WATER GLOBAL PRACTICE

Batoka Gorge Hydroelectric Scheme

A Macroeconomic Assessment of Public Investment Options (MAPIO)

WORLD BANK GROUP

About the Water Global Practice

Launched in 2014, the World Bank Group's Water Global Practice brings together financing, knowledge, and implementation in one platform. By combining the Bank's global knowledge with country investments, this model generates more firepower for transformational solutions to help countries grow sustainably.

Please visit us at www.worldbank.org/water or follow us on Twitter @WorldBankWater.

About CIWA

The Cooperation in International Waters in Africa (CIWA) was established in 2011 and represents a partnership between the World Bank, its African partners, and the governments of Denmark, the European Commission, Norway, Sweden, The Netherlands, and the United Kingdom. CIWA supports riparian governments in Sub-Saharan Africa to unlock the potential for sustainable and inclusive growth, climate resilience, and poverty reduction by addressing constraints to cooperative management and development of international waters.

www.worldbank.org/africa/ciwa

Batoka Gorge Hydroelectric Scheme

A Macroeconomic Assessment of Public Investment Options (MAPIO)

WORLD BANK GROUP

1818 H Street NW, Washington, DC 20433

Telephone: 202-473-1000; Internet: www.worldbank.org

Cover photo: © Marcus Wishart / World Bank.

Cover design: Jean Franz, Franz & Company, Inc.

Contents

Figures

Tables

Executive Summary

Maximizing the benefits from investment in hydropower requires a clear, predictable, and transparent process informed by robust analyses that can facilitate a multicriteria consideration of the range of options and alternatives that may be available. Inadequate management and planning can potentially lead to cost increases, poor implementation quality, insufficient operational and maintenance capacity, and negative environmental and social impacts. This can substantially lower the economic return on a program and impact on a government's public finances.

The upstream tools available to governments to assess the costs and benefits of different investment strategies are often too general or specific to determine the optimal investment strategy. Computable general equilibrium (CGE) models are often recommended to assess the impacts of large public investment programs on increased demand for services and the supply side effects of increased productivity in sectors that benefit from the completed program. However, such models are typically very complex, require considerable resources to produce, and are often too general to be of use to estimate the impact of specific programs. Despite providing a more systematic approach to the analysis, these constraints often prevent others from being able to successfully apply the models to key issues.

This paper outlines a simple model to assess the returns of a potential investment program in the hydropower sector. The Macroeconomic Assessment of Public Investment Options (MAPIO) model provides an analysis of impacts on key macroeconomic variables, such as exports, imports, gross domestic product (GDP), prices, and fiscal accounts. While its analytical capacity requirements are modest compared to CGE models, it can be easily applied to a variety of programs in different contexts provided accurate and detailed information is available regarding the project's construction, operation, and anticipated returns. The objective of this paper is to improve the tools available to facilitate the assessment of the macroeconomic implications of large infrastructure projects and enhance the capacity for management of public investment decisions.

The MAPIO Model was used to provide a macro-economic assessment of the Batoka Gorge Hydroelectric Scheme (HES). This is one of a series of hydropower investments conceived as part of a cascade on the Zambezi River Basin. The recommended option for the Batoka Gorge HES is a 181-meter-high, 720-meter long roller-compacted concrete (RCC) gravity arch dam with two surface power stations situated either side of the river; each with a total installed capacity of 1,200 megawatts, giving a total installed capacity of 2,400 megawatts. It is envisaged that the Batoka Gorge HES would be implemented over a 7-year period with the total cost estimated at US$2.6 billion.

The MAPIO model shows that the Batoka Gorge HES provides a robust financial and economic investment option with a net positive impact on the national economies in both Zambia and Zimbabwe. The analysis suggests that the project would generate significant financial and economic returns with limited impacts on prices and imports. The impact on the governments' fiscal accounts is expected to be modest, due to the concessional nature of the debt and the introduction of an innovative special purpose vehicle (SPV) model. The estimates are considered conservative and the returns remain robust when subjecting the model to extreme assumptions to test the sensitivity of the results.

While the MAPIO model provides a simple, cost-effective, and robust framework, it is important to acknowledge limitations of the model. The impact of the Batoka Gorge HES on public finances for Zambia and Zimbabwe would be pronounced, and accurate and timely information is required on the program and key macroeconomic indicators. In addition, informed judgements should be taken on the assumptions. In the case of Zambia and Zimbabwe, the estimation of benefits is solely based on estimated power generation and current international prices. The model does not include an analysis of noneconomic benefits, costs, or impacts on other sectors. Any decision to proceed with a project of this type and magnitude should be based on a multicriteria assessment that engages a diverse and complete set of stakeholders to consider the full range of options and alternatives that may be available to achieving the development objectives.

Acknowledgments

This assessment was carried out as part of a broader program of support in the Zambezi River Basin. This program is aimed at supporting the Riparian States in strengthening cooperative management and development of water resources in the Zambezi River Basin to facilitate sustainable, climate-resilient growth.

The assessment is not intended to represent nor replace appraisal of the project, and the presentation of the findings, their interpretations, and the conclusions expressed herein do not necessarily reflect the views of the World Bank, its Board of Executive Directors, the governments they represent, or any other organisation or individual acknowledged here. It is one of a number of supporting activities intended to compliment preparations being carried out by the Zambezi River Authority under the Zambezi River Basin Development Project for the Batoka Gorge Hydroelectric Scheme (HES). These include assessments of the feasibility, environmental, and social impacts; implications associated with potential changes in climate; and the institutional and financial arrangements within the broader context of the program aimed at improving the management and development of the Zambezi River Basin.

The team appreciates the cooperation and collaboration of Munyaradzi Munodawafa (Chief Executive), David Mazvidza (Director, Projects and Dam Safety) and Christopher Chisense (Director, Water Resources and Environmental Management), as well as James Sutherland, Bruce Harvey, and Nicolas Anjinho, from Ernst & Young Advisory Services (Pty) Ltd. The opinions expressed herein and any errors are the sole responsibility of the authors and should not be attributed to the individuals or institutions acknowledged.

The World Bank team included Marcus Wishart (Team Leader and Senior Water Resource Specialist), Jason Hayman (Economist), Johannes Herderschee (Senior Economist, Zimbabwe), Marko Kwaramba (Economist), Gregory Smith (Senior Economist, Zambia), Cecil Nundwe (Water Resources Specialist), Reynold Duncan (Lead Energy Specialist), Mirlan Aldayarov (Senior Energy Specialist), and Joseph Kapika (Senior Energy Specialist). The program was implemented under the guidance of Paul Noumba Um (Country Director), Ina-Marlene Ruthenberg (Country Manager, Zambia), Mukami Kariuki (Country Manager, Zimbabwe), and Jonathan Kamkwalala (Practice Manager, Water Global Practice) of the World Bank.

The team is grateful to the following peer reviewers for their comments: Sébastien Dessus (Program Leader, Equitable Growth, Finance and Institutions), William Rex (Lead Water Resource Specialist), and the Global Solutions Group for Hydropower & Dams (Pravin Karki, Global Lead Hydropower & Dams, GEEDR; Richard Taylor, International Hydropower Association; Dominik Godde, H2GO Consult GmbH; Mike McWilliams, McWilliams Energy), along with contributions from Pablo Benitez Ponce (Senior Environmental Economist, GEN01) and Magda Lovei (Practice Manager, GEN01).

Abbreviations

BOP	balance of payment
CAPCO	Central African Power Corporation
CGE	computable general equilibrium model
DAM	Day-Ahead Market
EIRR	economic internal rate of return
EWIRR	economywide internal rate of return
FIRR	financial internal rate of return
GDP	gross domestic product
GNDI	gross national disposable income
GNS	gross national savings
HCB	Hidroeléctrica de Cahora Bassa
HES	hydroelectric scheme
IDA	International Development Association
IPP	independent power producer
IRR	internal rate of return
ITPC	Itezhi-Tezhi Power Corporation
LHPC	Lunsemfwa Hydro Power Corporation
MAPIO	Macroeconomic Assessment of Public Investment Options
MDB	Multilateral Development Bank
MIGA	Multilateral Investment Guarantee Agency
NBPC	North Bank Power Company
NPV	net present value
PPP	public-private partnership
RCC	roller-compacted concrete
SAPP	Southern African Power Pool
SBPC	South Bank Power Company
SPV	special purpose vehicle
UDI	unilateral declaration of independence
ZAMCOM	Zambezi Watercourse Commission
ZESA	Zimbabwe Electricity Supply Authority
ZETDC	Zimbabwe Electricity Transmission and Distribution Company
ZPC	Zimbabwe Power Corporation
ZRA	Zambezi River Authority

Chapter 1 Introduction

Infrastructure is an important contributor to promoting economic development and sustaining prosperity across Africa. Investments in infrastructure have been responsible for more than half of Africa's growth performance and have the potential to make substantial contributions in the future. These benefits are even higher for critical sectors. However, existing limitations in infrastructure, particularly in the power sector, can depress productivity. The infrastructure gap across the continent is estimated to cost at least 1 percentage point in per capita growth. This is at least as much as red tape, corruption, and lack of finance.

