, the African Development Bank announced a grant for power development, including a feasibility study and environmental impact statement for Grand Inga (Showers 2011). Meanwhile, the SADC's Infrastructure Master Plan prioritized regional interconnection (SADC 2012). The DRC's role in sponsoring Grand Inga is limited to the country's SADC membership and participation in the Western Corridor Project, a coalition of regional regulatory bodies charged with encouraging the economic and energy development of the Inga region.

Given that the Grand Inga Dam remains at a relatively nascent stage of development, plans appear to be highly uncertain (as of late 2014). One iteration of the project, sponsored by the Western Corridor Project and the SADC, working together with SAPP, calls for as much as a 44,000 MW reservoir-style dam to be erected across the Grand Inga Cascades at a cost of U.S.$40 billion (see figure 2), which most likely will take the form of damming the entire Congo River and diverting flow into the Bundi Valley (Showers 2011). Another version of the project, however, which is being promoted by AECOM (a global equipment supplier) and Électricité de France, envisions a "progressive" or "staged" development of eight dams (St-Pierre 2012). This scheme would utilize primarily low-head run-of-river designs with no closing of the Congo River and no tunnels, using an open channel in the initial stages as the project grows in capacity from 7,792 MW in 2018 to 42,081 MW in 2040 (Jullien 2013). Because of these features, sponsors of this proposal argue that it would require little to no population displacement and minimal disruption of local forests, requiring about only 2.6 kilometers of land.

Despite these variations, on May 19, 2013, the DRC formally announced plans to proceed with some form of construction after an international summit, stating that "the first foundation stone" will be laid in October 2015 and that, once completed, the Grand Inga Dam could provide "electricity to half the African continent" (DRC 2013). According to the DRC, the first phase involves building a 4,800 MW unit at Inga 3 Basse Chute. Three consortia—China's Sinohydro and Three Gorges Corporation; Spain's Actividades de Construcción y Servicios, Eurofinsa, and AEE; and a South Korean–Canadian consortium consisting of Daewoo-Posco-SNC Lavalin—are currently bidding for the contract. As of early 2014 the U.S. Agency for International Development was reportedly considering joining the Chinese consortium (Shih 2014; Kavanagh 2013). The African Development Bank, International Finance Corporation, French Development Agency, European Investment Bank, and Development Bank of South Africa have all expressed interest in financing parts of the project, and South Africa has committed itself

Figure 2. Regional and National Map of the Grand Inga Dam Project



Source: Modified from International Rivers Network (2014)

to purchasing 2,500 MW of Inga 3's capacity, making it the primary purchaser (DRC 2013). In March 2014, meanwhile, the World Bank approved a U.S.$73.1 million International Development Association grant meant to finance early government oversight in the form of the independent Inga Development Authority. The grant is also intended to financially support initial environmental and social impact assessments (Yukhananov 2014).

According to earlier plans, another U.S.$40 billion will be needed for a proposed high-voltage distribution network, which will enable Grand Inga to become a major supplier to each of Africa's five power pools, relying on three major transmission corridors: the Northern Highway (Inga-Sudan-Chad-Egypt, 5300 km), the Southern Highway (Inga-Angola-Namibia-Botswana-South Africa, 2734 km), and the Western Highway

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(Inga-Congo-Gabon-Cameroon-Nigeria, 1400 km) (Fall 2010). The regional scope of the proposed Grand Inga project is its defining factor.

Energy Security in an African Context

Classically, energy security in the early nineteenth century meant one thing: the mechanization of warfare and a concomitant acceleration of the energy requirements for coal-powered warships and vehicles (Yergin 2006). Global concerns about energy security became more prominent during the World Wars, the energy crises of the 1970s, and both Gulf Wars (1991 and 2003), when energy security began to take on a broader meaning focused on security of supply for national economies: that is, lowering dependence on foreign sources of energy and developing energy reserves as quickly as possible (Sovacool 2011). The bulk of the global energy security literature continues to focus on the geopolitical aspects of energy security policy for industrialized countries, where such policy generally comprises measures to reduce the risks of supply disruptions below a certain tolerable level. Insecurity in energy supply originates in the risks related to the scarcity and uneven geographical distribution of fossil fuels, supply states with geopolitical interests that may conflict with demand states, and the operational reliability or unreliability of energy systems that deliver services to end users (Luft & Korin 2009).

In an African context, discussions of energy security have frequently focused on three distinct topics: energy access and development, governance, and the so-called resource curse. The first topic—commonly described as "energy poverty"—refers to the fact that close to a fourth of humanity still lives without electricity or other modern forms of energy, while as much as a third of the world's population still relies at least in part on traditional biomass such as cow dung or firewood, especially—though not exclusively—in the "bottom billion" economies of sub-Saharan Africa, Asia, and other parts of the developing world (Collier 2008). Projections from the International Energy Agency (IEA) subtly, but clearly, underscore the fact that many of the poor in Africa are not likely to receive the benefits of modern energy access anytime soon. When projecting the future in their *World Energy Outlook*, the IEA (2013) estimated that almost 1 billion people will still be without electricity by 2030 and that 2.6 billion people will still be without clean cooking facilities. Indeed, of the "bottom 30 countries" with the lowest levels of modern energy access, twenty-three of them are on the African continent (IEA 2012).

