ELECTRIFYING AFRICA: AN ENVIRONMENTAL HISTORY WITH POLICY IMPLICATIONS

by

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ABSTRACT. The European Union anticipates alleviating future energy shortages and fulfilling renewable energy mandates by importing "green" electricity from Africa. Historical precedent and environmental consequences have largely been ignored. This article presents an environmental history of African electricity generation at a continental scale, tracing its parallel developments with colonialism, as well as its pursuit in the independence eras of development assistance and neoliberalism. Initially electricity served European interests. Independent governments' development policies involved electrification primarily for industrial development; in North Africa, universal access was also a priority. Recurrent themes and cycles of environmental constraint, environmental disruption, and displacement of consequences from one ecosystem to another are addressed. Highlighted are inter-relationships among electricity generation, fuel supplies, ecosystems, and water cycles. Late twentieth century technologies and globalized markets re-valued African rivers and deserts as potential energy sources. Mega-engineering projects were rejuvenated or proposed. Rural electrification was labelled uneconomic social welfare unrelated to economic development policies of selling power through national, regional, continental and intercontinental interconnections. Historical analysis suggests new areas of research for sustainable development and alternatives to declensionist narratives. Decentralized, small-scale plants offer models of electricity supply for industrial and domestic needs, while investment in rural electrification produced measureable economic benefit at national levels. Will the EU renewable energy mandate simply displace Europe's environmental problems to Africa? Can Africa afford another water-intensive export commodity? Will the New African Century follow well-established patterns of exploitation, or take new, sustainable directions?

Keywords: dams, electricity, Neo-Europes, renewable energy, water cycle, Africa

Introduction

The European Union (EU) anticipates alleviating future energy shortages and fulfilling renewable energy mandates under the Kyoto Protocol by importing supplementary "green" electricity from the African continent. Proposed generation facilities built in African rivers and deserts would supply power through interconnected local, national, and regional electricity grids and undersea cables in the Atlantic and Mediterranean. Although still largely in Edgerton's (2007, p. xvii) 'strange world in which "technology" lives', these plans are logical extensions of (1) the global history of electrical power in which Europe, North America and Africa have been intertwined, and (2) the long history of European use of the African continent as an energy source. This article provides an environmental history of the arrival and spread of electricity on the African continent to help bridge the gap between twenty-first-century plans and biogeographical realities by revealing past patterns of interaction between electricity and larger landscapes.

Because it is a form of energy (Williams 1982), rather than a source, electricity's widespread generation and use depends upon ecosystems to provide abundant low-cost fuel. A history of electricity's expansion is, therefore, inherently an environmental history. Electrical power had clear, and at times determining, contexts and consequences for African environments, which have not been discussed in African or technology histories (i.e., McCann 1999; Beinart and McGregor 2003; and McNeill 2000; Crosby 2006, respectively). Neither political ecology defined as a study of ecological distribution conflicts that considers ecology to be the 'longue durée backdrop' to human history (Martinez-Alier 1999), or as concerned primarily with political economic forces (Walker 2005), nor Third World political ecology's emphasis on political/power analysis (Bryant 1997) have produced many studies of electricity generation and supply, and none with a clear environmental focus. In *Pacific Affairs*' Fall 2004 special issue 'The political ecology of electricity reform in Asia', Byrne *et al.* (2004) discussed the importance of environmental concern about reliance on nuclear energy as a unifying factor for the late 1980s emerging civil society. Electricity has also been mentioned in political ecological studies of urban infrastructure (e.g., Monstadt 2009) and decision-making related to large scale hydroelectric dams (e.g., Magee 2006). Jane Bennett's (2010) political ecology of things as "vibrant matter" considered interactions between the societies of northeastern North America and their interconnected electricity grid in the context of the 2003 blackout, but not the grid's larger environmental context.

In contrast, an environmental history, rather than a strictly technological, cultural or political-economic framework situates the evolving power plants and grids in their biophysical as well as sociocultural and political economic geographies, while allowing examination of environmental engagement over various lengths of time. The holistic, earth-centred environmental history proposed by Showers (2005) gives agency to all actors (human and non-human). In this way, voices of the usually unheard can reveal nuances and levels of complexity not previously imagined. For example, in the Kingdom of Lesotho, rural residents had an environmental, rather than political, critique of soil conservation engineering in the 1940s. They were careful that opposition to conservation structures was not interpreted as political opposition, since they valued the security afforded by British Protectorate status against their aggressive, land-hungry South African neighbours (Showers and Malahleha 1992; Showers 2005).

Holistic earth-centred environmental history was developed at a scale in which field measurement and oral history collection were possible. Dialogues could be established among the various sources that both confirmed information and stimulated further questions (Showers 1989, 1996, 2005; Showers and Malahleha 1992). Where the scale of study prohibits field investigation, a variety of field work techniques must be replaced by a variety of libraries and Internet sites. The framework's intellectual intention can be retained by establishing a dialogue among diverse primary and secondary sources. The larger and more diverse cultural and physical geographies covered by a continental approach enables use of comparative analysis, as described by Diamond (2005), to distinguish between site-specific environmental concerns and more general trends. The price paid for this vantage point is the loss of dialogue and ground-truthing made possible by interaction of local data collection techniques as well as the possibility of chance discovery of a cache of documents in a departmental or district office. Verification of detail from primary or secondary sources is not always possible. As always, attention must be paid to the possibility of secondary – and primary – sources repeating a common original source. With best possible verification, data are included under the assumption that the broad picture being painted will be refined by further investigation.

The following research grew out of a continental application of earth-centred environmental history which posed bioregional questions about African urban water and electricity use. Shifting patterns of water sources traced the expansion of water linkages between urban areas and increasingly distant rural landscapes, and revealed the unexpected dependence of urban electricity on rivers and coasts (Showers 2002). While the history of European and North American electricity inventors, inventions and innovation is well documented, and the African continent's exploitation for energy in the form of slaves and crops (calories) has been well-discussed, documentation of the origin and expansion of electricity exists only in scattered, time- and location-specific reports. Its environmental contexts have been entirely neglected. Archival materials, technical reports and (few) academic papers provided the evidence from which this African electricity history has been constructed. The resulting overview should point to rich intellectual and physical sites for applying more location-specific methods of data collection, including oral history and various kinds of environmental measurement.

By concentrating on the technology's use, rather than invention, global dimensions are revealed (Edgerton 2007). African experiences thus move from an unacknowledged periphery to a broadened centre. Approaching technological history through use not only reveals global dimensions, but also enables an analysis of "past futurisms", questions assumptions of superiority and modernity, and can give new dimensions to nationalism (Edgerton 2007). The application of environmental history perspectives strengthens Edgerton's (2007, p. xvii) argument that a study of "things" rather than "technology" 'connects us directly to the world we know'.

While rejecting associations of timelines with modernity or progress, in order to provide multiple perspectives, this article has been divided chronologically as well as thematically. The first two sections chart infrastructure construction in the colonial and independence eras. Although Crosby (1986) found no reason to include Africa in his flora- and fauna-based "Neo-Europes", any analysis of *technological* Neo-Europes would have to include this continent. The arrival and spread of electricity in the colonial era was clearly associated with European commercial interests. Because Britain claimed more of the African continent, emphasis is placed on its territories. The second section of this article addresses the proliferation of electricity generation after the Independence Decade (1960s). However, these developments were linked to the colonial era in two ways. European instrumentalist conceptualization of rivers (capitalist or socialist) dominated independence thinking, and colonial era plans were implemented after colonialism officially ended (as late as the early twenty-first century). The article's third section considers the history of electricity's identity as either public good or tradable commodity. Environmental consequences of electrification are the subject of the fourth section. Patterns of displaced environmental crises emerge, and recurrent themes and cycles of environmental constraint, disruption, and further constraint are described. Highlighted are the inter-relationships among electricity generation and fuel supplies, ecosystems, and water cycles. The article concludes that those who manage – or covet – African energy sources should be cognizant of past choices and patterns, and question the necessity of continuing twentieth-century trajectories of exploitation until exhaustion to supply expanding demand.

Colonial electrification

Between the European discovery of incandescent light in 1600 and the opening of the first American hydroelectric power plant in 1882, European countries staked claims for African territory. Ottawa, Canada, became the first city in North America to sign a contract for electric lights on all of its streets in the same year – 1885 – that a Belgian suggested the hydroelectric potential of the lower Congo River, and Africa was divided up at the Conference of Berlin. The next decade saw French and American inventors describe the electrolytic process for separating aluminium from its ore, the first commercial alternating current (AC) generator, and the spread across Europe of the Swiss Thury system for long distance direct current (DC), while Britain, France, Germany, Belgium, Spain and Portugal formalized their colonial presence in Africa. In 1895, when French West Africa was consolidated and British East Africa proclaimed, the Electric Light and Power Act, Cape of Good Hope came into effect and the world's largest AC generator (500 horsepower, 0.37 MW) was installed at the Niagara Falls, New York, USA hydroelectric plant to supply current to an aluminium smelter owned by the Pittsburgh Reduction Company (later Alcoa), as well as the city of Buffalo's street car and lighting systems more than 20 miles away. Both the electrical and colonial eras had begun.

African electricity development came about for three major reasons: an amenity or symbol of modernity for non-African settlers, a source of power for mines and industry (Worth 1998), or as a stimulus for industrial development. In most of colonial Africa, electricity was not seen as important for African or non-urban settlers' domestic lives. It was, however, the most cost-effective form of power for machinery and railroads. The growth of mining and manufacturing centres and railway development required large-scale electricity plants, prompting grid development. All colonial powers in Africa (save Spain and Italy) – and their associated private enterprises – built electricity generation facilities, but Britain and France constructed the most and the largest. Grids were most extensive in British settler territories.

As in Europe and North America, African electrification began with isolated, small-scale generators supplying farms/plantations, industries and transit systems with power, and municipalities with lighting. Most had steam driven turbines. These small-scale thermal plants were typically fuelled by gas in North Africa, wood in East and Central Africa, and coal in Southern Africa. Diesel engines fuelled with imported oil were widely used in West Africa. Run-of-the river (non-storage) hydroelectric systems arrived not long after their international commercial development. Consistent with other continents, modernity expressed in electrification coexisted with traditional power sources, affirming Edgerton (2007)'s 'jumbled up' time lines and 'modern time's non-existence' (Edgerton 2007 citing Latour 1993).

Although water is essential for electricity production – as fuel (hydro) or in processes of production (thermal) – water shortage was rarely considered in electricity planning and policy. Exceptions were turn of the nineteenth century South African Republic/Transvaal and mid-twentieth century Republic of South Africa. Elsewhere, water's role was solely an engineering problem; the consequences of generation for local and regional water cycles were rarely acknowledged. Instead, discussion on this dry continent concentrated on identifying customers who would finance costs of production and distribution, and/or provide profits. Ever larger African thermal and hydroelectric plants incorporated new technologies. Some "firsts" were achieved in hydroelectric dam design and long distance transmission. But, unlike most of North America and Europe, small-scale, isolated generation facilities did not die out as technological advances made possible larger, more centralized power plants with transmission to distant users. Small-scale plants continued to be built and operated throughout the twentieth century and into the twenty-first.