Meeting Africa's infrastructure needs and developing cost-effective modes of infrastructure service delivery will entail a substantial program of infrastructure investment. The estimated spending needs for infrastructure across the continent are estimated at around US$93 billion a year (15 percent of the region's gross domestic product [GDP]). Over 40 percent of the expenditure needed is in the power sector, which must install 7,000 megawatts of new generation capacity each year just to keep pace with demand. About one-third of the power investment needs (some US$9 billion a year) are associated with multipurpose water storage for hydropower and water resource management.

Existing spending on infrastructure in Africa amounts to US$45 billion a year. This includes budget and off-budget spending (such as state-owned enterprises and extrabudgetary funds) along with external financiers, such as private sector investment and development assistance. The public sector remains the dominant source of finance for water, energy, and transport; it is estimated that US$30 billion of annual spending is domestically financed by taxpayers and infrastructure users. The balance is financed through external sources. This public investment is largely tax financed and executed through central government budgets, whereas the operating and maintenance expenditure is largely financed from user charges and executed through state-owned enterprises. These investments are highly skewed in distribution and largely concentrated in a few countries across the continent.

There are a number of barriers to infrastructure investments in Africa. Private sector investments are often limited due to underdeveloped capital markets, low foreign direct investment, and a difficult business environment (including high interest rates). Continued volatility of commodity prices further exacerbates the challenges. Deep reforms are required to improve the business environment, develop local capital markets, and enhance public infrastructure. The continent's geopolitical history also presents a number of challenges, particularly for large-scale infrastructure, with over 70 percent of countries having a population of less than 20 million and about half having a GDP of less than US$10 billion in 2016 (nominal terms). Integrating physical infrastructure is both a precursor to and an enabler for deeper economic integration, thereby allowing countries to gain scale economies and harness regional public goods.

The impact of public investment on economic growth can be improved. To fill gaps in the market and catalyse further private investment, governments have typically increased financing of public investment programs. Many of these programs have been financed by increased borrowing, while a few have been able to fund these through increased revenues and development financing. These rely on strengthening public investment systems, including improvements in institutions and the procedures governing project appraisal, selection, and monitoring. Specific policy measures can also be introduced to improve the enabling environment, increase access to commercial financing and catalyse investment through public-private partnerships (PPPs). Indeed, evidence indicates that countries with sound public investment management systems tend to have more private investment. For many countries, such investment decisions require balancing much needed development spending without jeopardizing hard-won debt sustainability.

The power sector accounts for the most significant investment needs across the continent. Generation capacity per capita is currently about 0.04 megawatts per 1,000 people. This is less than a third of South Asia (with 0.15 megawatts per 1,000 people) and less than one-tenth of Latin America and the Caribbean. Although access to electricity more than doubled between 1990 and 2014, it is estimated that only 35 percent of the population have access to electricity, with rural access rates less than one-third of urban ones. Universal access by 2030 would require investments of between US$40 billion to US$50 billion annually. Current levels of annual investments are around US$9 billion to US$10 billion and generation capacity has changed little in over 20 years across the continent.

Investments in the power sector are complex and face a number of challenges. The power sector is characterized by underutilization of generation capacity due to poor maintenance of assets; high primary energy costs; inadequate transmission networks to facilitate evacuation; ineffective and insufficient distribution infrastructure (especially in rural areas). These are often unprofitable due to low (sub-economical) or politically influenced tariff structures for power utilities, which are exacerbated by low collection rates and high operational inefficiencies. As a result, a number of countries are experiencing a power crisis, adversely affecting their economies, with the economic costs of power outages typically ranging between 1 percent and 4 percent of GDP (Foster and Briceño-Garmendia 2010).

Private sector investments in the power sector across Africa are limited, both in size and distribution. While there have been a number of public sector investments, there are estimated to be only around 126 Independent Power Projects (IPPs) in 18 Sub-Saharan countries (Eberhard, Morella, and Antmann 2016). These account for an installed capacity of 11 gigawatts and US$25.6 billion in investments. This is more than 13 percent of the subcontinent's total installed generation capacity and 25 percent if South Africa is excluded. South Africa alone has 67 IPPs accounting for 4.3 gigawatts of the installed IPP capacity and US$14.4 billion of the total investment. In most instances IPPs represent a minority of total generation capacity and have mainly complemented incumbent state-owned utilities.

Investments in hydropower represent an important opportunity for improving the generation capacity of the power sector and addressing energy security across the continent. The feasible hydropower potential for Sub-Saharan Africa exceeds 270,000 megawatts, nearly half of which is considered both technically and economically feasible. Despite this, less than 10 percent has been developed to date (below the 24 percent observed globally). In addition to the challenges associated with large-scale infrastructure projects, most of Africa's hydropower resources are situated on internationally shared, transboundary waterways. This results in a complex interplay between the project type and financial structuring, socio-economic context, geographical characteristics, and the prevailing legal, cultural, and political regimes.

Maximizing the benefits from investment in hydropower requires a clear, predictable, and transparent process informed by robust analyses that can facilitate a multicriteria consideration of the range of options and alternatives that may be available. Inadequate management and planning can potentially lead to cost increases, poor implementation quality, insufficient operational and maintenance capacity, and negative environmental and social impacts. This can substantially lower the economic return on a program and impact on a government's public finances. Project-specific development can be guided by tools, such as the Hydropower Sustainability Assessment Protocol, that facilitate the identification and management of social, environmental, and technical issues at the project level.

The upstream tools available to a government to analyze the costs and benefits of different investment strategies are often too general or specific to determine the optimal investment strategy. Computable General Equilibrium (CGE) models are often recommended to assess the impacts of large public investment programs on increased demand for services (such as in the agriculture, construction, services, transport, manufacturing sectors) and the supply-side effects of increased productivity in sectors that benefit from the completed program. Such models are typically very complex, require considerable resources to produce, and are often too general to be of use to estimate the impact of specific programs. Despite providing a more systematic approach to the analysis, these constraints often prevent others from being able to successfully apply the models to key issues.

This paper outlines a simple model to assess the returns of a potential investment program in the hydropower sector. To assess impact, the model provides an analysis of impacts on key macroeconomic variables, such as exports, imports, GDP, prices, and the fiscal accounts. While this model's analytical capacity requirements are modest compared to CGE models, assuming accurate and detailed information regarding the project's construction, operation, and anticipated returns are provided, it can be easily applied to a variety of programs in different contexts. The model was first used to assess the macroeconomic impacts of the Kandaji Dam in Niger (Beguy et al. 2015) and has subsequently been used in Mauritania and Mauritius. The objective of this paper is to improve the tools available to facilitate the assessment of the macroeconomic implications of large infrastructure projects and enhance the capacity for management of public investment decisions.

Chapter 2 Development of Hydropower in the Zambezi River Basin

2.1. Investing in Southern Africa's Power Sector

Southern Africa is characterized by an aging power infrastructure that is increasingly challenged to meet regional power demands. The excess supply capacity that had been a feature of the region's electricity sector over several decades has been shrinking since 2007 due to insufficient investments in new generation capacity. The current total installed capacity of 57.1 gigawatts (of which 51.7 gigawatts are available) is not sufficient to accommodate current demand (around 53.8 gigawatts), especially since future demand is projected to increase by 2 percent to 3 percent per year, reaching peak loads of about 72 gigawatts by 2025. Expanding electricity supply in line with projected demand growth over time and significantly increased rates of access involves a major scale-up of generation and associated transmission capacity.