The second topic—governance—refers to high rates of accountability, respect for the rule of law, low levels of corruption, and high rates of government effectiveness and regulatory quality. The World Bank (2013:1–2) has described the concept this way:

> Governance consists of the traditions and institutions by which authority in a country is exercised. This includes the process by which governments

> are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them.

In the context of energy, good governance refers to stable, transparent, and participatory modes of energy policymaking, inclusive markets and institutions, sound policies for the licensing or permitting of infrastructure, high levels of accountability, and rule of law, all of which can lead to more effective energy systems (Sovacool et al. 2011; Sovacool & Mukherjee 2011). Governance has also been shown to be a major factor determining whether energy and mining projects contribute to, or harm, social well-being (Lange 2011). Yet ensuring good governance is not an easy task. The Chad–Cameroon oil pipeline project, for instance, witnessed "major interventions" by the World Bank to improve governance, but it was still widely considered a "failure" (Pegg 2006). Unfortunately, effective governance systems also tend to require "constant re-adjustment" (Titeca & de Herdt 2011:214), making continuity and enforcement especially difficult.

The third topic—the "resource curse"—relates to the difficulty of managing natural resources such as oil, gas, and coal. Paradoxically, countries rich in resources sometimes perform worse in terms of economic development, social well-being, principles of good governance, and peacekeeping than resource-poor countries do (Ross 2012; Humphreys et al. 2007; Le Billon 2004; Karl 1997). The value of those resources often means that the economies producing them become dependent on their extraction and less economically diversified. High export rates can create hyperinflation, rendering other industries less competitive and creating the "Dutch Disease" (Humphreys et al. 2007). The technology of resource extraction is often owned not by those within the country, but by large multinational firms. Large mining and extractive industries projects frequently displace local communities and also fail to benefit the poor (Sovacool 2010). Most scholars now agree that the "curse" can become a blessing when resource possession is accompanied by well-functioning economic and political institutions (Luong & Weinthal 2010; Lederman & Maloney 2007).

Drawing from this literature, and from our own work reviewing the theoretical literature on energy security (Sovacool 2011), evaluating energy security for developing states (Gaylord & Hancock 2013), surveying energy consumers (Sovacool et al. 2012; Knox-Hayes et al. 2013), and conducting interviews with energy experts (Sovacool et al. 2011; Sovacool & Mukherjee 2011; Sovacool 2013), we conclude that energy security is much more than merely the availability of fuels such as oil, natural gas, coal, and uranium. In short, it is no longer appropriate to envision and practice energy security as merely direct national control over energy supply. In much of the current discourse, scholars and practitioners argue

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that other issues must be considered, such as cultivating respect for human rights and the preservation of natural ecosystems along with keeping prices low and fuel supplies abundant, issues that extend beyond individual states (Xu 2010; APERC 2007). We therefore argue that energy security should consist of availability, affordability, efficiency, and stewardship.

Availability relates to the relative independence and diversification of energy fuels and services. Part of ensuring availability entails procuring "sufficient and uninterrupted supply" and minimizing reliance on imported fuels (Klare 2007). A related aspect of availability is diversification, or preventing the sabotage and attack of critical infrastructure, such as power plants, pipelines, dams, and transmission and distribution networks, and also diversifying the fuels, technologies, locations, and operators of energy systems. A second component of energy security extends beyond availability to include the basic *affordability* of energy services, a term that means not just lower but also predictable prices. A third component relates to *energy efficiency*, or the improved performance and increased deployment of more efficient equipment and changes in behavior. Energy efficiency enables the most economically efficient use of energy to perform a certain task (such as light, torque, or heat) by minimizing unit of resources per unit of output. Energy efficiency can include substituting resource inputs or fuels, changing habits and preferences, or altering the mix of goods and services to demand less energy. A fourth component, *stewardship*, emphasizes the importance of social and environmental sustainability as well as governance. Stewardship means ensuring that energy systems do not impinge upon the vitality of local communities, that they minimize the destruction of the natural environment, and that they adhere to norms of good governance and respect for human rights.

Assessing the Energy Security of Grand Inga

The Grand Inga project is emblematic of the region's integration-focused view of energy security and policy. It has the potential to provide thousands of construction jobs, improve the macroeconomic energy security of the DRC, massively increase sub-Saharan Africa electricity generation, and funnel foreign direct investment into sub-Saharan Africa. However, as we have seen, the DRC's existing electricity grid reaches only 11 percent of Congolese citizens and circumvents some of its biggest cities. Rather than improve access to modern energy services, the electricity from the Grand Inga Dam could instead energize mining projects and transfer revenues to South Africa and other regional countries. Moreover, under certain scenarios, the Grand Inga scheme could disproportionately benefit big industries and other countries, not the average Congolese household, and its sheer size and scale could make it susceptible to corruption and misappropriation of funds.