Thermal electricity: agriculture, administration, and municipalities

Electricity arrived on the African continent in the 1880s and 1890s with colonial administrators and private entities. Isolated generators gave way to utility companies with ever larger capacities and more formal government involvement. According to an Ethiopian government website, uncolonized Ethiopia's first diesel generator was a German gift to the Emperor, installed in the Grand Palace in 1887 (Ministry of Foreign Affairs 2010). The date probably refers to the Ethiopian calendar, and would be 1894–1895 on the Roman calendar. This could explain Pankhurst's (1985, p. 208) note that the Grand Palace's new reception hall, *addārāš,* the construction of which began in 1897, had '16 clusters of electric lights'. A private German company supplied Dar-es-Salaam, German East Africa's[1] (Tanzania) administrative centre, with electric street lights from wood-fired steam turbines before the turn of the twentieth century (Byatt 1920). In the south, British settler Cape Colony's (South Africa) diamond mining centre, Kimberly, was the first African city with electric street lights in 1882 (Eskom 2009). Cape Town had electric lights within a decade, a coal-fired plant to supply electricity in 1894, and electric tram service in 1896 (Gardener 1922; Palser 2008, 2009; Worth 1998). Electricity plants, rather than isolated generators, began to spread. In the British Colony of Nigeria a plant containing two 30 kw generator sets was built by the Public Works Department of the Government of Southern Nigeria in 1896 to light Government House and the immediate vicinity from 6pm to 11pm (Manafa 1979 cited in Kuruk 1989). The French Protectorate of Tunisia's first electricity plant at La Goulette was built in 1902 by a concessionaire who provided gas to Tunis. Other companies followed with generation plants in the cities of Sousse (1905), Sfax (1907), Ferryville (1909) and Bizerte (1911) (Cecelski *et al.* 2005). In central Africa, a small thermal station was established in 1906 at Livingston, British North-Western Rhodesia (Zambia) on the bank of the Zambezi River (ZESCO 2002). Electricity production proliferated in the early twentieth century with increased commercial and administrative demand.

Initially, generating electricity was primarily, but not exclusively, a private sector activity. Colonial governments were more interested in territorial control than infrastructure building. For example, British Gold Coast's (Ghana) electricity supply began with diesel generators installed, owned, and operated by industrial establishments (mines and factories) and other businesses, as well as municipalities (RCEER 2005). There were no bids in 1914 for government concessions to provide electricity to British Uganda Protectorate's Kampala township, which lacked a mining or industrial base. Government, 'feeling a heavy strain' on finances, decided to 'leave [the project] in abeyance' (Jackson 1914). There are also examples of publicly owned and operated municipal plants during the first decades of the twentieth century. Cape Town switched from proliferating private gas companies to a central municipal electricity generation station. The Cape Town Municipal Amendment Act No. 28 of 1902 guaranteed the city's 'sole right to sell and distribute electric energy within its own area' (Gardener 1922). In 1914 the Gold Coast's first public electricity supply was inaugurated by the government-owned Gold Coast railway system at Sekondi, the railway's headquarters (RCEER 2005).

At the end of World War I (1914–1918), Germany's African colonies were divided between France and Britain, with the exception of South West Africa (Namibia), which became a League of Nations Mandate supervised by the Union of South Africa. British colonial policy became more interventionist. Tanganyikan administrators decided to implement old German plans for a new electricity generating plant in Dar-es-Salaam, with a switch from wood to oil if more economical. The plant was to be run by the Department of Electricity because it generated revenue for the government, and potential customers were being turned away (Byatt 1920; Electricity Power Supply 1920). The Gold Coast's public electricity system was extended to Takoradi in 1928 (RCEER 2005). This was the same year that a single diesel generator was installed at Falconbridge, Freetown by the government of the British Colony of Sierra Leone (Olu-Wright 1968). Although 'miniscule in amount' (Simpson 1969), by 1940 the Southern Nigerian government and Native

Administration had provided electricity as a social amenity in major towns and scattered administrative and commercial centres with expatriate populations (Simpson 1969; Kuruk 1989). The largest electricity generation facility was owned and operated by the African Timber and Plywood Company, and used 'wood waste' to fuel a generator that supplied electricity to its mills and the adjacent port town of Sapele (Simpson 1969). Commercial demand stimulated further public and private thermal plant construction, but fuel availability constrained expansion.

Hydroelectricity: minerals and mining

African hydropower began as small generators placed in water courses by individuals, commercial ventures and municipalities. In 1880 the Cape Colony's Hydraulic Engineer John Gamble recommended installation of a water driven turbine at Cape Town's Molteno reservoir to provide the city with electricity. The plan was not implemented until 1897, when water flowing from the newly constructed Woodhead reservoir on Table Mountain provided power to drive the Pelton wheels (turbines) situated on the lower reservoir (Palser 2009; for photo see Eskom 2009). The majority of generator sets were installed in free-flowing rivers. Before World War I, German East Africa had two small hydroelectric plants, one at Hale's Falls on the Pangani River supplying a sisal factory, and another at Moshi for municipal lighting (Richards 1947). British East Africa's Nairobi Electric Power and Lighting Company constructed the Ruiru Hydro Electric Plant on the Ruiru River in 1908 to serve Nairobi (Richards 1947). A French company built a 130 hp (0.096 MW) capacity plant on the Bou Sellam River in the French colony of Algeria to supply its zinc concentrating plant in 1911. According to Pankhurst (1985), the first Ethiopian hydropower installation was on the Akaki River about 19 miles from Addis Ababa. It consisted of two 14 horsepower dynamos supplied by a Manchester firm. This is, perhaps, the 'small generating plant on the Awash River' reported by the US Geological Survey (USGS 1921a), the Akaki being a tributary to the Awash River. Between 1912 and 1914, officials in the East African Protectorate concerned about Nairobi's limited electricity supply corresponded with the Colonial Office in London about water rights and permits to use Thika River falls for hydro-electric generation; the Ndula I power plant was built in 1925 (Belfield 1914a; Burstall and Monkhouse 1914; Higlett 1914; Richards 1947). Mining consultant H. W. Laws recommended the purchase of tin mining leases on Nigeria's Jos Plateau that would include the N'gell River's Kwall Falls for hydropower production in 1910 (Laws 1910), but it was not until 1923 that the high transportation costs of Nigerian coal and imported oil costs prompted the installation of a 'simple 2 MW run-of-the-river hydro-electric generator' (Simpson 1969).

It took several decades of experience for colonial officials and businessmen to appreciate fully the seasonal nature of most African rivers; uneven flow plagued run-of-the-river electricity production. The Bou Sellam generator could not be operated in the summer months, 'demonstrating' the limits of hydroelectric generation without a storage dam in North Africa (USGS 1921b). In west central Africa, the 'partially developed' hydropower site on the Katumbela (Catumbela) River in the Portuguese Province of Angola fluctuated with seasonal flow from 4,000 hp to 20,000 hp (3–15 MW) (USGS 1921b). Further north, the private Nigerian Electricity Supply Company (NESCO) was operating an earthfill dam at Kurra Falls to generate 8 MW of electricity (Jimoh pers. comm. 2011) in 1929. The East African Ruiru Hydro-electric Plant was credited with having 'revealed' to the British the difference between African and European rivers, and was dismantled in 1933 (Richards 1947). Dam construction solved these problems. Impoundment increased electricity by ensuring reliable water flow, while dam walls increased hydraulic head. The 1912 raising of Egypt's Low Aswan Dam, for example, prompted a consortium of German and Italian companies (Società Generale per la Cianamide) to propose adding hydroelectric generation and an adjacent nitrogen fertilizer factory (Larkins 1927; Selous 1938).

Before the outbreak of World War I, the idea of large African hydroelectric plants existed. When British Under-Secretary for the Colonies Winston Churchill visited Uganda's Owen's (Nalubaale) Falls in 1907, he imagined the Nile 'beginning its journey to the Mediterranean' through a generator at Jinja, near the river's source in Lake Victoria (Olivier 1976). Hydroelectric dams are expensive to build because, unlike thermal plants, they require significant sums of money in advance of generation as well as assured markets. The magnitude of central African hydro-electric potential was a tantalizing frustration for turn of the twentieth century colonial governments because there were no identifiable customers within range of transmission. Large hydroelectric plants remained a fantasy until technological improvements and the development of industrial and manufacturing bases created economic viability.

The greatest stimulus to hydropower development was mineral exploitation. The explicit relationship between minerals and power, and between oil and water as power sources, was asserted in the 1921 United States Geological Survey (USGS) report *World Atlas of Commercial Geology*, Part II: *Water Power of the World* (USGS 1921b, p. 3):

> The development of the mineral resources of the world depends upon the local availability of cheap mechanical or electrical energy. In many regions such energy must be obtained from water flowing in surface streams; in others it must be generated from fossil fuels. The value of a mineral in the ground is intimately related to the source of the energy needed to recover it for commercial use. A knowledge of the water-power resources of the world is therefore essential to a proper study and utilization of the mineral resources. Furthermore, water power and mineral fuels will compete with each other in determining the selection of sites for manufacturing industries and in their development.

Water Power of the World provided the most comprehensive world survey of hydropower potential, continent by continent, and river by river. It noted that Africa held one-half of the world's hydroelectric potential, and the Congo Basin more than one-quarter (USGS 1921b, p. 33). The Congo Basin also contained deposits of copper and other minerals extending from Belgian Congo's Katanga Province into Northern Rhodesia, an area that became known as the Copperbelt.

Hydropower surveys were made for colonial governments. 'Water power resources in Southern Rhodesia' (Zimbabwe) was published by Southern Rhodesia's Hydrographic Engineer in 1925 (Anderson *et al.* 1960). The Gold Coast's Geological Survey of that year described hydroelectric possibilities on the Bui River (Kitson 1925). Guided by its ambassadors, the Egyptian government sent Egyptian engineers on an international hydroelectric study tour (Larkins 1927). In 1930 Frank Melland urged the British Royal Geographical Society to survey African waterfalls' potential to supply hydroelectric power for imagined railway systems (Melland 1932). Studies of specific hydropower sites were made before and after World War II (1939–1945), such as Hughes and Naylor's of Kenya's Tana River in 1935, and the East African government's consulting engineering report on Upper Nile/Nile Victoria hydropower sites (Richards 1947). The East African Governors Conference ordered a report on the hydroelectric resources of Kenya, Uganda and Tanganyika in 1946 (Richards 1947). Colonial governments in the Belgian Congo, Southern Rhodesia and Gold Coast ordered hydropower surveys for the Congo, Lunsemfwa, Zambezi and Black Volta rivers, respectively (Kitson 1925; *L'aménagement hydro-électrique du site d'Inga* 1957; Anderson *et al.* 1960; Olivier 1976).

Mining companies first built small dams and hydroelectric plants in the 1920s. Britain's Prince of Wales opened the Broken Hill Development Company's 2 MW Mulungushi plant on the Mulungushi River, Protectorate of Northern Rhodesia (Zambia), in 1925 to supply the lead–zinc mining complex at Broken Hill (Kabwe) (Bureau of Foreign Commerce 1956; Olivier 1976; Mihalyi 1977). The increasingly large and concentrated industrial demand for electricity on the Jos Plateau led to the formation of the Nigeria Electricity Supply Company (NESCO) which took over the existing Kwall station and also built a 'hydro-electric system' at Kurra Falls in 1929. By 1939, NESCO produced more electricity than the rest of Nigeria. Most was consumed by the tin mines and concentrating plant (Simpson 1969). Private small-scale hydro plants continued to be built in British territories during the 1930s, such as the Mesco hydro plant on Kenya's Maragua River and a tin mine's small plant on Uganda's Kagera River near Kigati (Richards 1947). Although essential in some locations, the era of small-scale generating plant construction ended in the 1920s as technological advances made centralized generation with transmission of large quantities of electricity over distances of 322 km commercially viable (Carpenter 1929).

During the 1930s the significance of African hydropower for European economies increased with expanding requirements for energy-intensive processes such as refining copper and aluminium. World War I had shown the advantages of aluminium in weaponry, and between 1927 and 1930 there was an international copper boom. So important was hydroelectricity that plants were built during World War II. In British colonies, the Ndula II hydro station was constructed on Kenya's Thika River, and the first stage of the Lumsemfwa River hydroelectric scheme at Mita Hills, a 12 MW run-of-the river plant, ensured electricity supplies to the Broken Hills mines (Richards 1947; Olivier 1976; ZESCO 2002). Ethiopia's 3 MW Aba Samuel hydro plant became operational in 1941 (Ministry of Foreign Affairs 2010).