Regional integration is the most efficient way to unlock the region's energy potential and can have great transformative impact. The challenge is that the efficient option in many cases relies on large generation and transmission investments of a scale that cannot be justified based on national demand alone. The Southern African Power Pool (SAPP) is dominated by coal as the primary source of generation (77 percent). The majority of this is sourced from the large deposits in South Africa, Botswana, and Zimbabwe, but many of the coal-fired power stations are old and require refurbishment. Eskom of South Africa dominates the power pool, accounting for about 80 percent of total SAPP demand, and produces roughly the same percentage of energy. In addition, a significant proportion of power is generated by a large number of hydropower plants in the Congo and Zambezi river basins. However, the cost of these investments is such that they are often only economically viable when arranged as regional projects that accommodate demand from multiple countries.

Inadequate electricity access poses a major constraint to economic development, ending poverty and boosting prosperity in Southern Africa. Access to electricity in Southern Africa is estimated at around 28 percent, below the continental average of 31 percent. If South Africa is excluded, the level of access for the remaining countries would barely reach 17 percent. This is the lowest rate among all sub-regions in Sub-Saharan Africa. While there are some efficiency gains to be made, increasing the number of connections to households and businesses requires more electricity flowing into distributions systems. As such, increasing access to electricity cannot realistically be expanded without also increasing the generation capacity in the region.

2.2. The Power Sector in Zambia

Zambia's power sector has been struggling with the challenge of supplying reliable electricity to meet the needs of a growing economy and providing universal access to electricity in order to improve the quality of life of citizens. The current installed generation capacity is 2,350 megawatts with demand forecast to grow 5.4 percent annually to 5,508 megawatts by

2035. Generation is heavily reliant on hydropower, which accounts for around 95 percent of total generation. This includes (i) Victoria Falls, commissioned in 1938, with an installed capacity of 108 megawatts (since 1972); (ii) Kafue Gorge, commissioned in 1971 and uprated over the years to provide an installed capacity of 990 megawatts; (iii) Kariba North Bank Power Station in Zambia, built and commissioned between 1975 and 1977, with four turbines that have been uprated over the years to provide 720 megawatts; (iv) Kariba North Bank Extension, commissioned in 2014, at 360 megawatts; and (v) the Itezhi-Tezhi power station, commissioned in 2016, with 120 megawatts (World Bank 2009, 2015).

Power generation has historically been more than sufficient to meet demand. In the 1970s, Zambia was an exporter of electricity to South Africa and Zimbabwe. This followed completion of the Kafue Gorge Hydroelectric Scheme (HES), combined with a slump in copper prices and decline in mining activity, which significantly reduced the national demand for electricity. However, this power surplus has been gradually reversed over the past 30 years due to limited investments in new energy generation coupled with an increase in demand for electricity (roughly 4 percent per annum). According to the Living Conditions Monitoring Survey, the number of household connections has climbed from 584,000 in 2010 to nearly one million in 2015,[1] yet power generation has been affected in part due to hydrological variability and increased utilization of water through the Kariba Dam HES. This has resulted in a growing power deficit, which reached around 591 megawatts in the last quarter of 2015, representing approximately 34 percent of demand.

The power crisis has impacted all areas of the economy, contributing to recent slower economic growth. To manage the power deficit, the national power utility, ZESCO, was required to run power outages on a rotational basis (load-shedding) around eight hours per day. The mining industry, which was unaffected by load-shedding, was requested to reduce its load by nearly a third, and ZESCO was required to import power at premium rates. Limited energy availability has significantly raised costs, artificially reduced output, and made some ventures financially unviable. Production processes requiring an uninterrupted electricity supply have been most affected. To overcome these constraints, the private sector has had to run costly generators or pay workers extra to work night shifts. Output, particularly in the industrial sector, has been adversely affected, and reports suggest many manufacturers are meeting only a third of scheduled production and have had to lay off workers. Households with access to grid electricity have also been adversely affected. During power outages, users have had to rely on charcoal or run expensive generators. Finally, public services have been affected by the power crisis with costs increasing and quality declining.

In response ZESCO developed new contracts with utilities in the SAPP and increased the import of expensive emergency power options to address the deficit. The cost of imports from the Day-Ahead Market (DAM) in the SAPP nearly doubled, from US$0.27 per

1. According to the Living Conditions Monitoring Survey almost all new connections have been in urban areas. Out of approximately 3 million households in Zambia, only 4 percent of rural households are connected compared to 67 percent of urban households.

kilowatt-hour in April 2015 to US$0.67 per kilowatt-hour in October 2015, while commercial imports reached US$0.188 per kilowatt-hour. Consequently, the total cost of emergency power (cost of supply minus tariffs) reached around US$44 million in 2015 and grew to US$340 million in 2016, placing further pressure on the government's public finances. The government has also invested substantially in the power sector to try and reduce exposure to hydrological risks and diversify sources of generation. Six power plants, amounting to about 1,730 megawatts, are at various stages of preparation and development, although some of these have been in the pipeline for more than a decade.

2.3. The Power Sector in Zimbabwe

Zimbabwe's power sector has similarly been struggling with the challenge of supplying reliable electricity to meet economic demands and increase access to electricity to improve the quality of life of citizens. The total installed capacity is 2,016 megawatts, with current demand in excess of supply, and it is forecast to grow to more than 4,000 megawatts by 2030. More than half the generation capacity (63 percent) is thermal (coal-based), while the balance (37 percent) relies on hydropower generation. However, only around three-quarters of the installed capacity (1,466 megawatts) is available for generation due to the low availability of the old thermal plants—most of which were commissioned between 1942 and 1957—and poor maintenance driven by insufficient financial resources. Around 60 percent of the currently available generation capacity is supplied by the Kariba HES. This creates additional vulnerabilities. For example, during the recent drought it was estimated that only 1,293 megawatts was available compared to the demand of roughly 2,000 megawatts.

The resulting power shortfall has negatively impacted on the economy. The national power utility, Zimbabwe Electricity Transmission and Distribution Company (ZETDC), has had to impose significant load-shedding and divert power away from industry. The manufacturing sector, which was already facing an adverse external environment, was particularly negatively affected. Significant power users were forced to temporarily close, with implications on labor and production. Meanwhile, households were compelled to rely on alternative energy sources, primarily charcoal, while public services were also adversely affected by the power outages.

The government has been trying to attract investments in the power sector in an effort to close the deficit in generation and meet projected demand for electricity. There are plans to build over 4 gigawatts of new capacity over the next decade. These investments are estimated at over US$7.5 billion in capital costs, not including transmission costs which would likely add at least another US$1 billion to total capital. The Batoka Gorge HES accounts for roughly 30 percent of this new planned capacity.

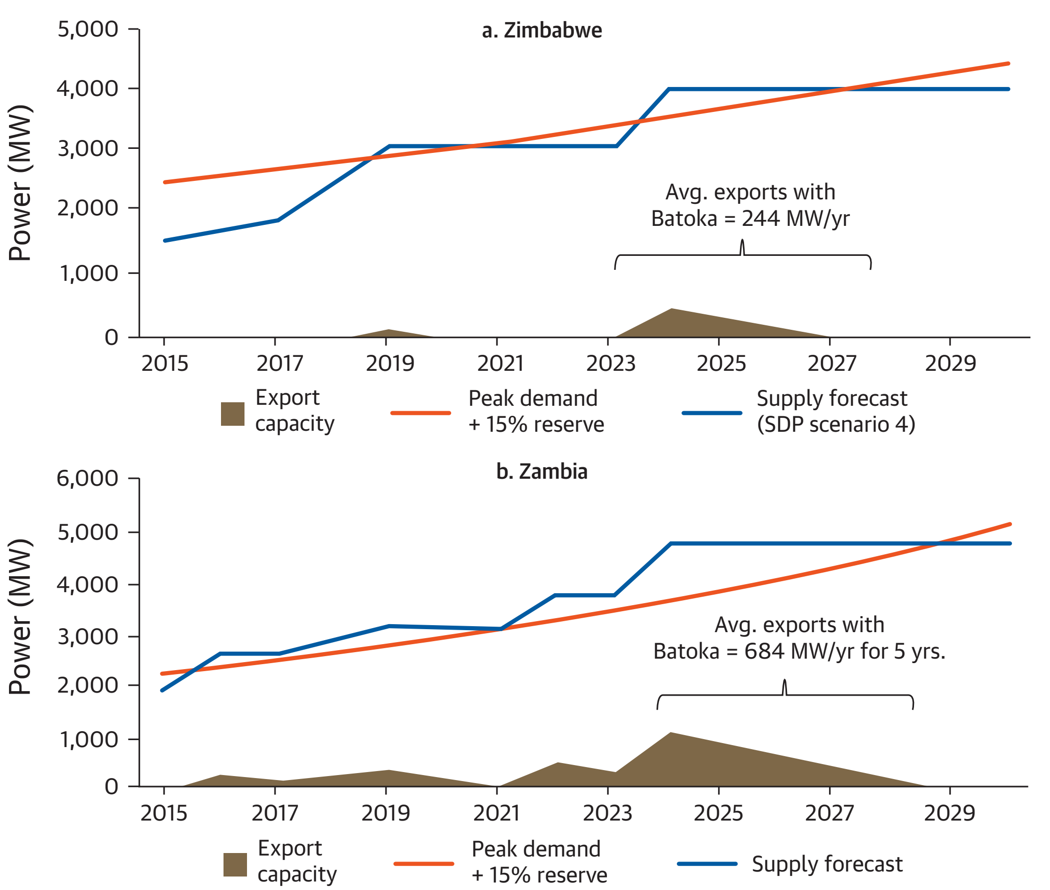
However, attracting new investment in the power sector has been difficult, and there have been no significant investments in the power sector over the last decade. The government has been severely hampered by a large public debt burden with limited access to external financing. Only 6 megawatts of small hydro projects have been developed. An additional 300 megawatts (2 × 150 megawatts) are currently being developed as part of the existing