So—will the Grand Inga scheme improve overall energy security, or degrade it? And will its energy security benefits accrue primarily to the

DRC, or to other regional actors? To address these questions, the following sections qualitatively assess the Grand Inga Dam according to each of the above-mentioned energy security dimensions.

Availability: Independence and Diversification

The simplest benefit of the Grand Inga scheme for the DRC will be enhanced availability of modern energy. Certainly, Grand Inga could perform well at the national level as a renewable, domestic source of electricity, adding 40,000 MW of capacity and functionally growing the DRC national grid by more than sixteen times. But supporters of the Grand Inga scheme tend to equate secure access to electricity with energy security, and whether the local population will benefit from this increase is a matter of policy. Since the state currently exports electricity, it already has the capacity to increase local access, but the government, and presumably its financial supporters, have thus far chosen not to use excess capacity for domestic purposes. It is unclear why this would be any different with Grand Inga.

In addition, another important dimension of availability is spatial, technological, or institutional diversity. In this regard, given the DRC's heavy reliance on hydropower, a new dam will not represent a great improvement over present circumstances. As figure 3 indicates, in 2011 hydropower supplied 99.6 percent of the DRC's 7882 gigawatt-hours of electricity. However, that hydroelectric supply has been incredibly erratic, fluctuating very often by double-digit rates between 1992 and 2004. In this regard, Grand Inga will therefore only worsen the DRC's lack of diversity and susceptibility to rapid fluctuations in supply.

Furthermore, even though a new dam will result in more electricity produced, this will not automatically ensure that more of the DRC's populace has access to it. As currently planned, money has not been allocated to increase local grids. While agreements are in place to set aside generation capacity for the DRC's growing electricity needs and select industrial sectors, long-distance transport remains the project's focus and explicitly supersedes the DRC's local needs. Rather than provide for the DRC's local energy requirements first, current plans call for immediate transmission to the regional network, the rationale being that to do so is more cost effective and in the end results in a better financial return for the DRC (Fall 2010). Moreover, at the level of spatial diversification, the Grand Inga Dam will be constructed in the immediate vicinity of Inga I and Inga II, which together already produce the bulk of the DRC's electrical capacity.

Regionally, the picture is more positive. International organizations have often recommended integration of electrical networks through regional power pools in order to enhance security of supply. Some studies support this approach, arguing that the incorporation of large-scale projects into regional networks can lead to stable and accessible expansion

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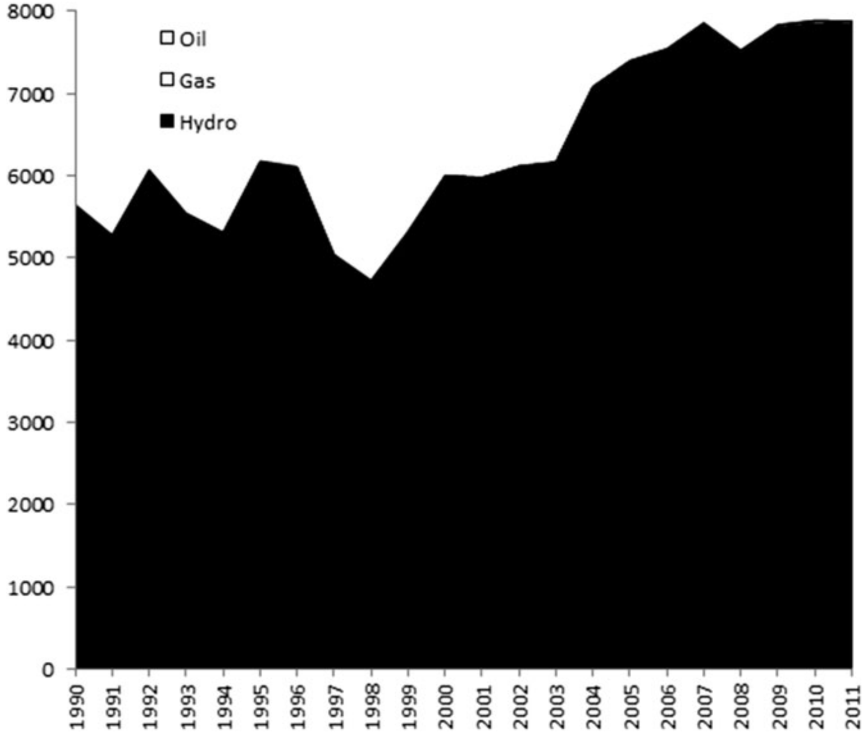
Figure 3. National Electricity Generation in the DRC, 1990–2011 National Supply (Gigawatt-hours)