Large dams and long distance transmission

Expanded colonial hydroelectric generation was stimulated by the post-World War II rearmament's growing demand for minerals, European reconstruction programmes, and the associated economic boom in Europe and North America. A looming European energy shortage and expanding market for energy-intensive products – especially aluminium – refocused attention on the processing and manufacturing potential of Europe's overseas territories (Colonial Primary Products Committee 1947). The energy-intensive aluminium industry had been associated with hydroelectric dam construction since their commercialization at Niagara Falls, USA (Muller 1945). Aluminium processing plants were used to justify African hydroelectric dams even in the absence of local sources of bauxite. Edgerton's (2007) technological futurology guided plans for large (wall height and length) dams. The grandest was Belgium's to dam the entire lower Congo River at Inga Falls, the site noted in the 1921 world survey. Because the economical transmission limit for electricity in the 1950s was 500 km, and losses from long-distance transmission lines were estimated at 70 per cent, it was not feasible for the proposed Grand Inga to supply Katanga's mines 1700 km to the east. Instead, proposals were drawn up to move European electricity-intensive processing and manufacturing enterprises (including aluminium, ferro-alloy and other metals and uranium enrichment) to new industrial sites, duty free zones and deep water ports to be constructed along the Congo River's estuary and mouth (Cotton 1957; see Showers 2009 for details). A 'Congolese Ruhr' would be created (Belgian Congo and Ruanda-Urundi Information and Public Relations Office, 1959), supplied by Inga Falls just 150 km inland (in a straight line) from the coast. Studies and plans made through the 1950s were not implemented (Showers 2009). 'Negligible by comparison' was an aluminium company consortium's proposal for a hydroelectric dam across the Volta River at Ajena, Gold Coast to power a bauxite processing plant (Tollintos 1955). Like the Congolese Ruhr, this industrial site would be near the generation plant.

In contrast, the Zambezi's Kariba Gorge was in a remote location on an international river whose use was constrained by international law. Dam construction there proved to be significant for British African colonialism, African hydropower development, and increased continental electrification. Although equidistant between Northern Rhodesia's mining areas and Southern Rhodesia's industry, there was no road to Kariba. The 1936 closure of America's Hoover Dam (wall height 221 m) had provided a model for remote sites supplying distant locations. But the dammed Colorado River flowed largely inside the USA's national boundaries. Few concessions had been made to significantly less powerful Mexico downstream. Damming the Zambezi required international negotiation. An August 1949 conference in Johannesburg was followed in November by discussions with the Portuguese about using the river's upper and lower reaches (Baker 1950; Lambert 1950). The next year, at a 30–31 May Technical Conference on the Development of the Zambezi River, agreements were reached about minimum flow regimes (Acting Chief Secretary 1955; Cox 1955).

After international agreement, pioneering engineering was required. The renowned French concrete arch dam designer André Coyne was asked in1954 to review plans drawn up by the Inter-Territorial Power Commission (Southern and Northern Rhodesia) (Olivier 1976). The previous year the Rhodesias had been incorporated into the Federation of Rhodesia and Nyasaland (Zambia, Zimbabwe and Malawi), and was looking for a prestige project (Clements 1960; Hall 1965). Strengthened by Coyne's advice, the Federation decided to proceed with Kariba Dam. Although Morocco's 1953 Bine El Ouidane Dam (also designed by Coyne) on the El Abid River had a higher wall (133 m), when Kariba's wall (128 m) was closed in 1959, it created the largest man-made lake in the world. Connecting a 'remote, undeveloped site' with urban and mining areas more than 550 km away using 330 kV transmission lines was a technological breakthrough that confirmed Britain as a major dam-building nation (Scott Laing 1957; Federal Power Board 1959; Anderson *et al.* 1960; Olivier 1976). From then on, large African dam construction could be financed by – and supply – distant markets. The era of large-scale African hydroelectricity had begun, and urban areas' exploitation of distant ecosystems increased (Showers 2002).

This breakthrough coincided with the spread of River Basin Planning – the idea of managing an entire river for human benefit – defined narrowly as navigation, irrigation, hydroelectric power production and flood control. Originally expressed bureaucratically in the USA's 1930s depression era Tennessee Valley Authority (TVA), river basin planning and its multi-purpose dams were formally embraced as a development tool in the 1950s after the UN Secretary General's 1956 declaration that 'river basin development was recognized as an essential feature of economic development', and a panel of experts reported in 1957 that individual water projects rarely succeeded outside of the context of drainage basin planning (Teclaff 1996, p. 368). According to Hoag and Öhman (2008), one of Africa's first river basin plans was the collaboration between the British East African government and FAO in the Rufiji Basin Survey (1954–1961). Despite the absence of hydropower plans, topographic surveys of dam sites were included (Hoag and Öhman 2008). In 1958 the Nigerian Government and the newly formed Electricity Corporation of Nigeria (ECN) authorized a study of the hydroelectric potential of the Niger River to be implemented jointly by the Netherlands Engineering Consultants (NEDECO), who had investigated the Benue and Niger Rivers for navigational purposes in 1953, and British consulting engineers Sir Alan Gibb and Partners, who had made the initial dam survey. Their mandate also included evaluation of river navigation, flood control and irrigation (for details see Simpson 1969). After the first shipment of oil from Port Harcourt Nigeria in 1958, the Nigerian government ordered a comparative cost analysis between the recently proposed hydropower projects for the Niger River and thermal plants fuelled by under-used natural gas from the oil fields. The report, issued in 1960, endorsed a series of three integrated multi-purpose dams as the cheapest fuel because of the many predicted benefits; natural gas would serve as an auxiliary fuel source (Simpson 1969). River basin planning spread across the continent (see Adams 1992 for West Africa). Most river basin planning dams were constructed for irrigation, but some were primarily for, or had capacities of, hydroelectricity generation.

Hydropower, political power and continental proliferation

Leaders of newly independent African nations were enthusiastic about hydroelectriticy. Kwame Nkrumah, Africa's first president of an independent country, Ghana, fully accepted colonial, private sector plans for the Akosombo dam at Ajena on the Volta River (Report of the Preparatory Commission 1952; Kuruk 1989). Tanzania's Julius Nyrere similarly considered hydropower to be a tool for economic liberation and development. The Second Five-Year Plan emphasized electricity's importance for industrial development. Nyrere commissioned surveys of the Rufiji River basin's hydropower potential in the 1960s and 1970s, resulting in six hydroelectric dams, as well as plans for a very large dam at Stiegler's Gorge (Hoag and Öhman 2008). Cold War and Middle Eastern politics were manifested in the mid-1950s' Egyptian decision to build the High Aswan Dam on the Nile. After the withdrawal of western aid, Egypt received financial and technical assistance from the Soviet Union and Czechoslovakia. The 1970 dam had the continent's largest installed generation capacity, 2100 MW. The second largest capacity came from revived colonial plans. Zaire's first president, Mobuto Sese Seko (née Joseph Désiré Mobutu), embarked on the first stage of Belgian plans for Grand Inga with two "small" dams in an adjacent river valley. When the 1972 Inga I's 351 MW were combined with Inga II's 1,424 MW in 1982, the total was close to Aswan's installed capacity. Unlike Egypt, where national electrification was a policy objective, the Ingas' power was to supply Katanga's European-owned copper mines using new long-distance transmission technology. Hydroelectric dam construction for economic (largely industrial) development became a feature of most independent African nations.

As symbols, large dams were also contested politically, especially in former Portuguese and British central and southern Africa, where minority rule continued after the colonial era had ended (Showers 1998, 2001). With the collapse of the Federation of Rhodesia and Nyasaland, and Northern Rhodesia's Independence, tensions grew over Kariba. The turbines were located on the Southern Rhodesian side. After racist Southern Rhodesia's 1965 Unilateral Declaration of Independence in 1965 brought World Bank loan repayments into question (Lynch 1964; Anonymous 1968; Leech 1968; Olivier 1976), there was international support for Zambia's construction of an alternative on the Kafue River (Kafue Hydroelectric Scheme with Itezhitezhi storage dam). That same year the Portuguese Ministry of Overseas Development created the Grupo de Trabalho para o Zambeze to finalize technical and financial studies of the Cabora Bassa (Cahora Bassa) dam. It could be financed by selling electricity to Apartheid South Africa. A technological advance – a Swedish thyristor valve – enabled transmission from the lower Zambezi River near the Indian Ocean 1400 km inland to a South African electricity sub-station at Pretoria. When closed in 1975, Cabora Bassa represented not only a technological breakthrough, but also the resolve of racist minority governments. It was attacked while under construction by Mozambican independence fighters; after independence, transmission lines were sabotaged by South African anti-apartheid guerillas (Bolton 1983; Borges Coelho 1993; Isaacman and Sneddon 2000). In both colonial and independence eras, hydroelectric dams were also opposed on environmental grounds by people whose land or lives would be destroyed. Initially, dissent was criminalized or ignored (for Kariba, see Robbins and Legge 1959; Howarth 1961; Colson 1971; Tremmel 1994). In the late twentieth century, however, voices of rural people were amplified by international connections (e.g., International Rivers Network, IRN). Coalitions of local people with European and North American NGOs had greater access to the international financial institutions funding large dam construction. When formalized as the World Commission on Dams, documentation of local struggles and perspectives on social and environmental consequences was more widely circulated and influential.

While a detailed account of each nation's hydroelectricity development is far beyond the scope of this article, general trends can be discussed from tables. The best publically available list of African dams with locations and some properties is the 2006 FAO database, Aquastat. This self-described incomplete list contains partial, and sometimes unverified, information for 1,281 dams in 37 continental African nations, but does not include all dams mentioned in this article. Entries for 1,079 dams provide dates of closure (completion) or commissioning (generation), 116 of which are identified as electricity-generating. Four tables were constructed from the former subset. The data are grouped in conventional geographic regions – north, west, east, central and southern – and according to division under colonialism, although current country names are used. No attempt was made to correct or update the data set.

Table 1 shows the number of dams constructed by colonial and independent governments in each decade from before the 1920s to the mid-2000s. This table demonstrates that while nationally important, electricity was not the major reason for dam building; only 116 (11%) had generation capabilities. Water control and irrigation were the primary justifications. Of all dams constructed, 714 (66%) were in British or former British territories, and 306 (28%) in French or former French territories. However, more hydroelectric dams were built in regions dominated by France (50, or 43%) than Britain (36, 31%). The very large number of dams in British territories reflects settler attempts to mitigate persistent water shortage in South Africa and, to a lesser extent, in Southern Rhodesia.

The most striking trend is the sharp increase in dam numbers from the 1950s, reaching a zenith in the 1980s. This can be explained by a combination of political, economic and technical factors. The 1950s was the last decade of colonialism in most of Africa, as well as the period when, internationally, large dam construction and long distance transmission technologies began to make significant advances. It has been argued that because dams were symbols of state power (Colson 1971), large dam construction increased as African nationalism strengthened (Showers 1998, 2001). Portugal fought to retain its colonies until 1975. From the 1950s, when nationalist struggles became pronounced, through the 1970s, it built 11 hydroelectric and 20 irrigation dams in Angola and Mozambique. Independence and majority rule did not reach Rhodesia, South West Africa and South Africa until the last decades of the twentieth century (1980, 1990 and 1994, respectively). Water control, with dam construction as a central feature, was a major government activity. Apartheid South Africa implemented 1960s plans for river engineering, including the Orange River Project's two hydroelectric dams. In contrast, the 1962–1963 South African Odendaal Commission's programme for exploiting the Cunene River (South West Africa-Angola border) was only partially implemented before independence struggles halted construction (Castelinho 1972; Bender 1978; Lau and Stern 1990). The Ruacana Diversion weir generated electricity until sabotaged. Other plans remained in filing cabinets until revived and promoted by the independent Namibian government in the 1990s as examples of modernity and progress (Showers 1998, 2001). Implementation was then resisted by citizens on cultural and environmental grounds (Meissner 2005).