750-megawatt installed capacity at the Kariba South Power Station on the Zambezi River as part of the Kariba Dam and Hydroelectric Complex.

New investments are further constrained by tariffs that are below the cost of supply. The average tariff is currently at 9.86 USc per kilowatt-hour compared to a cost of 14 USc per kilowatt-hour, coupled with significant arrears amounting to nearly US$1 billion. ZETDC has over 800,000 customers, with residential customers accounting for the largest share of energy consumption (33 percent) followed by industry (26 percent), commercial (18 percent), mining (18 percent), and farming (5 percent). System losses are at 17 percent, including 12 percent distribution (technical and commercial) and 5 percent in transmission.

Both Zambia and Zimbabwe are suffering from a significant power deficit, with user demand exceeding existing capacity. While planned investments are projected to increase supply over the coming decade, user demand is forecast to continue growing at around 5 percent per annum. Even after assuming all planned investments in the power sector have been completed and are running, analysis shows that Zimbabwe and Zambia will be running power deficits by 2028 and 2029, respectively (figure 2.1, panels a–b). Moreover, this analysis

FIGURE 2.1. Supply, Demand, and Export Forecasts for Power in Zimbabwe and Zambia, 2015–29



Source: World Bank calculations based on national master plans.

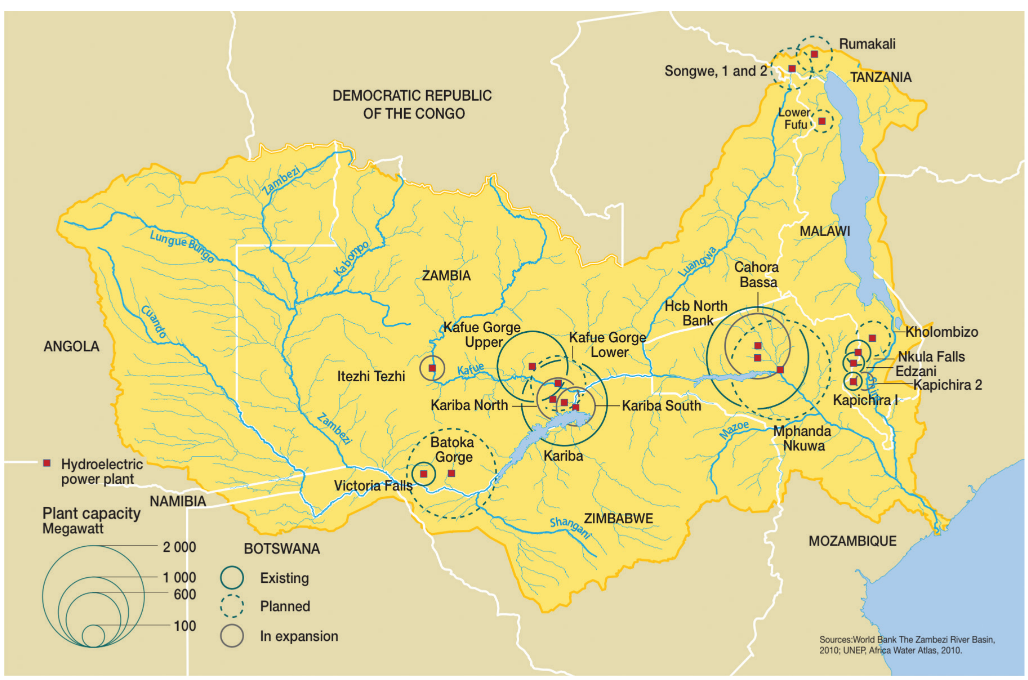
does not take into account the possibility of further exogenous shocks (such as drought) in terms of disrupting power supply. Therefore, a significant investment program is required to address a future energy deficit and measures implemented to mitigate hydrological risks.

2.4. Addressing the Deficit: Hydropower Development in the Zambezi River Basin

The hydropower resources of the Zambezi River Basin are integral to the development of the power sector in Zambia and Zimbabwe. The Basin has in excess of 5,000 megawatts of installed hydropower generation capacity (map 2.1 and table 2.1), with the potential approaching 15,000 megawatts (figure 2.2 and table 2.2). Development of the hydropower sector, according to the generation plan of the SAPP (NEXANT 2008), would include some 53 projects, with an estimated investment of US$10.7 billion over more than 15 years. If the full hydropower potential in the Zambezi River Basin were developed, this would have the potential to double the production of firm energy from 22,776 gigawatt-hours per year to around 43,000 gigawatt-hours per year. Average energy production would also double from 30,000 gigawatt-hours per year to around 60,000 gigawatt-hours per year due to the extension of existing facilities and the addition of new infrastructure. This is sufficient to meet all or most of the estimated 48,000-gigawatt-hour per year demand of the Riparian States.

More than US$16 billion worth of investments have been identified at the prefeasibility or feasibility stage of preparation within the Zambezi River Basin (World Bank 2010). Many of

MAP 2.1. Dams and Hydropower Facilities in the Zambezi River Basin



Source: SADC et al. 2012, after World Bank, 2010.

TABLE 2.1. Existing Hydropower Projects and Reservoirs in the Zambezi River Basin

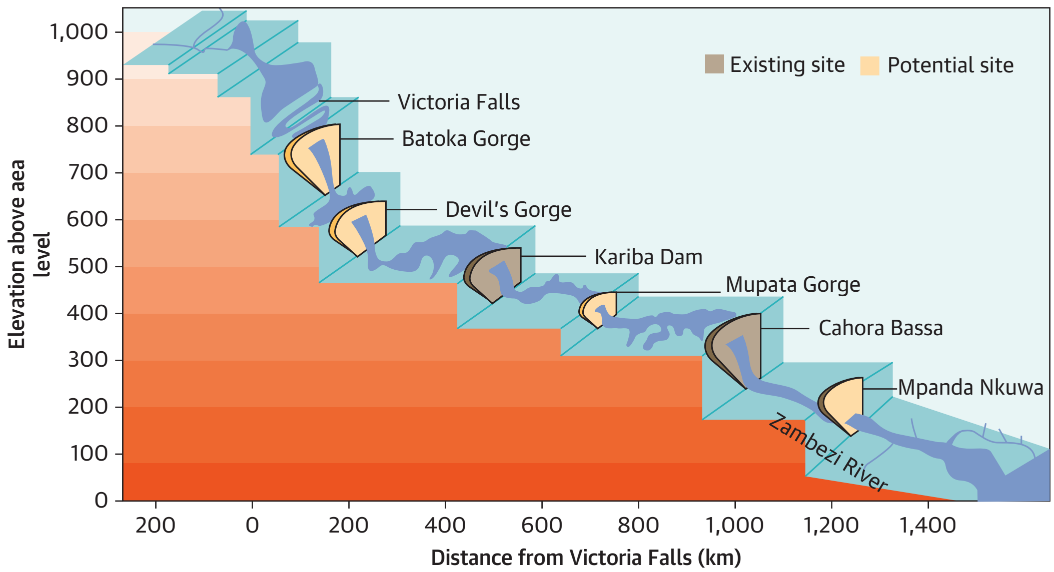
Hydropower project	Operator	River	Country	Type	Capacity (MW)
Kariba South[a]	ZPC	Zambezi	Zimbabwe	Reservoir	966
Kariba North[a]	ZESCO	Zambezi	Zambia	Reservoir	990
Victoria Falls	ZESCO	Zambezi	Zambia	Run-of-River	108
Itezhi-Tezhi	ITPC	Kafue	Zambia	Reservoir	120
Kafue Gorge Upper	ZESCO	Kafue	Zambia	Reservoir	990
Mulungushi	LHPC	Mulungushi	Zambia	Reservoir	20
Lunsemfwa	LHPC	Lunsemfwa	Zambia	Reservoir	18
Lusiwasi	ZESCO	Lusiwasi	Zambia	Pondage	12
Cahora Bassa	HCB	Zambezi	Mozambique	Reservoir	2,075
Wovwe	ESCOM	Wovwe	Malawi	Pondage	4.35
Nkula Falls (A and B)	ESCOM	Shire	Malawi	Pondage	124
Tedzani (I–IV)	ESCOM	Shire	Malawi	Pondage	92.7
Kapachira Stage 1	ESCOM	Shire	Malawi	Pondage	129.6