Source: International Energy Agency (2013)

of energy services on the African continent (Bazilian et al. 2012). The SADC (2013), of which the DRC is a member state, recently echoed this assumption when it finalized its Infrastructure Master Plan, outlining a "15-year blueprint to guide the implementation of cross-border infrastructure projects between 2013 and 2027." Official materials detailing the SADC Master Plan (SADC 2012) equate the regional integration of the energy sector in particular with energy security. Similarly, the World Energy Council (WEC), a supporter of the Grand Inga scheme, as well as official South African government planning documents (Fall 2010), state that the system will enhance energy security since it provides a huge resource base in a region starved for energy. Other studies have noted that Grand Inga could relieve energy shortfalls within regional power pools, increasing the system's overall reliability and sufficiency (Sebitosi & Okou 2010). In this scenario, SAPP's abandonment of bilateral trade agreements in favor of a regional, hydropower-based energy economy represents an optimal model. South Africa, for example, experienced an energy supply crisis from December 2007 to January 2008. The economic shock brought

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new focus to the need for secure and stable access to electricity (World Bank 2012).

One regional drawback, however, is the centralized character of the Grand Inga scheme, which suggests that the network's stability will depend on the security of the dam and its long-distance connectors. Relatively small accidents could prove exceedingly disruptive, as could incidents of sabotage on the part of disenfranchised groups within any of the countries supplied with electricity by the project. In early 2013, for example, Islamist extremists from Mali, wearing explosive-laden vests and carrying AK-47 rifles, drove across the border in unmarked trucks into Algeria, seized the internationally managed In Amenas gas compression plant, and killed thirty-seven employees of British Petroleum, Statoil, and the Algerian national oil company Sonatrach, suspending production for two weeks at a cost of at least U.S.$100 million (Nossiter & Sayare 2013; CNN 2013). The siege ended only when the extremists threatened to explode the entire plant—which would have leveled a 25-square kilometer radius—prompting Algerian Special Forces to storm the complex, killing twenty-nine militants. The more the Grand Inga Dam becomes central to regional energy security plans, the more it could become a magnet for this type of terrorist activity.

In this vein, Grand Inga's dependence on long-distance HVDC transport suggests some vulnerability to deliberate or accidental disruption. In sub-Saharan Africa such installations have a mixed history in this regard. The Inga-Kolwezi line, for example, has functioned reliably for decades despite its presence in an area of frequent armed conflict. Mozambique's 1,420-kilometer Cahora Bassa HVDC line, by contrast, became a target for rebel fighters shortly after it began transmitting hydroelectricity to South Africa, resulting in a complete breakdown (Lacher & Kumetat 2011). Political stability in transport regions will most likely play a vital role in mitigating this central vulnerability in the system, although currently the DRC is home to 2.3 million displaced persons and refugees, and war, ethnic strife, and mass forced migrations have torn apart the country's institutions and population since 1994 (UNDP 2013).

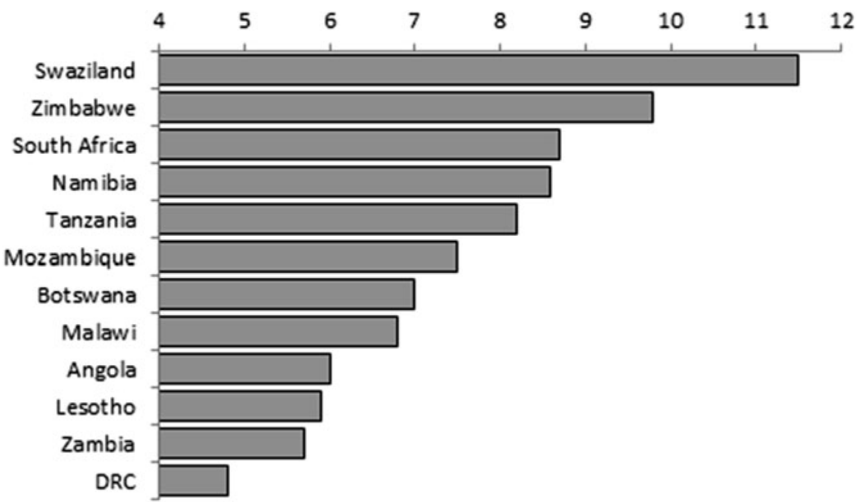
The Congo Basin's hydrological system—the source of "fuel" for the dam—may also be threatened by other factors. Deforestation is a significant concern, and there is reason to believe that continued logging and conversion of forestland may affect the Congo's hydrological cycle and thus over time the Congo River's capacity to generate hydroelectricity. For example, a 2005 study involving tropical forest areas in Gabon and the DRC found that deforestation in timber concessions had decreased rainfall by as much as 15 percent (Roy et al. 2005). In recent years industrial logging has begun to expand in the DRC and elsewhere in the Congo Basin, and any increased industrialization that may accompany the Grand Inga project will likely continue this trend. If Grand Inga is to provide a consistent and lower-cost source of electricity in the long term, then, the Congo Basin's ecological health will play an instrumental role.