Despite the significance of dams to colonial governments, only 265 (25%) of the dams covered by Table I were built before the 1960s: 57 (22%) in French colonies and 194 (73 per cent) in British. Thirty-seven (14%) generated electricity. Of these,

Table 1. African hydroelectric and all dams by colonizer, region and decade, <1920–mid-2000s.

		<1920s	<1920s	1920s	1920s	1930s	1930s	1940s	1940s	1950s	1950s
		H	A	H	A	H	A	H	A	H	A
Britain	North	0	2	1	1	2	3	0	0	0	0
	West	0	0	1	1	1	1	0	0	0	0
	East	0	0	0	0	0	0	0	1	1	2
	Central	0	1	1	3	0	2	0	5	2	9
	Southern	0	24	0	17	0	24	0	20	0	78
Britain totals		**0**	**27**	**3**	**22**	**3**	**30**	**0**	**26**	**3**	**89**
France	North	0	1	1	2	3	14	1	3	8	13
	West	0	0	1	1	0	1	0	3	2	18
	Central	0	0	0	0	0	0	0	0	1	1
France totals		**0**	**1**	**2**	**3**	**3**	**15**	**1**	**6**	**11**	**32**
Portugal	**(central)**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**7**
Belgium	**(central)**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**5**	**5**
Italy	North	0	0	0	0	0	0	0	0	0	0
	East	0	0	0	0	0	0	0	0	0	0
Italy totals		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Uncolonized		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
DAM TOTALS		**0**	**28**	**5**	**25**	**6**	**45**	**2**	**33**	**24**	**134**

		1960s	1960s	1970s	1970s	1980s	1980s	1990s	1990s	2000s	2000s	Totals	Totals
		H	A	H	A	H	A	H	A	H	A	H	A
Britain	North	2	2	1	1	0	0	0	0	0	0	**6**	**9**
	West	4	10	0	25	6	22	0	6	0	0	**12**	**65**
	East	2	2	3	3	3	9	1	4	0	1	**10**	**22**
	Central	0	21	2	35	0	29	0	0	0	0	**5**	**105**
	Southern	0	100	1	115	2	126	0	8	0	1	**3**	**513**
Britain totals		**8**	**135**	**7**	**179**	**11**	**186**	**1**	**18**	**0**	**2**	**36**	**714**
France	North	4	21	4	13	3	67	2	42	1	10	**27**	**186**
	West	4	30	5	34	8	30	0	0	0	0	**20**	**117**
	Central	0	0	1	1	1	1	0	0	0	0	**3**	**3**
France totals		**8**	**51**	**10**	**48**	**12**	**98**	**2**	**42**	**1**	**10**	**50**	**306**
Portugal	**(central)**	**2**	**6**	**4**	**7**	**2**	**4**	**0**	**0**	**0**	**0**	**13**	**24**
Belgium	**(central)**	**0**	**0**	**0**	**0**	**7**	**7**	**1**	**1**	**0**	**0**	**14**	**14**
Italy	North	0	0	0	6	0	4	0	0	0	0	**0**	**10**
	East	0	1	0	0	0	0	0	0	0	0	**0**	**1**
Italy totals		**0**	**1**	**0**	**6**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**11**
Uncolonized		**2**	**2**	**1**	**3**	**0**	**0**	**0**	**4**	**0**	**0**	**3**	**10**
DAM TOTALS		**20**	**195**	**22**	**243**	**32**	**299**	**4**	**65**	**1**	**12**	**116**	**1079**

Data source: FAO (2006).
Notes: H = hydroelectric dams; A = all dams (including hydroelectric).
British North = Egypt, Sudan; British West = Ghana, Nigeria, Sierra Leone; British East = Kenya, Tanzania, Uganda; British Central = Malawi, Zambia, Zimbabwe; British Southern = Botswana, Lesotho, Namibia, South Africa, Swaziland. French North = Algeria, Morocco, Tunisia; French West = Benin, Burkina Faso, Cameroon, Côte d'Ivoire (Ivory Coast), Guinea, Mali, Mauritania, Senegal, Togo; French Central = Congo Republic, Gabon; Portugal = Angola, Mozambique; Belgium = Democratic Republic of Congo (DRC). Italy = Libya, Eritrea. Italy's brief claim to Ethiopia has been ignored. Contrary to Aquastat, DRC dams are listed as hydroelectric dams, but consistent with Aquastat, Inga II is counted in the 1970s.

Table. 2. Hydroelectric and all dams in African settler territories by colonizer, region and decade, <1920– mid-2000s.

SETTLER			<1920 H	<1920 A	1920s H	1920s A	1930s H	1930s A	1940s H	1940s A	1950s H	1950s A
Britain	East	Kenya	0	0	0	0	0	0	0	1	0	1
		E. Total	0	0	0	0	0	0	0	1	0	1
	Central	Malawi	0	0	0	0	0	0	0	0	1	1
		Zimbabwe	0	1	0	2	0	2	0	5	1	8
		Zambia	0	0	1	1	0	0	0	0	0	0
		C. Total	0	1	1	3	0	2	0	5	2	9
		S. Africa	0	24	0	17	0	22	0	20	0	75
		Namibia	0	0	0	0	0	2	0	0	0	3
		Botswana	0	0	0	0	0	0	0	0	0	0
		Swaziland	0	0	0	0	0	0	0	0	0	0
		S. Total	0	24	0	17	0	24	0	20	0	78
Britain settler totals			**0**	**25**	**1**	**20**	**0**	**26**	**0**	**26**	**2**	**88**
France	North	Algeria	0	1	0	0	0	8	0	2	1	3
		Tunisia	0	0	0	1	0	0	0	0	3	5
		Morocco	0	0	1	1	3	6	1	1	4	5
France settler totals			**0**	**1**	**1**	**2**	**3**	**14**	**1**	**3**	**8**	**13**
Italy settler totals												
	North	Libya	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Portugal	Central	Angola	0	0	0	0	0	0	0	0	3	3
		Mozambique	0	0	0	0	0	0	0	0	2	4
Portugal settler totals			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**7**
SETTLER TOTAL			**0**	**26**	**2**	**22**	**3**	**40**	**1**	**29**	**15**	**108**

SETTLER			1960s H	1960s A	1970s H	1970s A	1980s H	1980s A	1990s H	1990s A	2000s H	2000s A	**Totals H**	**Totals A**
Britain	East	Kenya	1	1	2	2	2	8	1	4	0	1	**6**	**18**
		E. Total	1	1	2	2	2	8	1	4	0	1	**6**	**18**
	Central	Malawi	0	1	0	0	0	0	0	0	0	0	**1**	**2**
		Zimbabwe	0	20	0	33	0	29	0	0	0	0	**1**	**100**
		Zambia	0	0	2	2	0	0	0	0	0	0	**3**	**3**
		C. Total	0	21	2	35	0	29	0	0	0	0	**5**	**105**
		S. Africa	0	94	1	104	1	119	0	1	0	0	**2**	**476**
		Namibia	0	2	0	7	0	2	0	2	0	0	**0**	**18**
		Botswana	0	1	0	1	0	1	0	3	0	0	**0**	**6**
		Swaziland	0	1	0	3	1	3	0	1	0	1	**1**	**9**
		S. Total	0	98	1	115	2	125	0	7	0	1	**3**	**509**
Britain totals			**1**	**120**	**5**	**152**	**4**	**162**	**1**	**11**	**0**	**2**	**14**	**632**
France	North	Algeria	1	4	0	3	0	22	0	8	0	3	**2**	**54**
		Tunisia	1	12	0	2	1	14	0	1	0	0	**5**	**35**
		Morocco	2	5	4	8	2	31	2	33	1	7	**20**	**97**
France totals			**4**	**21**	**4**	**13**	**3**	**67**	**2**	**42**	**1**	**10**	**27**	**186**
Italy	North	Libya	**0**	**0**	**0**	**6**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**10**
Portugal	Central	Angola	2	4	2	3	2	4	0	0	0	0	**9**	**14**
		Mozambique	0	2	2	4	0	0	0	0	0	0	**4**	**10**
Portugal totals			**2**	**6**	**4**	**7**	**2**	**4**	**0**	**0**	**0**	**0**	**13**	**24**
SETTLER TOTAL			**7**	**147**	**13**	**178**	**9**	**237**	**3**	**53**	**1**	**12**	**67**	**852**

Data source: FAO (2006).
H = hydroelectric dams; A = all dams (including hydroelectric).

Table 3. Hydroelectric and all African dams in non-settler territories by colonizer, region and decade, <1920-mid-2000s.

			<1920	<1920	1920s	1920s	1930s	1930s	1940s	1940s	1950s	1950s
NON-SETTLER			H	A	H	A	H	A	H	A	H	A
Britain	North	Egypt	0	2	0	0	1	2	0	0	0	0
		Sudan	0	0	1	1	1	1	0	0	0	0
	West	Nigeria	0	0	1	1	1	1	0	0	0	0
		Sierra Leone	0	0	0	0	0	0	0	0	0	0
		Ghana	0	0	0	0	0	0	0	0	0	0
	East	Uganda	0	0	0	0	0	0	0	0	1	1
		Tanzania	0	0	0	0	0	0	0	0	0	0
	Southern	Lesotho	0	0	0	0	0	0	0	0	0	0
Britain totals			**0**	**2**	**2**	**2**	**3**	**4**	**0**	**0**	**1**	**1**
France	West	Benin	0	0	0	0	0	0	0	0	0	0
		Burkina Faso	0	0	0	0	0	1	0	2	0	16
		Cameroon	0	0	0	0	0	0	0	0	1	1
		Côte d'Ivoire	0	0	0	0	0	0	0	0	1	1
		Guinea	0	0	0	0	0	0	0	0	0	0
		Mali	0	0	1	1	0	0	0	1	0	0
		Mauritania	0	0	0	0	0	0	0	0	0	0
		Senegal	0	0	0	0	0	0	0	0	0	0
		Togo	0	0	0	0	0	0	0	0	0	0
	Central	Congo Rep.	0	0	0	0	0	0	0	0	1	1
		Gabon	0	0	0	0	0	0	0	0	0	0
France totals			**0**	**0**	**1**	**1**	**0**	**1**	**0**	**3**	**3**	**19**
Belgium	Central	DRC	0	0	0	0	0	0	1	1	5	5
Belgium totals			**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**5**	**5**
Italy	East	Eritrea	0	0	0	0	0	0	0	0	0	0
Italy totals			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Uncolonized		Liberia	0	0	0	0	0	0	0	0	0	0
		Ethiopia	0	0	0	0	0	0	0	0	0	1
UNCOLONIZED TOTALS			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
NON-SETTLER TOTALS			**0**	**2**	**3**	**3**	**3**	**5**	**1**	**4**	**9**	26

9 (24%) were in British territories and 17 (46%) in French colonies. During the 1960s, when long-term projects like dam construction were still directly linked to colonial planning, 195 (18%) dams were closed or commissioned, 20 (17%) of which generated electricity. This accelerated rate of construction undoubtedly reflected new electricity production technologies as well as economic expansion.