Source: World Bank, 2010. See table A.1 for a full list.
Note a: Original capacity uprated over the years with additional generation capacity installed in both North and South Bank Power Stations.

these proposed investments were identified long ago and have been in the pipeline for several decades. In addition to the challenges of financial mobilization within numerous competing demands, the geopolitical history and contemporary transboundary nature of many of the resources have created a complex environment within which to advance the sustainable development of common pool resources. With the combined gross domestic product (GDP) among the Zambezi River Basin Riparian States estimated at over US$100 billion, and recognition of the importance of a shared prosperity and increasing commitments toward regional integration, there is significant potential for collective development of the regions' rich, natural endowments. Despite this increasing prosperity, poverty is persistent across the basin, and coefficients of inequality for some of the riparian states are among the highest in the world. Reflecting the dual nature of the regional economy, new investments in large infrastructure coexist alongside a parallel, subsistence economy reliant upon environmental services provided by the river. Appropriate measures are needed to balance these mutual dependencies among different users.

Coordination around the development and operation of hydropower resources within the Zambezi River Basin has the potential to contribute substantial benefits. In addition to the opportunities for cooperative development, it has been estimated that improved coordination in operation of the hydropower facilities envisaged under the SAPP could provide an additional 23 percent generation over uncoordinated (unilateral) operation. Even in the absence of the full development scenarios outlined in the SAPP, coordinated basin wide operation of existing hydropower facilities could increase firm energy production by seven percent over the current situation, from 22,776 gigawatts per year to 24,397 gigawatts per

FIGURE 2.2. **Hydropower Resources in the Zambezi River Basin**



Source: SADC et al. 2012.

year. The economic value of this basin wide cooperation in terms of additional generation with minimal investment is estimated at US$585 million over a 30-year period.

There are a number of additional benefits from improved cooperation beyond the energy sector. The results of a multi-sectoral investment analysis (World Bank 2010) have shown that cooperative water development in the Zambezi River Basin could result in substantial benefits. The potential outcomes envisaged over the next 10 to 15 years under the Integrated Water Resources Management (IWRM) Strategy through cooperation include the following:

(i) Poverty reduced throughout the basin as a result of expanded development, improved coordinated and sustainable water resources management.

(ii) Energy security through hydropower investments (US$10.7 billion) resulting in an additional 35,300 gigawatt-hours per year of firm energy and an additional 60,000 gigawatt-hours per year of average energy.

(iii) Agricultural production increased, enhancing regional food security through an additional 343,000 hectares, increasing irrigation to 775,000 hectares per year (85 percent in Malawi, Zambia, and Zimbabwe).

(iv) Increased employment, particularly in the agricultural sector, with over 500,000 jobs created.

(v) Economic resilience increased and sustained growth benefits through reduced exposure to floods (greater than US$1 billion avoided losses on average per year) and adaptive measures to climate change.

TABLE 2.2. Potential Hydropower in the Zambezi River Basin

Country	Projects (no.)	Capacity (MW)
Angola	9	28
Malawi	16	2,844–3,329
Malawi / Tanzania	1	340
Mozambique	11	5,876–6,146
Tanzania	2	374
Zambia	10	1,710–1,720
Zambia / Zimbabwe	3	3,440–4,000
Zimbabwe	2	600
Total	54	15,212–16,537

Source: World Bank, 2010. See table A.2 for a full list.

(vi) Regional transport costs and travel times reduced through bridge investments and navigation.

(vii) Water supplies secured for urban and industrial demands (greater than 1,000 million cubic meters per year to Botswana, Malawi, Zambia, and Zimbabwe).

(viii) Environmental restoration of the Zambezi Delta and improved fisheries production through systematic introduction of basin wide environmental flows.

(ix) Tourism and Mining contributions to GDP increased through integrated, sustainable development.

(x) Fisheries production enhanced through improved management of water resources.

2.5. The Challenge of Transboundary Water Resource Development

The development of water resource infrastructure within an international, transboundary context, such as the Zambezi River Basin, poses a number of challenges above those typically experienced with national investments (figure 2.3). Such transboundary investments require careful planning and implementation to manage interdependencies among a range of factors. In addition to the typical challenges associated with large complex projects, including financial structuring, transboundary projects need to consider the enabling institutional arrangements, socioeconomic and biogeographical features, as well as the prevailing legal, cultural, and political regimes among multiple countries.

Hydropower projects are heterogeneous and depend on a number of unique characteristics. Therefore, planning and implementation of a hydropower project needs to be customized to accommodate these issues. Such programs involve a number of stakeholders with different rights, roles, and responsibilities with often differing objectives. This can result in coordination failures, particularly where the coordinating agent lacks the capacity to manage the program being implemented. Finally, there are often legal and economic issues associated with such complex projects. These require a robust legal framework and analytical tools to assess the likely economic outcomes of different options to ensure the optimal outcome is decided on.

FIGURE 2.3. Factors Influencing Choice of Delivery Models for Infrastructure Projects

Project type and physical characteristics	Geopolitical issues	Historical context	Legal and economic regime	Infrastructure project
• Purpose of project: to provide bulk water, generate hydropower, and manage flooding, etc. • Location of the project within the basin, watercourses, land use options and ecosystems it influences, etc. • Size and physical design of the project	• Degree of trust and level of constructive relations between partners in the basin • Level of consensus and support for the project among parties	• Social and political conditions that motivated the development of transboundary infrastructure • Relative power of different nations and organizations involved in transboundary transactions	• Are there stable and predictable laws to govern project development • Is the rule of law judged to be dependable and able to mitigate against expropriation of assets • Are counterparts to the project (i.e., off-takers) likely to honor commitments • Is there a local capital market to provide funds	

While various considerations involved in cooperative action present complex challenges, they also provide opportunities to optimize regional benefits and mitigate shared risks. These risks include those of climate variability and change, which often disproportionately impact poor and vulnerable communities. As competition for water resources grows, national projects are exhausted, and climate change intensifies hydrological variability and unpredictability, the number of projects developed jointly by Riparian States will increase.

Non-cooperative and competitive behavior among Riparian States within transboundary river basins can result in sub-optimal development outcomes. The use of a common resource by one Riparian State driven by individual rationality can diminish the ability of the other Riparian States to use the same resource and create problems of over appropriation or congestion. The aggregation of individual decisions from rival demands on the water resource can also lead to potential overuse and degradation. The difficulty in excluding individual Riparian States from deriving benefits from within the basin also leads to problems of free-riding or insufficient maintenance of supplies. These issues can contribute to increased tensions among Riparian States, giving rise to the debate around cooperation versus conflict.

Other barriers that can accentuate the challenge of optimizing opportunities around international common pool waters resources include the asymmetric information available among the Riparian States, technical uncertainties, conflicting national versus collective interests, political and sovereign rationality, asymmetric country characteristics, and upstream downstream interests. This is particularly relevant if unilateral developments proceed to place demands on the available water resources while ignoring the costs imposed on other Riparian States.