Affordability: Predictability and Equity

As an advantage to the DRC, the Grand Inga scheme is likely to bring in billions of dollars of foreign direct investment. More reliable energy supply for mining enterprises could help the DRC develop this sector, which is expected to grow by 13.7 percent on average until 2015. The DRC is considered one of the richest African states in minerals, especially in gold, copper, cobalt, and diamonds (*Mining Journal* 2012). Given the interest of the World Bank, the African Development Bank, USAID, and the E.U., supply-side financing for Inga may not be of great concern. The coalition that builds and operates Grand Inga is scheduled to make a good return on its investment. The WEC predicts that Grand Inga will supply electricity to the retail market at a price of U.S.$0.01 to 0.013 per kilowatt hour, favorable compared to almost every other source of electricity. Despite this low end-user cost, calculations (from 2010) of Grand Inga's eventual capacity suggest that, assuming an annual production of 280 gigawatt-hours, annual revenues will amount to U.S.$12 billion, plus U.S.$2.8 billion paid to the DRC for use of its water (Fall 2010). Rates of return are therefore reasonable, assuming that Grand Inga performs reliably. In terms of the cost of electricity, the DRC already has the lowest tariffs in the region (see figure 4). Presumably Grand Inga will help these low rates to continue, depending on policy initiatives.

Nonetheless, some affordability shortfalls associated with Grand Inga begin with the fact that it is a remarkably expensive project in terms of initial capital costs. If the calculations done in 2010 are still correct, the

Figure 4. Average Electricity Tariff Rates for SAPP Members, 2012–13



Source: Southern African Power Pool (2014)

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Grand Inga Dam installation will require U.S.$30–$40 billion in funding, while the transmission network will require another U.S.$40 billion. By comparison, the DRC's entire GDP in 2011, as estimated by the World Bank (2012), was U.S.$27.5 billion. In addition, Grand Inga's scale requires a long period for construction, with full commissioning held off until 2025 to 2030. Given that developers were yet to break ground in late 2014, this time estimate on the part of the WEC may be overly optimistic.

Indeed, evidence from the historical record does not bode well for large-scale dams: most suffer major cost overruns and suffer from diseconomies of scale. One recent study from the megaproject analyst Bent Flyvberg and his colleagues utilized reference class forecasting to assess the outcomes and costs of 245 dams—186 of them hydroelectric dams—built between 1934 and 2007 across five continents and sixty-five countries and collectively involving more than U.S.$353 billion worth of investment. The study found "overwhelming evidence that budgets are systematically biased below actual costs of large hydropower dams" and that "actual costs were on average 96% higher than estimated costs" (Ansar et al. 2014:43). The authors highlight that these cost overrun figures are exceptionally conservative since they do not take into consideration such factors as inflation, substantial debt servicing, and other environmental and social damages. A follow-up study of more than four hundred electricity infrastructure projects around the world concluded that cost overruns afflicted more than three out of every four of the hydroelectric projects in the sample (75.4%) and that these exhibited a mean cost escalation of 70.6 percent per project (Sovacool et al. 2014).

At the regional level, and perhaps conversely, the Grand Inga could contribute to lower prices due to its improved reliability. One study suggests that Congo basin hydropower, if integrated into regional grids, can aid in offsetting decreases in hydropower reliability in other areas. In this scenario, declining hydropower potential at facilities such as the Cahora Bassa, Kariba, and other hydropower schemes in the Zambezi River Basin could be mitigated by greater exploitation of the Congo Basin, which remains hydrologically stable (Yamba et al. 2011). In South Africa, for example, access to the Grand Inga scheme will potentially result in less volatile end-user costs by mitigating the country's reliance on coal.

That said, because increased regional integration is central to the Grand Inga scheme, the improvement in performance of regional electricity markets will do much to decide the scheme's affordability. Orvika Rosnes and Haakon Vennemo (2011), in their detailed assessment of the four regional power pools, conclude that earlier studies were overly optimistic in their depiction of regional integration and failed to account for higher investment costs. According to their simulations, investment costs for regional integration will be higher than they would be for a similar range of localized electricity improvements because of the additional demands of long-distance infrastructure and the capital cost of prioritizing new, centralized hydropower over existing thermal generation.

Other studies of Africa's electricity networks observe that regional integration carries its own economic hazards. For example, regionwide improvements to grid networks and long-distance transport must contend with the problem that the costs can be much easier to monetize than the benefits, a shortcoming that becomes especially clear where costs are incurred in one country while the benefits are felt in many (Welsch et al. 2013). This issue may lead to free-riding strategies, including strategically delayed investments. The implication is that for the Grand Inga Dam to truly promote affordability, regional cooperation will most likely be required on an unprecedented scale.