Table 1 also clearly indicates independent Africa's eagerness for water control and hydropower. Fifty per cent (542) of all dams were built in the Development Assistance Era of Independence (1970s and 1980s), but only 10 per cent (54) generated electricity. More were built in regions controlled, or once-controlled, by the British (365 or 67%) than by the French (146 or 27%), but slightly more hydroelectric dams (22, 4 per cent) were constructed in French territories than in British (18, 3%). The sharp drop in the number of dams commissioned or closed during the subsequent Neoliberal Era of Independence (1990s and 2000s) – 77 dams (7% of total), including 5 hydroelectric dams (1% of hydroelectric projects) – reflects a range of factors from economic to environmental. Detailed analysis is beyond the scope of this article. That 10 per cent (59) of 619 dams closed or commissioned from the 1970s to 2006 generated electricity, when water control was the major emphasis, may reflect the influence of river basin planning.

While separation by region and decade accounts for major climate differences in a very general way and suggests differing colonial administrative interest, the distinction between settler and non-settler territories is important for interpretation. Tables 2 and 3 refine Table 1's analysis, identifying construction in settler (Table 2), and non-settler (Table 3) regions.

Of the 265 dams closed or commissioned in

(Table 3 Continues)

NON-SETTLER			1960s H	1960s A	1970s H	1970s A	1980s H	1980s A	1990s H	1990s A	2000s H	2000s A	**Totals H**	**Totals A**
Britain	North	Egypt	0	0	1	1	0	0	0	0	0	0	**2**	**5**
		Sudan	2	2	0	0	0	0	0	0	0	0	**4**	**4**
	West	Nigeria	2	6	0	23	5	21	0	6	0	0	**9**	**58**
		Sierra Leone	1	1	0	0	0	0	0	0	0	0	**1**	**1**
		Ghana	1	3	0	2	1	1	0	0	0	0	**2**	**6**
	East	Uganda	0	0	0	0	0	0	0	0	0	0	**1**	**1**
		Tanzania	1	1	1	1	1	1	0	0	0	0	**3**	**3**
	Southern	Lesotho	0	2	0	0	0	1	0	1	0	0	**0**	**4**
Britain totals			**7**	**15**	**2**	**27**	**7**	**24**	**0**	**7**	**0**	**0**	**22**	**82**
France	West	Benin	0	0	0	1	0	0	0	0	0	0	**0**	**1**
		Burkina Faso	0	25	0	14	1	17	0	0	0	0	**1**	**75**
		Cameroon	0	0	3	5	3	4	0	0	0	0	**7**	**10**
		Côte d'Ivoire	1	2	2	14	2	3	0	0	0	0	**6**	**20**
		Guinea	2	2	0	0	0	0	0	0	0	0	**2**	**2**
		Mali	0	0	0	0	1	3	0	0	0	0	**2**	**5**
		Mauritania	0	0	0	0	0	1	0	0	0	0	**0**	**1**
		Senegal	0	0	0	0	0	1	0	0	0	0	**0**	**1**
		Togo	1	1	0	0	1	1	0	0	0	0	**2**	**2**
	Central	Congo Rep.	0	0	1	1	0	0	0	0	0	0	**2**	**2**
		Gabon	0	0	0	0	1	1	0	0	0	0	**1**	**1**
France totals			**4**	**30**	**6**	**35**	**9**	**31**	**0**	**0**	**0**	**0**	**23**	**120**
Belgium	Central	DRC	0	0	0	0	7	7	1	1	0	0	**14**	**14**
Belgium totals			**0**	**0**	**0**	**0**	**7**	**7**	**1**	**1**	**0**	**0**	**14**	**14**
Italy	East	Eritrea	0	1	0	0	0	0	0	0	0	0	**0**	**1**
Italy totals			**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
Uncolonized		Liberia	1	1	0	0	0	0	0	0	0	0	**1**	**1**
		Ethiopia	1	1	1	3	0	0	0	4	0	0	**2**	**9**
UNCOLONIZED TOTALS			**2**	**2**	**1**	**3**	**0**	**0**	**0**	**4**	**0**	**0**	**3**	**10**
NON-SETTLER TOTALS			**13**	**48**	**9**	**65**	**23**	**62**	**1**	**12**	**0**	**0**	**62**	**227**

colonial territories before the Independence Decade, 204 (77%) were for water control in settler colonies, 158 (77%) of which were in South Africa. Twenty-one (8%) generated electricity in settler colonies. Of these, 13 (62%) were in Algeria, Tunisia and Morocco, and 3 (14%) in Northern Rhodesia, Southern Rhodesia, and Nyasaland. Fewer hydroelectric dams were built in British settler territories because southern and central Africa's electricity came from coal-fired thermal plants. During the 1960s when 195 dams came into operation, 147 (75%) were in settler colonies, seven (5%) of which generated electricity. One was in the British sphere of influence (Kenya), and 4 in the French (Algeria, Tunisia and Morocco).

In contrast, Table 3 shows that while only 40 (15%) of the 265 dams built before the 1960s were in non-settler territories, 16 (40%) were hydroelectric dams. Of these, nine (56%) operated in British territories (Egypt, Nigeria, Sudan, Uganda), four (25%) in French (Cameroon, Congo Republic, Côte d'Ivoire, Mali) and six (38%) supplied Belgian Congo. This reflects the dominance of mining and mineral processing in non-settler colonies, and Central African copper mining in particular. Table 4 summarizes the difference between settler and non-settler dam construction.

More dams for water control were built in settler societies (204, 90%) than non-settler (24, 10%) through the 1950s, but only slightly more hydroelectric dams in settler (21, 57%) than non-settler (16, 43%) territories. Although more hydroelectric dams were commissioned or closed after the 1960s (59, 61%) than before (37, 39%), many more were built for water control: 228 (29%) before the Independence Decade, but 560 (71%) afterwards. Water management remained the primary justification for dam construction.

Table 4. Summary hydroelectric and all African dams in non-settler territories by colonizer, region and decade, <1920– mid-2000s.

NON-SETTLER	<1920 H	<1920 A	1920s H	1920s A	1930s H	1930s A	1940s H	1940s A	1950s H	1950s A
Non-settler totals	0	2	3	3	3	5	1	4	9	26
Settler totals	0	26	2	22	3	40	1	29	15	108
Total dams constructed	0	28	5	25	6	45	2	33	24	134

	1960s H	1960s A	1970s H	1970s A	1980s H	1980s A	1990s H	1990s A	2000s H	2000s A	**Totals** **H**	**Totals** **A**
Non-settler totals	13	48	9	65	23	62	1	12	0	0	**62**	**227**
Settler totals	7	147	13	178	9	237	3	53	1	12	**54**	**852**
Total dams constructed	20	195	22	243	32	299	4	65	1	12	**116**	**1079**

Public good or commodity?

Electricity's varying identity as essential infrastructure, public good or tradable commodity determined its spread. In the beginning, provision was very local. With expanding markets and technological possibilities came a need to clarify who would provide electricity to whom, and for how much. In British colonial Africa, electric utilities were established as public corporations, but with a certain autonomy. Their existence, as has been demonstrated, did not preclude private sector generation (Kuruk 1989). Regulation began in the Cape Colony. Cape Town's 1895 Electric Light and Power Act established municipal, rather than private, supply. Although first, this legislation did not prove to be a model for the continent – or for British territories. In 1903 the British East African Protectorate adopted India's first attempt to legislate electricity provision, the Electricity Act, Act No. XIII of 1887 (Eliot 1903). Seven years later the Afrikaner South African Republic/Transvaal's Transvaal Power Act of 1910 licensed private electricity providers and regulated prices (Price 1922). In 1914, Kenya's Governor Belfield (1914b) noted that power stations on the Ruiru River were not to supply electricity farther than 2 miles, and only for the development of properties. Commercial generation was not allowed, as a monopoly concession had been granted. Gold Coast's Electricity Supply Ordinance of 1920 granted extensive powers to regulate the supply of electricity not only in the Colony, but also in Ashanti and the Northern Territories (Kuruk 1989).

The first British African colonies to leave colonial status were Cape and Natal. They joined Afrikaner Transvaal and Orange Free State in 1910 to form the British Dominion of the Union of South Africa. Electricity provision and railway expansion were priorities for the new government. Stimulated by European experiences of reduced transport costs when railways switched from steam to electricity, Charles Mertz was asked, in 1919, to report on electricity generation and South African railway electrification (Lewis 1931; ESCOM 1949). Central to discussion of his report was whether electricity should be a public good or privately controlled commodity. Outside of municipally-supplied Cape Town (and especially on the Witwatersrand), electricity was provided by competing private companies following patterns established in Britain and the USA, the latter 'in electrical matters, ... probably the most progressive in the world' (Price 1922, p. 35). A committee charged with drafting an electricity bill was expected to use the Electricity (Supply) Act 1919 (Great Britain) as its model (Dew 1922). Instead, the Commission was impressed by the Canadian Province of Ontario's publically owned Ontario Hydro-Electric Power Commission. Selling electricity at cost price had stimulated both rural and industrial development (General Manager South African Railways 1922). ESCOM – the Electricity Supply Commission of South Africa – was established in 1923. Its mandate of publicly providing cheap electricity for economic development was restricted to European interests; most people continued to live with candles, coal, and kerosene.

Grids, institutions and networks

Increased transmission capabilities enabled interconnection of power stations and electricity grids. At first grids were small, servicing municipalities, mines and industries. Expansion was largely driven by industrial and mining demand (for discussion of Nigeria's post World War II colonial grid expansion see Simpson 1969). Electricity was generally reserved for Europeans by pricing and restricted grid design, but in some places majority populations were officially blocked. Police in 1950s Algeria were charged with preventing residents of informal settlements accessing services – from water and sewerage to electricity (Knight 1953). Kariba demonstrated how improved technology could connect widely separated islands of Neo-European technological modernity over the heads of excluded African majorities. Continental independence in the 1960s brought different approaches. North African nations like Egypt, Algeria and Tunisia embarked on national electrification campaigns, with goals of universal access in urban areas and grid extension from urban industrial centres to smaller towns, villages and isolated homesteads (e.g. Cecelski *et al.* 2005). In sub-Saharan Africa, at the May 1970 invitation of Énergie Électrique de la Côte d'Ivoire, representatives of 13 independent west, central and island nations,[2] with Ghana as an observer, met in Abidjan to consider the possibilities of creating a self-help organization of nations at similar levels of development. The primary aim was 'to promote the development and integration of African power systems through the interconnection of networks, the exchanges of experiences and know-how as well as the pooling of energy resources' (UPDEA undated).

The president of the resulting Union of Producers, Transporters and Distributors of Electric Power in Africa (UPDEA) came from Côte d'Ivoire, the vice president from Liberia, and the Treasurer from Zaire (UPDEA undated). UPDEA grew slowly, eventually becoming associated with the Organization of African Unity (OAU, founded in 1963). An African Energy Commission (AFREC) was proposed by the 1980 Lagos Plan of Action as a continental African-controlled structure to 'ensure, co-ordinate and harmonize the protection, preservation, development and the national exploitation, marketing and integration of the energy resources of the African continent' (AFREC undated). It was not implemented.

Further south, where Apartheid South Africa's industrial economy (and, to a lesser extent, Southern Rhodesia's) was regionally dominant, independent nations created an oppositional organization. The Front Line States coalesced in the late 1970s, and was formalized as the Southern African Development Cooperation Conference (SADCC) in 1980. SADCC's primary goal was reducing economic dependence upon, and vulnerability to, South Africa. This would be accomplished by building economic and, particularly, regional infrastructural security through regional cooperation for the development of each individual state (Schoeman 2002). National economic strategies varied, but most followed models of developing industrial or mining sectors to create income for the nation and jobs for local people. Electricity was essential, but universal access was not a general goal. The SADCC nations contained considerable energy resources – hydropower, oil and coal. One-fifth of African hydroelectricity came from the two Zambezi River dams – Kariba and Cabora Bassa (Boyd 1985). Unlike the rest of Sub-Saharan Africa, SADCC nations had skeletal infrastructure, substantial energy production capacity, and significant international technical and financial support. A Technical and Administrative Unit (TAU) was established to assist 'regional energy sector, donor agencies, and recipient countries in identifying and ranking projects as well as enhancing capacity' (Hodges 2001, p. 14). SADCC's 1982 policy document 'Towards an Energy Policy for Southern Africa' (cited in Nhamo 1998–1999) asserted that member nations were committed to 'developing a coordinated approach to the problems of energy development, conservation and security, to ensure that energy can be made available in the most cost-efficient and cost-effective manner'.