However, cooperation around the development and management of transboundary waters can substantially increase long-term gains and provide sustainable benefits (Subramanian, Brown, Aaron 2012). These benefits can include increased financial and economic returns; accelerated economic development; improved human well-being; enhanced environmental sustainability; increased political stability and peace dividends; improving access to external markets; increasing economies of scale, as evidenced through the lower marginal cost of unit power production in the case of hydropower; improved management and coordinated operation of water infrastructure to accommodate multi-purpose uses of water; the possibility of jointly facing common external threats, such as floods, droughts, and other climate risks—as well as water-borne diseases such as malaria and river blindness; and optimizing the location of infrastructure to increase benefits and reduce costs.

There are a range of possibilities for structuring coordinated development of transboundary water resources infrastructure. The various different options relate to the nature of the relationship between the project proponent(s) and the Riparian States that own the resource in terms of how the infrastructure is developed and how the returns from the investment are shared (figure 2.4). These can be considered along a continuum of institutional options, reflecting different levels of coordination and cooperation. These institutional decisions give rise to different potential revenue streams and inform the available financing options.

FIGURE 2.4. Options for Structuring Transboundary Water Resources Development

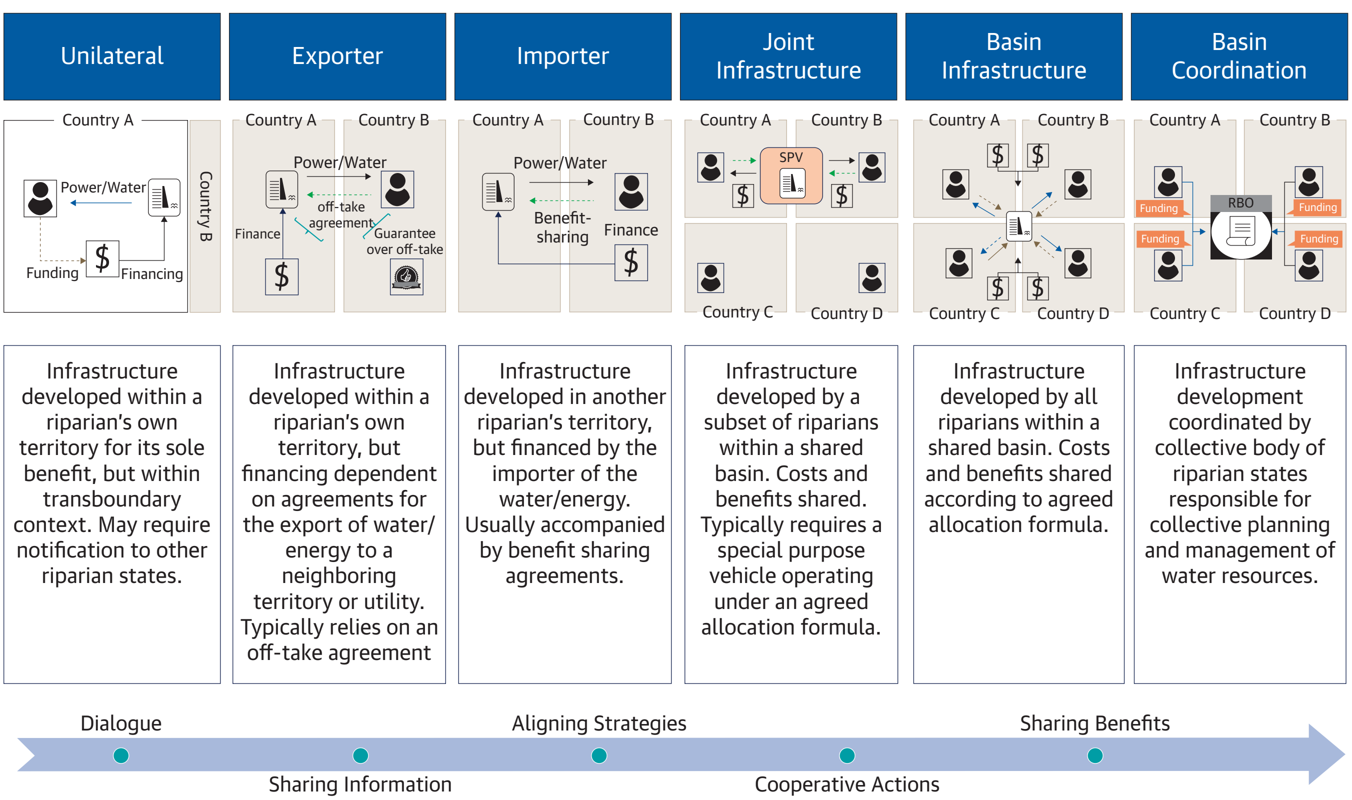
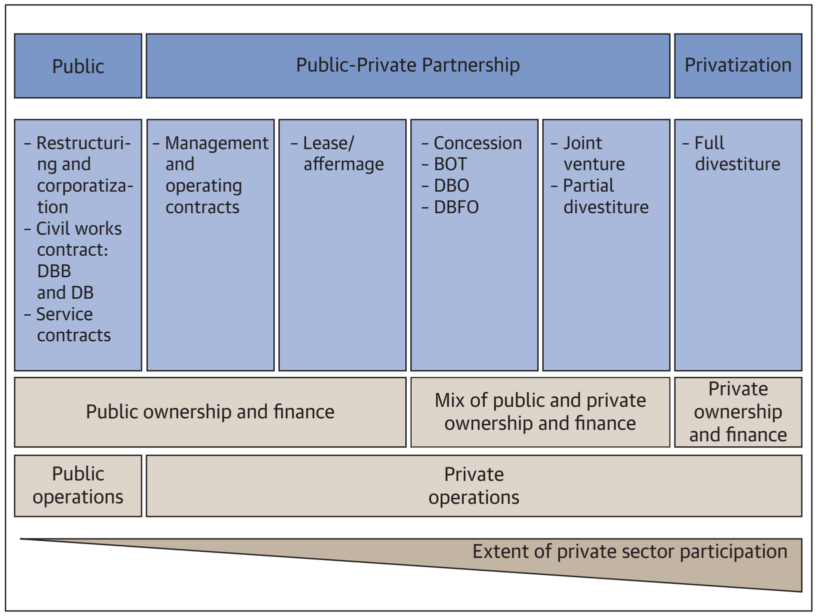


FIGURE 2.5. **Public and Private Sector Delivery Models**

- Different delivery models are available for transboundary infrastructure from the purely public to fully privatized.
- Each implies a different set of institutional, management, and financial relationships between parties.
- Particular models can confer advantages over others, but the benefits—as well as the decision over what model to deploy—depend on a wide variety of contextual issues including project size, complexity, public sector capacity, private sector capacity, and access to appropriate finance.



Note: BOT = buy-operate-transfer; DB = design-build; DBB = design-bid-build; DBFO = design-build-finance-operate; DBO = design-build-operate.

Maximizing the allocation of financial resources for development, without adversely impacting public finances, requires a range of financing options (figure 2.5). These include leveraging revenue streams to draw on private resources when they can help achieve development goals, and reserving public financing for other sectors and services when private sector engagement is not optimal nor available. The choice of model depends on a number of contextual issues, from the size and complexity of the program, the access to adequate finance, and the capacity of public sector(s) and the capacity of private sector.

Hydropower investments are characterized by stable, long-term revenue streams coupled with low operation and maintenance costs. These provide the basis for attracting repayable finance, which can include loans, bonds, and equity. There are various ways of increasing the leverage exerted by the revenue streams in attracting repayable funding sources. These work either by mitigating specific risks that would otherwise hamper financing, or by packaging the finance in a form that is more attractive to potential suppliers. These levers include guarantees, insurance, co-financing, B loans, blending, or output-based aid, etc.. The funds can be applied to provide public or private goods that in turn generate revenues.

Revenue commitments from Member States have leveraged roughly US$4 billion in project financing contracted by basin organizations for transboundary infrastructure development. However, little private sector investment has been mobilized to date given the complexities associated with the common pool nature of transboundary water resources. Specific, targeted measures will be required to provide the necessary comfort and confidence to address the complex risks and crowd in private investment in the future.