Efficiency: Innovation and Education

At both national and regional levels, there are no current plans to require revenues from the project to accrue into a natural resource fund or pay for investments in clean energy, nor will they subsidize any type of demand-side management or load management program, ecosystem payment scheme, or natural resource fund for future generations. Many new major energy projects that are "supply" oriented can, however, still undertake efforts to improve efficiency, lower overall energy demand, and/or produce savings for future generations. For example, in Costa Rica the Private Forest Project collects a 5 percent tax on gasoline, revenues from the sale of carbon credits, and donations from hydropower companies and then distributes funds to encourage plantation owners and forest managers to preserve or afforest their land. More than one thousand property owners signed contracts within the first two years of the program and U.S.$16–$20 million are currently dispersed annually to protect forests (Brown & Sovacool 2011). Similarly, in Ecuador the government has pledged to place all of the revenues from the development of oil fields—a supply-side measure—back into energy efficiency programs and strategic investments in small-scale renewable energy (Davis 2007–8; Larrea & Warnars 2009).

Although updated local networks may come as an eventual result of access to Grand Inga's regional distribution network, Grand Inga itself, for now, plans to evacuate most of the generated electricity through long-distance transport corridors to consumers outside the DRC. This type of an energy strategy is itself inefficient due to the efficiency losses involved. For example, the estimated amount of power lost in transporting 2,000 MW over a 1,500-kilometer transmission line from Cahora Bassa to South Africa is equal to the consumption capacity of Mozambique, the host generating country (Sebitosi & Okou 2010). Also, and perhaps understandably, Grand Inga will do nothing to decrease electricity consumption. In fact, there is some evidence that planners intend to encourage the reverse in order to minimize debt-to-equity ratios and maximize profits (Sebitosi 2008).

Stewardship: Social and Environmental Sustainability

An analysis of Grand Inga's stewardship potential yields mixed results, with a positive assessment for the region but a likely negative one for the DRC.

Although hydropower generation is not carbon free, the greenhouse gas emissions associated with its lifecycle are typically much lower than those associated with coal and other fossil fuels. According to one study, hydroelectric plants produce an estimated 0.5–152 grams of "carbon dioxide equivalent" per kilawatt hour compared with coal-fired plants, which produce some 900–1,200 grams (Steinhurst et al. 2012). However, there is evidence that reductions in emissions related to Grand Inga may be at least partially offset by some of the dam's adverse impacts. Some analysts suggest that due to high levels of biodegradation, tropical reservoir dams can release larger amounts of "carbon dioxide equivalent" from their reservoirs than previously recognized. Though their numbers are controversial, these studies together estimate that emissions factors for tropical reservoir dams could be half that of fossil fuels, thus making them worse performers than wind energy, solar energy, or even nuclear power (Kemenes et al. 2011; IPCC 2011).[2] This means that the true emissions savings potential of Grand Inga lies in its design; a reservoir-based system will be much worse (from a climate standpoint) than run-of-river configurations.

Drawbacks at the national level in terms of stewardship will likely be more severe. If built according to the more standard reservoir-style design, Grand Inga will not improve environmental sustainability in the DRC and will likely have a net negative impact. The physical structure of the dam will alter water quality and flow, though low-head systems will partially mitigate this impact. Still, even low-head dams can negatively influence water quality through changes in the concentration of dissolved oxygen, nutrient loads, and suspended sediments, and tidal encroachment can aggravate the erosion of river banks (Sovacool & Bulan 2011). Also, dams can negatively influence the population of freshwater fish, which become disoriented in slow-moving waters, and fish living near the dam will be susceptible to pulverization from passing through the turbines or from supersaturation and excess nitrogen from the water around the concrete face.

The Congo Estuary, which lies just downstream of the Inga Falls, has unique geomorphic characteristics. Where the Congo meets the Atlantic, it flows with considerable power through a deep undersea canyon, depositing organic materials that heavily influence ecosystems throughout the Atlantic Ocean (see Showers 2011). These phytoplankton-driven ecosystems in turn act as important carbon sinks, thereby playing a vital role in regulating regional climate. In a worst-case scenario, Grand Inga could therefore affect climate cycles while offering no relief from existing environmental burdens within the DRC.

In fact, with a possible increase in industrial logging, the secondary environmental impacts of Grand Inga could become significant. Other large hydroelectric projects have been documented as contributing to flooding, earthquakes, fisheries losses, and disease epidemics from standing pools, slower moving water (schistosomiasis), and even the spread of HIV/AIDS due to the mass displacement and impoverishment of local people and an increase in prostitution.[3] Run-of-river configurations for Grand Inga would mitigate much of the environmental danger inherent to the original reservoir design (Naidoo 2009), but these are uncertain to be implemented.