As regional institutions worked to improve national electricity supplies, the idea of sharing electricity regionally emerged. This required interconnected grids. Grid planning and implementation was stimulated by the British-led international commodification of electricity in the 1980s (Showers 2009). Within ten years, electricity was transformed from essential infrastructure for national development to a marketable export commodity.

Power pools and intercontinental trade

SADCC formed an Electricity Subcommittee (ESC) in 1990 as a forum in which utilities could discuss, plan and further develop a regional power supply. The African Development Bank established its African Energy Programme in 1991. The following year the Association of the Electricity Industry of Europe (UNIPEDE) and the new Maghreb Electricity Committee (Comité maghrébin de l'électricité, Comelec) sponsored the creation of an umbrella group of Mediterranean basin electricity

Table 5. Sub-regional power pools.

Year	Name and acronym	Interconnected nations
1990s	Maghreb Electricity Committee (Comelec)	Mauritania, Morocco, Algeria, Tunisia, Libya
1995*	South African Power Pool (SAPP)	Angola, Botswana, Dem. Rep. Congo, Lesotho, Malawi, Mozambique, Namibia, Tanzania, Swaziland, Zambia, Zimbabwe
2000*	West African Power Pool (WAPP)	Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea Bissau, Guinea, Liberia, Mali, Niger, Senegal, Sierra Leone, Togo
2003*	Central African Power Pool	Angola, Dem. Rep. Congo, Rep. Congo, Gabon, Equatorial Guinea, São Tomé and Principe, Cameroon, Chad, Rwanda, Burundi
2003*	East African Power Pool	Burundi, Dem. Rep. Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania, Uganda

Source: UPDEA (undated).
* year of inception according to UPDEA.
For electricity grid maps see Global Energy Network Institute (GENI undated).

associations. Called MEDELEC, it was charged with exploring the possibility of a 'Mediterranean Ring' of electricity grids linking all nations and states around the sea (for maps see MEDELEC 2007; Global Transmission 2009). The same year, the re-organized SADCC, renamed SADC, discussed creating a regional electricity power pool (DEAT 2005). The arrival of this neoliberal model of electricity as commodity rather than provider of essential services coincided with the end of Apartheid South Africa. After South Africa joined SADC in 1994, ESCOM played a significant role in SADC energy policy and programmes. In 1995 SADC created the Southern African Power Pool (SAPP; SAPP undated) with headquarters in Harare, Zimbabwe. Two years later, at the other end of the continent, the first Europe-Africa interconnector was commissioned – an undersea cable between Spain and Morocco. Electricity began to flow from Europe to Africa (Granadino and Mansouri 2007).

Meanwhile, the role of South Africa's electricity provider, ESCOM, was being reconsidered. In 2000, ESCOM became Eskom Holdings, and profit-making electricity generation was separated from the public service of national electricity supply. Subsidiary Eskom Enterprises was created to engage in unregulated international contracting and revenue generation. It became involved with hydroelectric projects throughout the continent and opened offices in Uganda, Nigeria and Mali. Eskom Holdings became the largest electricity utility in Africa (Ashe 2002; Eskom Holdings 2002; for overview see Pottinger 2003). In 2001 SADC's SAPP constructed a Short Term Energy Market (STEM) to be the 'stock exchange of regional power' (GF SE 2006). The STEM's purpose was to facilitate supplying individual customers or utilities with electricity contracts of up to one month in duration. Internet-based trading was introduced (GF SE 2006). According to Elmissiry (2000), this marked the beginning of SAPP's transformation to a 'fully competitive, market-based body'.

No longer was electricity essential infrastructure for economic development. It was to become a commodity that could be produced, valued, exported and speculated upon – a new kind of "cash crop" that changed perspectives on investment in large-scale energy projects, including civil engineering costs associated with hydroelectric power dams. Proposals once considered too large, too expensive or too socially or environmentally destructive gained new economic justification. A shift of emphasis away from coal-, oil- and gas-fired power plants to hydropower was anticipated (Elmissiry 2000).

Despite the many regional organizations, it was not until 1995 that the first Pan-African Conference of Energy Ministers was convened in Tunis. The long-discussed AFREC was officially constituted in 2001 at the OAU's 37th Summit Conference in Lusaka, Zambia. With headquarters in Algeria, AFREC would associate with both private and public entities. Table 5 presents AFREC's plans for regional electricity grids and power sharing.

The African Heads of Government adopted the New Partnership for Africa's Development (NEPAD) in 2001 (PSI 2003). The following year, after the OAU became the African Union (AU), it adopted NEPAD as its 'integrated socio-economic development framework for Africa' (Hanson 2009;

NEPAD 2010a). Drafted by representatives from Algeria, Egypt, Nigeria, Senegal and South Africa, NEPAD codified the neoliberal agenda. A list of founding principles included 'anchoring the development of Africa on its resources and resourcefulness of its people' (NEPAD 2010b). NEPAD's Energy Infrastructure Initiative interpreted this to mean that the 'rich energy resources' of the continent should be 'fully developed' through regional cooperation. The old self-help organization UPDEA received technical assistance to formulate a new vision. Its purpose became the creation of sub-regional power pools throughout the continent, with the goal of an interconnected system enabling electricity 'to flow from North to South, from Central to West and East of the continent' (UPDEA undated). These interconnected grids could not only 'light up Africa', but also supply Europe and the Middle East. Rural electrification was not included in this vision.

While African technicians worked on sub-regional and continental grids (in theory and practice), energy hungry Europe looked south (Global Transmission 2009). In 2003 the 'Declaration of Intent on the Maghreb Electricity Market and its Integration into the European Union Internal Electricity Market' was signed. It resolved to achieve a Maghreb Regional Electricity Market (MEM) to integrate gradually into the EU's electricity internal market and promote regulation systems in the Maghreb based on those of the EU Electricity Internal Market Organization. The EU would serve as secretariat and encourage finance and industry participation (Euro-Mediterranean Partnership 2003; EU 2007). A second undersea cable between Spain and Morocco was commissioned in 2006, and plans were discussed for Algeria–Spain, Algeria–Italy, Tunisia–Italy and Libya–Italy interconnections. These would reverse the flow of the 1997 cable, exporting electricity from Africa to Europe (Granadino and Mansouri 2007; Global Transmission 2009; GENI undated).

Environmental consequences of electricity production

Although both economic interests and political realities were major forces in the arrival and spread of electricity, it was the environment which had a non-negotiable role. Environmental factors constrained electricity production, and electricity production constrained, if not destroyed, ecosystem function. Technological advances enabled urban exploitation of increasingly distant ecosystems. Each time environmental limits were reached, changes in fuel and technology or technological innovation enabled not only continued, but increased, generation without environmental consideration. Directly or indirectly, the water cycle was always engaged, and disrupted.

Coal, forests and rivers

Most early electricity plants were thermal. South Africa's coal underlay the development of Johannesburg's late nineteenth century mining enterprises and creation of the Witwatersrand's industrial economy. The northern expansion of southern African railways enabled coal shipments from mines in Natal and Transvaal, as well as from Southern Rhodesia's Wankie (Hwange) Colliery, to the Copperbelt and Katanga. To circumvent Wankie's limited production, Katanga mines also imported German and Dutch coal (Birchard 1940; Bureau of Foreign Commerce 1956). The Benguela Railroad, opened in the late 1920s, provided the shortest route between the port at Lobito, Angola and Katanga's Elizabethville (Varian 1931). Despite improved rail links, coal was unreliable and expensive. Mining and refining companies turned to Congo River tributaries. In 1936, electricity from the 68 MW Mwadingusha dam at Lufira River's Cornet Falls reduced Katangan coal imports from 400 million to 77 million tons (Birchard 1940); see Table 6.

A similar pattern was followed in the parts of east and central Africa where temperature and rainfall supported abundant tree growth. Wood from imagined vast and unused tropical dry forests initially provided a low-cost, local fuel. In 1922, Dar-es-Salaam's new British-built thermal plant using 'forest wood, carefully seasoned' was more economical to run than similar small coal-fired stations in England. Fuel costs were '0.62 pence per working unit', compared to the cheapest in England – Clacton at 0.88 pence (Chief Engineer and Manager 1923). Wood was also the primary fuel for Kenya's thermal plants in Ruiru, Eldoret and Nakuru (Richards 1947). The Ruiru plant purchased wood from African contractors in the 1940s. Its consumption of 100 tons/day was equal to harvesting 4 acres of forest/day. A 1947 report expressed concern about supplies, noting that although rotational plantings of the preferred tree – black wattle (*Acacia* spp.) – were possible, an alternative fuel would be needed in future (Richards 1947). On the Northern Rhodesian Copperbelt, four plants used more than one-half

Table 6. Hydropower affect on thermal plant coal consumption.

Location	Date	Amount used	Consumer	Coal source
Johannesburg, South Africa	1890s	No data	Gold mines	Near Johannesburg
Northern Rhodesia	1950s	100,000 tons/month	Copper Mines	Wankie Colliery, Southern Rhodesia
Katanga Province Belgian Congo	1920	100 million tons	Copper mines and processing	Wankie Colliery, Southern Rhodesia
	1925	280 million tons		South Africa; Germany; Netherlands
	1930	400 million tons		
	1936 (after hydropower*)	77 million tons		

Sources: Birchard (1940); Department of Information (1956).
* Mwadingusha hydroelectric plant, Cornet Falls, Lufira River.

million cords of wood in 1952, resulting in some 300 square miles of woodlands being felled (Bureau of Foreign Commerce 1956). Imported coal initially supplemented dwindling wood supplies (Mihalyi 1977). In 1953, 80,000 tons were required each month, but only 45,000 arrived. Electricity plants (re)turned to wood, which was three times as expensive (Wills 1967). Forest consumption rose from 5,790 ha in 1947 to an unsustainable 15,031 ha nine years later. A 1956 US government investor's publication observed that new technology at the Wankie Colliery '500 miles to the south' allowed increased production, so 'the wood burning era should be drawing to a close' (Bureau of Foreign Commerce 1956, p. 59). However, water, not coal, replaced wood. That year the Le Marinel hydroelectric plant on Belgian Congo's Lualaba River provided hydropower not only to Katangan copper mining and processing, but also, via innovative long-distance transmission lines, to adjacent Copperbelt mines. Northern Rhodesian tree harvests dropped to 1,1613 ha/year; see Table 7 (Department of Information 1956; Bureau of Foreign Commerce 1956).

Dammed rivers resolved colonial problems associated with uncertain, expensive and finite fuel supplies by displacing environmental disruption from terrestrial to aquatic ecosystems. Dammed rivers also seemed to provide the energy required for the Development Assistance Independence Era's economic expansion. Table 1 showed the extent to which independent Africa turned to hydropower. Coastal West and East African nations based their electricity policies on hydropower. Of the 54 hydroelectric dams built in the first two independence decades, 19 (35 per cent) were constructed on West African rivers. Hydroelectricity accounted for 90 per cent of Côte d'Ivoire's supply in the 1970s (Hodgkinson 1999). Although Nigeria and Cameroon had major hydropower dams, Ghana's Akosombo at Ajena, run by the Volta River Authority (VRA, modelled on the TVA), had the largest installed capacity (912 MW). By 1967 most Ghanaian electricity users had switched from diesel to hydropower. Five years later the VRA began exporting electricity to neighbouring Côte d'Ivoire, Togo and Benin. With the 1982 commissioning of the Volta River's Kpong hydroelectric plant, Ghana became West Africa's major electricity exporter (RCEER 2005; Anonymous 2006). Kenya's, Tanzania's and Uganda's interconnected grids similarly depended upon hydropower. Impounded water was producing an urban and industrial Africa.