Chapter 3 The Batoka Gorge Hydroelectric Scheme

The Batoka Gorge Hydroelectric Scheme (HES) is one of a series of hydropower investments originally conceived as part of a cascade on the Zambezi River Basin. The dam has been proposed along the main stem of the river and was first identified in 1972 as a result of a study by the Central African Power Corporation (CAPCO), which sought to establish possible power sources to meet the power demands of Zambia and Zimbabwe. The study was updated in 1981 and suggested that the dam site be moved 12 kilometers upstream, above the existing Kariba Dam and hydroelectric scheme, and approximately 47 kilometers downstream of the Mosi-oa-Tunya (Victoria Falls).

A severe drought in Zambia and Zimbabwe in 1991 and 1992 caused the water levels in the Kariba reservoir to decline dramatically, severely impacting hydropower generation. This exposed the vulnerability of the two countries to over-dependence on a single power source. As a result, the governments decided to commission a feasibility study through the Zambezi River Authority (ZRA) in 1993. These studies confirm the Batoka Gorge HES as the least cost option regarding average specific energy generation cost for development both countries on the Zambezi River. The new power station was expected to enhance electricity generation in Zambia and Zimbabwe by 1,600 megawatts and would be shared equally, with the intention to commission the scheme by 2004. However, further development of the Batoka Gorge HES was delayed due to an unresolved impasse between Zambia and Zimbabwe (Box 3.1).

The final layout for the proposed Batoka Gorge HES is informed by the need to develop the full potential energy of the shared section of the Zambezi River between Zambia and Zimbabwe, which falls under the mandate of ZRA. This includes the Kariba Dam and hydroelectric complex and the proposed Batoka Gorge HES along with an additional site for the proposed Devil's Gorge Dam and HES located immediately downstream of Batoka and upstream of Kariba.

The recommended option for the Batoka Gorge HES is a 181-meter high, 720-meter long roller-compacted concrete (RCC) gravity arch dam with two surface power stations on either side of the river, each with a total installed capacity of 1,200 megawatts, giving a total installed capacity of 2,400 megawatts. At the full supply level of 763 meters above sea level, the reservoir is estimated to store 1,392 million cubic meters of water and have a surface area of 25.6 square kilometers. No resettlement is envisaged for the dam or reservoir, which is fully contained within the gorge, and would be operated as a run of river scheme. The hydraulic backwater effect has been evaluated against the dam height and generation capacity to understand the implications of different options and explore a range of measures to balance different interests.

It is envisaged that the Batoka Gorge HES would be implemented over a seven-year period. The total cost for the proposed program is estimated to be in the order of US$2.6 billion.[1] This consists of US$1.5 billion for the dam component and US$1.1 billion for the costs associated

1. Preliminary cost estimates based on initial assessments and modeling. This excludes the financing costs.

BOX 3.1. Cost of Delays in Implementing the Batoka Gorge HES

The delays in implementation of the Batoka Gorge HES centered around a colonial era debt associated with the original development of the Kariba Dam and HES. The original proposal was to build the Kariba Dam on the Zambezi River and two hydropower stations, one on the north and one on the south bank of the river, to supply power to the then Federation. However, Zambia gained independence from the British in 1964, following the breakup of the Federation, while Rhodesia's white minority subsequently announced a Unilateral Declaration of Independence (UDI) on November 11, 1965, proclaiming itself an independent sovereign state. During this period, sanctions limited the ability to invest in the joint development of the second power station on the north bank, and Zambia proceeded with construction of the north bank power station on a unilateral basis with support from the World Bank. The Rhodesians fought to maintain minority rule until free elections resulted in Zimbabwean independence in 1980.

In 1987, the ZRA was established as a body corporate by parallel legislation in Zambia and Zimbabwe (Zambezi River Authority Agreement, 1987) and replaced the Central African Power Corporation (CAPCO). It was agreed that CAPCO's assets and liabilities would be shared between the ZRA and the two national power utilities. In 1996, a valuation of the assets determined that the equivalent of US$70.81 million was due to Zambia. This valuation was based on and related to investments made by Zambia in the north bank power station during the UDI. However, subsequent agreement on the applicable financing terms and conditions was reached only in 2012 after a high-level political process between Ministers from Zambia and Zimbabwe to resolve the impasse. This process included analytical work on the financial and economic implications of the impasse as well as options for moving forward.

The delayed implementation of the Batoka Gorge HES resulting from the impasse resulted in substantial forgone revenues. Conservative estimates of the direct revenues to the power utilities through electricity sales are at least US$700 million annually, or more than US$9 billion since the original planned commission date. In addition, the macro-economic impacts associated with the cost of unserved electricity are estimated to have cost the two countries more than US$45 billion.

The agreement between Zambia and Zimbabwe opened the way to review and update the studies for development of the Batoka Gorge HES. The studies were launched in 2014 to review existing information and provide an assessment of the feasibility of the various different options. These are positioned within a broader program of support to the climate resilient, sustainable development of the Zambezi River Basin. This program is founded on the Integrated Water Resources Management Strategy for the Zambezi River Basin, along with the Multi-Sector Investment Opportunity Analysis and the Strategic Plan for the Basin being carried out under the auspices of the Zambezi Watercourse Commission (ZAMCOM).

with the two power stations, transmission lines, and electro-mechanical equipment. This figure does not include annual operational costs or financing costs, which are factored into the Macroeconomic Assessment of Public Investment Options (MAPIO) model and included in the impact analysis.

The available data suggest that the Batoka Gorge HES is one of the least cost hydropower projects per megawatt in Sub-Saharan Africa (table 3.1). These projects include new build, along with rehabilitation and extension projects. While the aggregated cost estimates may vary in terms of the elements they include and the date at which they were defined, the US$0.88 million per megawatt for the Batoka Gorge HES reflects a lower cost per megawatt than the extension of the Kariba Dam HES carried out by the national power utilities on the north and south banks. The Government of Nigeria recently announced the award of a US$5.8 billion contract to build the 3,050-megawatt Mambila hydroelectric power project in the State of Taraba (PM News 2017). The project to be delivered by a consortium of Chinese state-owned construction firms features four dams between 50 and 150 meters tall over six years at a cost equivalent to US$1.9 million per megawatt. The 750 megawatt Kafue Gorge Lower Project under development in Zambia through a Private-Public Partnership (PPP) arrangement is estimated to cost US$2.59 million per megawatt.

Given the transboundary nature of the Batoka Gorge HES, several options have been considered for structuring and financing the project. These range from an entirely publicly owned and financed project to a fully privately owned and financed project (table 3.2). Various institutional arrangements have also been considered to manage the project development, operations, and maintenance, as well as to facilitate the project financing and structuring. A multi-criteria assessment has been used to decide the appropriate development model. This is based on (i) Ease of financing; (ii) Risk Management; (iii) Whole of Life Costing; (iv) Innovation Capacity; (v) Economies of Scale; (vi) Competitive Tension.

TABLE 3.1. Planned Hydropower Projects in Southern Africa

Project	Country	Capacity (MW)	Cost (US$m)	Cost per MW (US$m)
Cahora Bassa North Bank Extension	Mozambique	1,245	800	0.64
Batoka Gorge	Zambia, Zimbabwe	2,400	2,100	0.88
Kariba North Bank Extension	Zambia	360	420	1.17
Inga 3	Congo, Dem. Rep.	4,320	6,000	1.39
Mphanda Nkuwa	Mozambique	1,500	2,400	1.60
Kariba South Bank Extension	Zimbabwe	300	533	1.78
Itezhi-Tezhi	Zambia	120	217	1.81
Grand Inga	Congo, Dem. Rep.	39,000	80,000	2.05
Kafue Gorge Lower	Zambia	750	1,940	2.59
Rusumo Falls	Burundi, Rwanda, Tanzania	80	468	5.85

Source: World Bank calculations.
Note: Cost in $US, millions, base case, not escalated unless otherwise stated.