Nationally the Grand Inga scheme in its current configuration also will do little in terms of social sustainability. It is unclear how many will be displaced by the scheme. An earlier report suggested at least eight thousand people, whereas the 2013 press release from DRC said there will be "no involuntary population displacement" under the newly conceived plan (Panzu 2013). As proposals for the project move forward, analysts should keep in mind that the World Bank's (1996) Operations Evaluation Division found that the actual number of people to be resettled under Bank-funded dam projects ended up being 47 percent higher than initial estimates. Some NGOs, notably International Rivers (2011, 2014), have leveled complaints against the project, citing a long history of uncompensated displacement of local populations associated with earlier Inga hydropower projects.

Indeed, from a human sustainability perspective many scholars argue that large dam projects have resulted in significant displacement and resettlement of local populations that subsequently suffer from a variety of economic, social, and health repercussions while multinational corporations, political elites, and more powerful states gain greater energy access. Issues include the "migration and resettlement of people near the dam sites; changes in the rural economy and employment structure; effects on infrastructure and housing; impacts on non-material or cultural aspects of life; and impacts on community health and gender relations" (Tilt et al. 2009). Despite recommendations based on extensive case studies (Carnea 1997; Scudder 2006), quantitative assessments (Scudder & Gay 2006), and analysis from the World Commission on Dams (2000)—a groundbreaking exercise that included stakeholders from government, the private sector, and civil society (see Dubash et al. 2001)—few projects adequately promote sustainable economic and social plans and needed institutions for resettled peoples.

More recently, however, countries have attempted to increase the financial concessions for displaced people, even instituting benefit-sharing programs (Wilmsen et al. 2011). These plans have run into problems with inefficient use of funds, insufficient governmental capacity to distribute funds and maintain the programs, and the lack of local engagement in planning (Cernea 1997; Scudder 2006). Despite these challenges, a number of studies highlight that positive outcomes can be achieved when key stakeholders create and support institutional arrangements that incorporate long-term perspectives on the livelihoods of those resettled, the affected community is involved throughout the process, and governments and/or developers provide ongoing financial and institutional support.[4]

Regionally the picture is more positive, as the dam could facilitate the provision of adequate food, shelter, clothing, water, sanitation, medical care, education, and access to information across sub-Saharan Africa. The electricity from the dam could support lighting, communication, transport, commerce, manufacturing, and industry. It could enable refrigerated vaccines and emergency and intensive health care, the pumping of clean groundwater for drinking, and irrigation to increase agricultural productivity. Furthermore, high-speed transportation, telecommunications, information technology, and a variety of other services that enhance the quality of life depend on electricity (UNDP APRC 2013; Asian Development Bank 2007).

Nonetheless, evidence that the Grand Inga scheme may be less cost effective at meeting energy access goals than cheaper alternatives needs to be considered. Distributed generation and smart grid technologies, for example, could allow the development of local grids at a much greater efficiency and more appropriate scale (Welsch et al. 2013). The International Energy Agency (IEA 2013) estimates that the capital cost of providing "modern energy services" to all deprived households in the ten largest fossil fuel exporting countries in Africa—which includes the DRC—would total around U.S.$30 billion. It is likely that the Grand Inga plan, at some U.S.$80 billion in total projected cost, may not be the most cost efficient mechanism for providing access to electricity or for otherwise improving quality of life for the majority of DRC citizens. Moreover, another assessment noted that while 40,000 MW seems like a great deal of electricity, it constitutes only 10 percent of the capacity and investment needed to achieve "full access" throughout sub-Saharan Africa (Bazilian et al. 2012)—the implication being that Grand Inga by itself cannot meet the region's energy access goals.

Finally, a scheme as large and expensive as the Grand Inga Dam could invite and exacerbate corruption and maldevelopment. The DRC is not a country renowned for good governance. As previously mentioned, it ranks last in human development (tied with Niger) and is in the bottom five countries in terms of ease of doing business. One recent assessment called the business climate in the DRC "disgusting" (*Economist* 2013). An independent panel led by former U.N. Secretary General Kofi Annan investigated five deals struck there between 2010 and 2012 and compared the sums for which government-owned mines were sold with independent assessments of their value. It found a gap of U.S.$1.36 billion, double the state's annual

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budget for health and education. In November 2012 the International Monetary Fund went so far as to cancel its entire loan program with the DRC after the government refused to explain a mining deal thought to be corrupt (*Economist* 2013). As a sign of these governance troubles, the DRC ranks poorly even against an average level of sub-Saharan Africa governance indicators (World Bank 2013). Finally, after touring the Grand Inga site in December 2013, the head of USAID told reporters that the DRC would need to create a governance structure for Inga before it could attract U.S. funding (Kavanagh 2013).