Climate change, rivers and gas

The dream of economic growth from unrestricted, low-cost hydroelectricity was shattered by severe droughts in the 1980s and 1990s. Reduced river flow lowered dam levels dramatically, and generation faltered. The 1983–1984 drought prompted the 1985 Ghana Generating Planning Study to advise reduced dependence on hydroelectricity and increased natural gas-fired thermal plant construction (RCEER 2005). In 1992 Kariba's output declined by 8 per cent. Akosombo lost two thirds of its capacity in 1998 (Anonymous 2006). Persistent drought caused Kenya and Tanzania to ration electricity in 2000. In 2004, Tanzania's hydropower plants operated at 50 per cent capacity (Mukheibir 2007). West Africa's response to the 1997–2000 drought's constraint on generation was increased construction of natural gas-fired thermal plants. Côte d'Ivoire became West Africa's major electricity provider by exploiting its natural gas reserves in the Bight of Benin. Electricity

Table 7. Hydroelectric power's affect on thermal plant wood consumption.

Location	Date	Consumer	Rate of consumption
Dar es Salaam, German East Africa	1910s	Municipal lighting, and factories	Seasoned forest wood (no amount given)
Ruiru plant, Kenya Colony	Late 1940s	Municipal lighting, and factories	100 tons/day = 4 acres forest/day
Northern Rhodesia	1947	Copper mining and processing	5,790 ha/yr clearfelled forest
	1948		5,930 ha/yr clearfelled forest
	1949		9,074 ha/yr clearfelled forest
	1951		13,590 ha/yr clearfelled forest
	1952		300 sq miles
	1955		15,031 ha/yr clearfelled forest
	1957 (after hydropower*)		1,1613 ha/yr clearfelled forest 77 million tons

Sources: Chief Engineer and Manager (1923); Richards (1947); Lewis and Berry (1988).
* Transmission line extended to Northern Rhodesia from Belgian Congo's Le Marinel Hydro Electric Station, Lualaba River.

exports to drought-stressed Ghana – as well as to interconnected Togo, Benin, Mali and Burkina Faso (Madamombe 2005) – followed the commissioning of the Azito plant's Phase I (150 MW) in 1999 and Phase II (150 MW) in 2000. By 2006, half of Côte d'Ivoire's electricity came from gas-fired thermal plants, and only 17 per cent from hydroelectric dams (Azitoenergie 2004; CIA 2010).

Rather than eliminating dependence on water, the switch to gas- and oil-fired thermal plants simply changed its nature. Water is obviously the fuel in a hydroelectric plant, but its essential role in thermal plants is masked. Steam driven turbines require boilers full of water and, whatever their fuel source, almost all thermal power plants require water in their cooling systems (Gleick 1993). Situating the Azito plant on a lagoon's banks ensured abundant cooling water (Azitoenergie 2004).

Some conventional thermal plants' cooling water is lost as steam, some is used in cleaning, and the rest is returned to its source. However, the returned water has been altered, and disrupts receiving aquatic systems. Cooling water is generally hotter than the environmental norm, and contains contaminants and toxins (Heimbigner 1983; IAEA 1983; Sweers 1983; Egborge 1998). Temperature affects everything from biological activity of aquatic organisms to amounts of dissolved oxygen and forms of nitrogen, as well as interactions between a river bed's mud and the water flowing over it. Temperature fluctuations can cause fish kills and algae blooms (IAEA 1983; Miller and Brighouse 1984). In the 1990s, the National Electric Power Authority's (now the Power Holding Company of Nigeria) Sapele power plant at Ogorode, Nigeria, reportedly polluted the Benin River by discharging boiling water (Egborge 1998). Chlorine, a recognized biocide, is the most commonly used cleaning agent in power plants, and is released in power plant discharges. Most thermal generators threaten aquatic systems to which they are connected.

Goldstein and Smith's (2002, p. viii) comparison of different thermal plants' water requirements is reproduced here as Table 8. Nuclear power's usually unacknowledged substantial need is worth noting.

When evaporative losses are considered, hydroelectric dams (not in Table 8) are also water consumers. An average of 1.1 metres of depth/km^2 of surface area is frequently used in calculations, but individual reservoir evaporation depends upon local climate. Estimated loss from the Aswan High Dam is 2.7 metres of depth/km^2 of surface area, or 11 per cent of the reservoir capacity. Similar calculations led California researchers to conclude that hydroelectric plants had an average environmental loss of 5.4 Kl of water/10 MWh electricity generated (Gleick 1994, cited in Mukheiber 2007, p. 7). Other than dams' significant river disruption, electricity's demands on – and damage to – aquatic systems and water cycles has largely been omitted from public discourse.

Electricity grids and water shortage

Water shortage prompted the first proposal for a regional African electricity grid. Abundant surficial coal and severely underpaid labour ensured

Table 8. Cooling water withdrawal and consumption (evaporation to the atmosphere) rates for common thermal power plant and cooling system types (converted from US gallons to litres).

Plant and cooling system type	Water withdrawal (litres/MWh)	Typical water consumption (litres/MWh)
Fossil/biomass/waste fuelled steam, once-through cooling	75,708 – 189,270	~ 1,136
Fossil/biomass/waste fuelled steam, pond cooling	1,136 – 2,271	1,136 – 1,817
Fossil/biomass/waste fuelled steam, cooling towers	1,893 – 2,271	~ 1,817
Nuclear steam, once-through cooling	94,635 – 227,124	~ 1,514
Nuclear steam, pond cooling	1,893 – 4,164	1,514 – 2,725
Nuclear steam, cooling towers	3,028 – 4,164	~ 2,725
Natural gas/oil combined-cycle, once-through cooling	28,391 – 75,708	~ 379
Natural gas/oil combined cycle, cooling towers	~ 871	~ 681
Natural gas/oil combined cycle, dry cooling	~ 0	~ 0
Coal/petroleum residuum-fuelled combined-cycle, cooling towers	*~ 1	~ 757

* includes gasification process water
Source: Goldstein and Smith (2002).

Apartheid South Africa's low-cost electricity, but the capacity of rivers to provide cooling water was almost exhausted. In the mid-1970s, engineer Henry Olivier was asked to review regional hydroelectric power sources that could benefit South Africa. In his 1976 report, Olivier proposed a 'pan-African grid' (see Fig. 1) that would 'export and import electricity on the best use or most economic basis' (Olivier 1976, p. 26).

The grid was to be anchored by the newly commissioned Cabora Bassa and still-imagined Grand Inga dams. Existing transmission lines in South Africa, Zambia, Rhodesia and Mozambique would be connected, and Zaire, Malawi and Tanzania would be added. By market logic electricity would move to South Africa, allowing decommissioning of some water-consuming coal-fired electricity plants. Olivier (1976, p. 26) estimated that importing 40,000 MW would save 'in avoided evaporation of cooling water for thermal stations, about 500,000 megalitres of water a year or 3000 million gallons a day – the equivalent of a sizeable river'. Regional opposition to Apartheid meant that Olivier's water conserving plan was not implemented. However, the idea of a regional electricity grid (largely benefitting South Africa) was resurrected, expanded, and promoted when electricity became an export commodity and Apartheid had ended. Grand Inga was central to Eskom's continental interconnector plans, those considered under NEPAD, and Table 5's subregional power pools (Showers 2009; Eskom map in Mukheibir 2007). The rationale for the grid was industrial expansion and revenue generation, not water conservation.

In the late twentieth century, as electricity became a commodity and markets were globalized, Europe confronted a predicted power shortage and the need to conform to "clean" power sources under its Kyoto commitments. Having neither the land base for biofuels production nor undammed rivers for increased hydroelectric generation, and recognizing the limits of European-generated solar and wind power's potential for centralized, large-scale electricity generation, the European gaze turned to the African continent. Long-imagined unused resources had been formalized by apparently authoritative, yet highly inaccurate, documents such as Bot *et al.*'s (2000) *Land resource potential and constraints at regional and country levels*. With expanded intercontinental grid connections, Europe could displace its electricity crisis to the African continent. International carbon off-setting funds would provide initial capital for green energy projects, revenues from which could finance achievement of African Millennium Development Goals. This was described as a win-win solution – even though most Africans would remain dependent upon kerosene and candles, and water cycles, as well as terrestrial and aquatic ecosystems, could be seriously disrupted.

Along with proliferation of plans for bio-fuels production, two major projects were identified: the long-considered Grand Inga Project advanced by SADC nations (Naidoo 2009; Showers 2009, 2011) and a private sector proposal named DESERTEC. DESERTEC (undated) calls for a ring of concentrated solar plants (CSP) around the Sahara Desert to supply North Africa, the Middle East and Europe with electricity. CSP plants are steam turbines powered by sunlight reflected from parabolic mirrors. Engineers proposed that most plants would be built near the Atlantic or Mediterranean coasts and use sea water. Presumably the non-coastal plants would use water from aquifers (fossil or other) and the Niger River. Rather than returning sea water to source, it would be desalinated, providing a new supply of fresh water – and another commodity – for desert landscapes. Irrigated lands and new (and expanded) towns were proposed. Understudied are the consequences for either the donating aquatic systems or receiving terrestrial and aquatic ecosystems, with or without rainfall shifts predicted under climate change models. This project fits historical patterns of environmental exploitation for narrowly defined economic benefit, and casting environmental change as beneficial – if noted at all.

Electricity generation, water cycles and scale

Most obviously with dam construction, and less obviously from thermal plant operation, electricity has interacted with African water cycles. As in all environmental interventions, scale is important. A run-of-the-river's dam is less intrusive than one which impounds, and a 3 MW thermal plant requires and pollutes less water than a conventional 350 MW plant. Water flowing in river beds is one of the most visible phases of terrestrial portions of water cycles. But this channelled flow is also connected to water flowing through sediments in the river bed, and to water tables stretching far and deep into larger landscapes. Changes in vegetation affect water table levels which, in turn, affect river flow, just as changes in river flow affects water tables and, thus, vegetation. Based on classical forest hydrological research (i.e. Bosch and Hewlett 1982; Bonell and Bruijnzeel 2004), studies of altered tropical forests (Giambelluca 2002), and especially examinations of the very different properties of the tropical dry forests which dominant the African continent (Sandström 1998), one can assume short- and long-term terrestrial and hydrological effects from forest clearing to supply power plants. Extensive cutting undoubtedly altered the water table, associated steam flow, and possibly soil properties. These relationships were unclear at the time, and the field of hydrology did not exist, so they were not documented. Similarly, no studies of the disappearing forest ecosystems were made. It could be argued superficially that the historical switch to hydropower protected East and Central African forests and terrestrial hydrologies. A closer look suggests that deforestation's destruction was actually replaced by that of dams' to less visible (and valued) aquatic ecosystems.

The environmental consequences of late twentieth century dams are better documented – from the loss of land through submergence to changed adjacent water tables, altered water chemistries, and disrupted flow regimes. Tables 1–4 suggest patterns of dam construction, but not their significance as environmental intrusions. Most are very large structures, and many create extensive reservoirs (see Showers 2011 for dam and reservoir dimensions and scale significance). The environmental effects of flooded landscapes, stored water, and interrupted river flow have been well discussed elsewhere for individual dams. Review literature includes McCully (1996), Davies and Walker (1986), Davies and Day (1998). A journal, *Regulated Rivers*, documents dammed rivers' altered properties.

Although popular attention has largely focused on livelihoods, land, species and biodiversity lost near dam sites, there are larger regional and, perhaps, global consequences. Consideration of the cumulative effects of "hydrological alterations" – dam construction and associated water diversion, exploitation of groundwater aquifers, stream channelization and inter-catchment water transfers – on a global scale began in the 1990s. The September 2000 special issue of *BioScience* (vol. 50, no. 9) reviewed the literature and first symposium on this topic (Rosenberg *et al.* 2000). Dams trap sediments with nutrients attached to them, preventing deposition along river banks and at river mouths where deposition created and sustained deltas. Sediment and nutrient starvation alters not only river structures, but also flora and fauna species and population numbers. Evaporative losses remain undervalued, and the significance of reduced oxygen levels is rarely discussed. Water flowing over rapids and waterfalls becomes enriched with oxygen, which can be transported to the ocean. The Congo River's plume and subterranean canyon extend far out into the equatorial Atlantic Ocean. Showers (2009) suggested possible global consequences should plans for Grand Inga reduce the Congo's water quality (including oxygen content) or flow regimes.

Lessons learned or lessons ignored?

The spread of electricity on the African continent provides further illustration that whether colonial or independent, socialist or capitalist, nineteenth and twentieth century governments and elites acted as if the environment existed solely for unconstrained human use. With each encounter of an environmental limit came a technological response. Coal's limited availability, forest depletion and seasonal rainfall were resolved by dammed rivers. Drought-affected dams led to gas- and oil-fired thermal plants with more discrete water requirements. Local water scarcity was mitigated by regional electricity grids. Rather than warnings of ecosystem crisis, environmental constraints were viewed as challenges to overcome. Yet, electricity generation is integrally connected to, and dependent upon, the function of local, regional and intercontinental water cycles. In the rush to industrialism, modernity, and improved GNP, ecosystem vitality and water cycle integrity have been of little concern. Late twentieth century technology combined with the redefinition of electricity as an export commodity resulted in ever larger plans for landscape interventions. A parallel trend has been the reduction of mid-twentieth century environmental concern to checklists. Once a list of endangered species is agreed upon, all that remains is protecting the agreed species – or a shred of habitat for minimal population survival. The idea of preserving entire ecosystems and ecosystem function receded until reclaimed by environmental economists' ideas of valuing environmental services and protecting them. But, once again, at a slightly different scale, the environment was reduced to a checklist (Showers 2011). With the marketing of electricity and domination of neoliberal ethics, gains made by globalized citizens and environmental protest have been overwhelmed. Discredited hydroelectric dams have new economic viability, justified by mandates for green and renewable sources of electricity, and technological futurism devoid of environmental context guides terrestrial project development. Colonial patterns of a plundered and commodified natural world and ignored majority populations are being repeated by African nationalist elites. Participatory preparation of checklists is offered as environmental protection.

Is this declensionist narrative the only blueprint for the future? It is widely agreed that electricity improves the quality of human life and is essential for economic growth. The World Bank's Africa Energy Team claimed that 'no country in the world has succeeded in shaking loose from a subsistence economy without access to the services which modern energy provides' (World Bank 2002). Although the twentieth-century notion of centralized power generation is becoming 'increasingly obsolete' in parts of Europe, the idea remains on the African continent, where mega-engineering projects and centralized power systems are promoted (Karekezi 2002). As in the colonial era, the current dominant economic model focuses on large-scale energy consumers whose activity influences macro-economic indicators like GNP, and labels a broad range of domestic and rural electricity benefits and beneficiaries as "uneconomic" or expensive social welfare.

Tunisia's experience of rural electrification provides an example of the economic benefit accruing at a national level from grid extension to remote villages and dispersed populations. Electricity resulted in reduced health care costs, decreased urban migration, and stimulation of small businesses (Cecelski *et al.* 2005). Newly independent Tunisia also exemplified a nation that had not only essential political will, coherent planning, and inter-linked campaigns for economic and rural development after independence, but also economic stability. After building up and supplying its industrial base, the electricity grid was extended to rural areas. As in South Africa in the 1920s, Tunisia in the 1970s turned to Canada for a model. Hydro-Quebec advised on low-cost technologies for rural electrification (Cecelski *et al.* 2005).

Zambia provides an example of Tunisia's direct opposite. It had similar post-colonial political will and initial coordinated planning, but confronted uncontrollable economic crises. Within a decade of independence world oil prices increased drastically while that of copper, Zambia'a main export, plummeted. Exports of copper declined, reducing the nation's forex reserves; industry collapsed, the price of imported good increased, and Zambia's debt (and cost of debt-service) became enormous (IMF 2002). Structural adjustment measures implemented intermittently in the 1980s included currency devaluation; deregulation of foreign exchange; removal of subsidies and price controls for food and other essential goods; the privatization of the major parastatal corporations; and, finally, the sale of the mines (Ferguson 1999; IMF 2002). Under these conditions, domestic mining and manufacturing were depressed. According to Ranganathan and Mbewe (1995), by the mid-1990s, the power utility (ZESCO) 'seemed to have nothing under its control'. Its costs were decided by exchange rate fluctuations, and revenues by the world price of copper. ZESCO had excess capacity that Zambia's industrial base could not absorb, and little capability to add new consumers. The utility's 'normal decision rules' were 'not optimal' (Ranganathan and Mbewe 1995, p. 1096).

Zambia's economic crisis is, perhaps, an extreme example of the condition of many African countries.

Rural populations dispersed across large landscapes are not easily – or cheaply – served by conventional electricity grids, and governments lack reliable sources of income. Karekezi (2002) and Haanyika (2008) see this as a crisis of centralized power models that could be addressed by decentralized and renewable energy technologies such as mini-hydropower, biomass gasification, and solar photovoltaic systems. Decentralized systems are smaller and less complicated, local materials can be used in construction, and local people trained to operate and maintain them. Their capital costs are generally lower than conventional plants. Consistent with Africa's long history of isolated small-scale generators, experiments with, and applications of, renewable energy technologies have been gradually spreading across the continent. Karekezi (2002) notes that a network of energy agencies, NGOs and local experts (African Energy Policy Research Network, AFREPREN) is emerging to provide information and support for renewable systems. Resources directed at the identification, improvement and distribution of truly renewable energy technologies could serve, with minimal environmental disruption, the 70 per cent of Africans who live in rural areas, stimulating local and regional economies.

Conclusion

Electricity's mercurial form and invisible transmission facilitates its conceptualization as a purely economic entity while obscuring fundamental environmental interactions, dependencies and consequences surrounding its production. Discussion of electricity generally centres on costs, and how best to reduce them. Political ecologists can expand the debate by considering the socio-economic power of distribution and sales. When cast as "vibrant matter" (Bennett 2010), inter-relations between electricity grids and human societies are added. While time is considered in political ecological analysis, it is not central. Histories of technology's use consider geographies of adoption, adaptation and redefinition over varying periods of time that may well incorporate analyses of political power. But none of these approaches address the fundamental environmental interactions and dependencies associated with electricity. A more encompassing framework is an earth-centred environmental history, which situates people, their interacting grids, and electricity generation in the environments essential for their function.

This research framework provides a coherent structure from which a broad range of questions can be addressed using many academic disciplines' methodologies without violating their integrity. A holistic earth-centred environmental history could enhance political ecologists' investigations of power and its contestation. More nuanced interpretations of resistance are possible when analysis moves beyond the distribution of political power to the environmental contexts of resistance. Histories of electricity concentrating on invention and innovation privilege Europe and North America. In contrast, this environmental history of electricity's use identified the new category of technological Neo-Europes, and established a clear link between colonialism, electricity, and the creation of technological Neo-Europes on the African continent. It also documented both the ecological consequences of electricity generation and the magnification of urban exploitation of distant (invisible) ecosystems that accompanied expanded transmission capabilities. The expanded perspectives provided by holistic earth-centred environmental history not only help to contextualize and refine studies made from narrower approaches, but also serve to guide researchers to include the environment as an actor in human activities. However apparently separated by technology, even the most urbanized person depends daily upon the functioning of near and distant ecosystems and the global water cycle. Twenty-first century research must begin to redress the absence of environmental concern from past analysis by acknowledging the fundamental connections between human society and increasingly distant landscapes. Globalization research has asserted the inter-connectedness of political-economic systems, and climate change concerns have emphasized the importance of transcending strictly local analyses to appreciate the inter-relations among interacting cycles and systems operating at continental and oceanic scales. Environmental history can facilitate researchers and policy makers to situate contemporary observations in the global environmental past, enabling identification of trends and patterns to be either emulated or avoided.

For centuries, Europeans ignored local land use practices and imagined the African continent to consist of untapped and unlimited "natural resources" that could, and should, be "harnessed" for human use. Economic growth was a preoccupation, and theories of economies of scale demanded ever-larger engineering projects requiring collaboration with intercontinental financial institutions and businesses. Environmental assumptions were challenged by expanding electricity production. Unpredictable or dwindling fuel supplies were met with technological intervention and attempted environmental control. Electricity's consequences occurred at different temporal and spatial scales, but if officially noticed, were characterized as beneficial. Opposition was outlawed or ignored. As hydropower came to dominate electricity generation, rivers lost their ecological identities and became physical entities defined by flow measurements. This utilitarian approach to rivers, as expressed in hydroelectric dams, was embraced by independent governments. The notion of unlimited water was fundamental to both colonial and independence era planning. Yet it was water shortage that ultimately constrained electricity production.

In 2011 the EU's *Roadmap for moving to a competitive low carbon economy in 2050* (EC 2011) advocated the increased use of electricity, and its importation from the under-served and drought-stressed African continent. Twenty-first century plans for Africa-Europe electricity transmission will certainly encounter historical patterns as well as biogeochemical realities. Tunisia's Development Assistance Independence Era history demonstrates that universal (urban and rural) access to electricity is a cost-effective investment rather an expensive welfare project. Continental experience has shown that while mega-electricity projects can contribute to the balance sheets of multinational corporations and improve national macro-economic statistics, the technological futurism informing such projects is challenged by lower-than-expected performance, disrupted ecosystems, destroyed livelihoods, and majority populations without benefit. A historical approach also reveals conventions of European industry exploiting African ecosystems for low-cost electricity.

Further investigation of past interactions between landscapes and electricity's production and consumption should help current researchers make the transition from theoretical modelling to the more substantive analysis required for sustainable political-economic planning, environmental monitoring, and design of mitigation programmes. First and foremost among conventions to be challenged is the idea that increased use of electricity will mitigate the climate change crisis. Almost all forms of electricity generation interact with the water cycle by reducing the amount or quality of terrestrial water supplies and increasing the (direct or indirect) release of water vapour, a powerful greenhouse gas. Historical environmental analysis will also assist in the refinement of climate change research. These are tools required for Diamond (2005)'s long-term planning and willingness to reconsider core values that determined the success or failure of past societies facing environmental limits. This overview of African electricity's environmental history has suggested many areas of research that could identify crucial points for future innovation, mitigation and, above all, conservation. It also provokes fundamental questions. Does the twenty-first-century EU renewable energy mandate simply displace Europe's environmental crisis from atmosphere to earth, and from one continent to another, or will Europe come to terms with its limits? Can the African continent afford another water-intensive export commodity? Will the New African Century embrace long traditions of environmental degradation, or seek a new path towards genuine environmental sustainability and equitable access to power?

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Notes

1. For historical consistency, place names will reflect the era under discussion. On first mention, current names follow in parentheses.
2. The Central African Republic, Zaire, People's Republic of Congo, Côte d'Ivoire/Ivory Coast, Gabon, Upper Volta (Burkina Faso), Mauritius, Madagascar, Liberia, Mauritania, Niger, Senegal and Chad.

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