Conclusions

We present four conclusions. First, the proposed Grand Inga Dam will likely improve some elements of national and regional energy security, but there are downsides as well, some of them severe. Grand Inga, together with its continent-scale transmission network, could potentially strengthen connections between Africa's tenuous regional grid networks and power pools, enhancing security of supply and providing greater source diversification at the level of national grids. Assuming the creation of a true economy of scale in the process, enhanced affordability could lead to dramatically increased access and even create an environment conducive to the development of less centralized networks able to incorporate new, localized generation. Any such step toward a more socially integrated power system will likely enhance energy security both as a contributor to stable supply and as an element of social stewardship, although this will require the robust strengthening of, and commitment to, local and regional institutions and good governance. Hydroelectricity on this scale could also potentially displace coal-fired thermal generation in multiple locations simultaneously, leading to an impressive net reduction in emissions from the largely fossil fuel–dependent continent.

However, these potential energy security benefits from Grand Inga would come at a price—as do most decisions related to energy. Most of the proposed system's benefits stem from its large-scale and long-distance transmission network. Considerable care will be required to mitigate the risk that the DRC's hydropower resources are managed solely as an extractive commodity, which would trigger "resource curse" consequences and potentially send generated capacity into regional markets with only token gestures to its development potential for the Congolese. More significantly, the negative environmental consequences of the dam could be significant, and, if a reservoir-based design is pursued, could include the emission of millions of tons of greenhouse gases, the risk of flooding, increased seismicity and earthquakes, fisheries losses, alterations to water quality, and disease epidemics. According to this view, the Grand Inga Dam scheme relies on outdated thinking and an inappropriate model of electrification based upon centralized and capital-intensive technology

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that has as much negative environmental and social impacts as it does strengths.

Second, the Grand Inga scheme illustrates the importance of scale to the analysis of energy security. In this particular case, most (though not all) of its costs and risks will befall the DRC, whereas most of its benefits, especially enhanced regional energy access through electricity exports, will accrue to the sub-Sarahan Africa region. In a sense, the more successful Grand Inga becomes in enhancing energy security for the region, the more likely will the DRC experience an overall reduction in its own energy security. Regional security, in other words, may come at the expense of local security. Still, this trend could be offset by strategic investments in proper social and economic safeguards, including greater input for citizen groups. This view should impel policymakers to include provisions in future large-scale projects that advance energy security at the local level.

Third, the potential energy security impacts—positive and negative—are not inevitable. Our assessment depends on considerable assumptions and on uncertain plans, which are likely to be altered. Several policy changes could significantly affect the energy security calculation. As an example, the Grand Inga could become one of the first projects to take seriously the detailed recommendations from the World Commission on Dams, which would go a long way toward ameliorating damage to displaced populations. International financiers could require the winning consortium to build electricity grids in the urban and rural areas of the DRC that currently lack access and assist in building any other infrastructure needed to connect those without electricity. The proposal could include a fund to develop energy efficiency standards, educate the local population and businesses on the benefits of greater efficiency, and create a system of incentives to increase compliance. The international community should insist on increased transparency in regard to this project. Despite the dramatic impact the project could have in the DRC and the region, there are few open-source documents detailing the plans. The 2013 announcement suggests that the plans have improved since scholars published reports on the Grand Inga in 2009–11. Open documents claim that there will be no forcibly displaced persons and that the economic impact will be much lower than the previous scheme. If accurate, this is good news, but scholars, NGOs, and others in civil society—especially local people—need to be part of the process now, before plans are set in stone.

Fourth, and beyond the topic of Africa, this study validates the necessity of allowing for a complex view of energy security. According to the most traditional definition of energy security—which does not include sustainability—the Grand Inga proposal seems a clear winner. But according to a more contemporary definition—one that incorporates availability and affordability alongside efficiency and stewardship—the conclusion is murkier. The enhanced access to electricity for so many Africans may essentially trump the potential damages that may occur within the DRC. This is a conflict that needs to be explicitly recognized throughout the planning process for the Grand Inga Dam and in wider discussions about energy policy and technology.

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List of Acronyms and Abbreviations

DRC	Democratic Republic of the Congo
GDP	Gross Domestic Product
HVDC	High Voltage Direct Current transmission line
IEA	International Energy Agency
MW	Megawatt
NEPAD	African Union's New Partnership for African Development
SADC	Southern African Development Community
SAPP	Southern African Power Pool
WEC	World Energy Council

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Notes

1. As of 2012, the World Bank reports that South Africa's installed electricity capacity was 45,245 MW.

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2. We did not use the IPCC numbers for hydropower because they excluded changes in land use.
3. See Wang et al. (2012, 2013); Tilt et al. (2009); Manyari et al. (2007); Brismar (2004); Lerer and Scudder (1999); Adams and Hughes (1986).
4. See Biswas (2008, 2012); Fujikura et al. (2009); World Commission on Dams (2000); Cook and Mukend (1994).