TABLE 3.2. Institutional Options Evaluated for Development of the Batoka Gorge HES

Options		1	2	3	4	5a	5b	6	7
Description		Split model (separate procurement for dam and power plants)						Integrated (single procurement / ownership for dam and power plants)	
Ownership	NBPC	ZESCO	Private IPP Co.	Private IPP Co.	ZESCO	ZESCO	Private IPP Co.		
	Dam Owner	ZRA	ZRA	Private Dam Co.	Private Dam Co.[a]	ZRA	ZRA	ZRA	Project Co.
	SBPC	Zesa	Private IPP Co.	Private IPP Co.	Zesa	Private IPP Co.	Zesa		
Financing	NBPC	Public	Private	Private	Public	Public	Private		
	Dam financing	Public and private	Public and private	Private	Private	Public and private	Public and private	Public	Public and private
	SBPC	Public	Private	Private	Public	Private	Public		

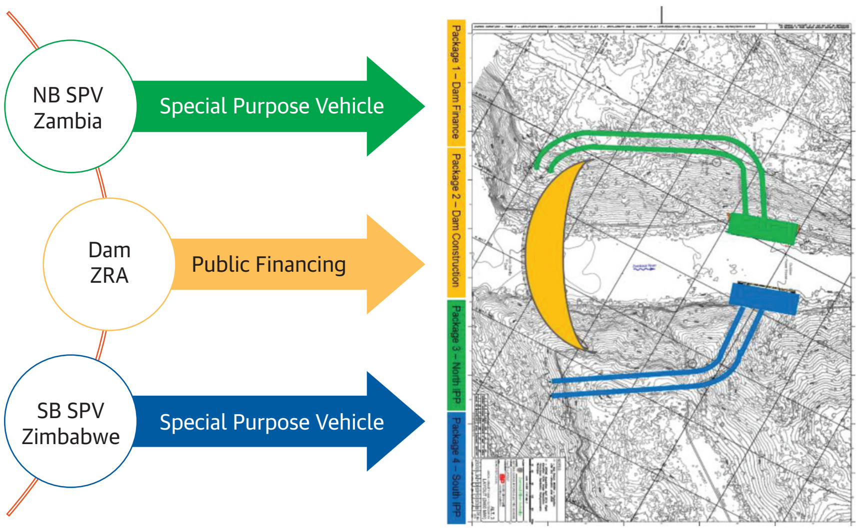
Note: HES = Hydroelectric Scheme; IPP = independent power producer; NBPC = North Bank Power Company; SBPC = South Bank Power Company; ZESA = Zimbabwe Electricity Supply Authority; ZRA = Zambezi River Authority.
a. ZRA operates.

A “three-in-one” split development model has been proposed and adopted for development of the Batoka Gorge HES (figure 3.1). The “three-in-one” split development model would include a publicly-financed dam under the ZRA and two Special Purpose Vehicles (SPVs) for the power plants: one on the north under the Zambian power authority, ZESCO, and one on the south bank under the Zimbabwe Power Corporation (ZPC). This model is based on an initial framework developed by the World Bank with the ZRA that was subsequently subjected to a detailed assessment by the ZRA’s Transaction Advisors and endorsed by the Council of Ministers.

This model enables greater flexibility around financing, providing a range of tailored options around the development of the SPVs. This is particularly important given the resource-constrained environment faced by both countries. Moreover, it enables the ring-fencing of various associated risks considering the contributing factors. It also retains public ownership of the dam, which can leverage additional benefits through the joint ownership and conjunctive operation with the Kariba Dam. However, there are a range of potentially viable alternatives that may become the preferred option due to a variety of reasons.

The SPVs are intended to enable a range of different financing options. They offer a complete spectrum of public-private options from participation by national utilities to full independent private operation. This could extend to participation in the SPVs by other countries or national utilities within the Zambezi River Basin and or the Southern African Power Pool (SAPP). Such cooperative ventures could build on the precedent of existing models in Zimbabwe with the participation of Namibia and Botswana in rehabilitation investments.

FIGURE 3.1. "Three-in-One" Split Development Model Proposed for the Batoka Gorge HES



Source: World Bank.
Note: NB = North Bank; SB = South Bank; SPV = Special Purpose Vehicle; ZRA = Zambezi River Authority.

The complex financing structure of the Batoka Gorge HES presents some unique challenges. Similar to other large hydropower investments, it requires mobilizing a large volume of financing, with long lead times, to achieve a return on investment, and uncertainty regarding timelines and costs (due to the complex technical nature of large dam and hydropower projects). However, the "three-in-one" split development model introduces a number of additional interface risks. These arise as a result of three different implementing entities, risks associated with the timing of financing for the dam and associated infrastructure at the time of bidding for the SPVs, multiple financiers, and inter-dependencies in the subsequent revenue streams. This means financing could be challenging to secure and costly if not planned and sequenced.

Developing an integrated financing solution requires a thorough understanding of the different risks faced by potential financiers and how best to mitigate them. These risks could be reduced by advancing the commitments for public sovereign financing for the dam and provide comfort to investors in the SPVs. There are a number of instruments that can help improve the enabling environment and manage the associated risks. Investment guarantees and political risk insurance, such as those provided by the International Development Agency (IDA), the Multilateral Investment Guarantee Agency (MIGA, part of World Bank Group), along with various other private sector and bilateral options, often combine to spread their exposure on a single investment. For example, insurance covers loss of investments because of restrictions on repatriating profits out of the country, expropriation and nationalization, breach of contract, and war and civil disturbance. Policies typically range from US$200 million to US$500 million, with a duration of up to 20 years.

The relative merits of different configurations, particularly in the packaging procurement strategy, will need to assess the relative risks associated with interface of the three different sub-projects. Procuring all packages concurrently, with options to combine several packages, would ensure economy and efficiency. Finally, the success would depend on the availability or commitment to provide financing for the public sector components at the time of bidding. Given the current pressures on public finances in Zimbabwe and Zambia, it is envisaged that the public sector component would need to be primarily financed by concessional loans, predominantly provided by Multilateral Development Banks (MDBs).

Chapter 4 Macroeconomic Assessment of Public Investment Options

4.1. Introduction to the Model

The Macroeconomic Assessment of Public Investment Options (MAPIO) model is designed to estimate the impact of an investment program on key macroeconomic variables. The model assesses the impact of the program in two ways: (i) the increase in demand that occurs as a result of the program's implementation; and (ii) the additional impact on the economy's output as a result of the program's completion. The assessment is not intended to replace appraisal of the project, or to assess all costs and benefits, in particular any externalities that would only be captured macro-economically through the introduction of taxes or subsidies.

The first step to construct the model was to produce baseline macroeconomic accounts for Zambia and Zimbabwe.[1] These economic projections were constructed on the assumption that the Batoka Gorge Hydroelectric Scheme (HES) was not developed. The projections adopt conservative assumptions and reflect long-term trends. The second step uses data on disbursements of the Batoka Gorge HES over the implementation period and the estimated likely benefits of the dam to work out the additional impact on macroeconomic variables. These are combined with specific details of the program to produce new macroeconomic accounts for Zambia and Zimbabwe. Further details are provided in Appendix B.

The MAPIO model was applied to assess the impact of the Batoka Gorge HES over a 33-year period (2018–50), including the estimated seven-year implementation period (2018–24) and the operational period post-construction (2025–50). A number of different scenarios were explored to examine the sensitivity of the results for the Batoka Gorge HES to a range of different assumptions.

4.2. Assumptions and Key Characteristics of the Model

There are a number of key characteristics of this model, namely:

- A large proportion of financing for the dam is expected to be concessional financing (54 percent), market loans would make up the second largest proportion (28 percent), while slightly more than a sixth of total costs (18 percent) would be financing through special purpose vehicles (SPVs).[2]
- The development model endorsed by the two countries envisages the establishment of SPVs that would be used to finance the power stations on the north bank and the south bank. The SPVs would comprise a debt and equity component and represent an innovative

1. Based on World Bank estimates.
2. Concessional financing is defined as having the following characteristics: a 2.5 percent interest rate, 10 years' grace, and a repayment period of 40 years. Market-based lending is defined as lending at an 8 percent interest rate, 0 years' grace, and a repayment period of 20 years. Additional domestic lending required is assumed to be at a 6 percent interest rate with a 10-year repayment period. For the purposes of this analysis, identical borrowing terms are applied to Zambia and Zimbabwe.

use of public private partnerships to enable financing of the program. Upon completion of the program, the SPVs would retain a share of revenues to pay profits on the equity share and make debt repayments.[3]

- The model is based on the assumption that the majority of the program (90 percent of costs) would be implemented by local firms and labor. Costs are only for imported capital, imported labor, and margin, which is typically quite large. This magnifies the demand effects of the program during implementation; therefore, Scenario 1 examines the impact if only 20 percent were implemented by local firms and labor.
- The model assumes most of the increased demand (due to implementation of the program) will result in an initial rise in supply. The effect on prices will be muted, assumed to be around 10 percent by year five.

The model is limited in its treatment of wider effects. First, multiplier effects resulting from the benefits accruing from the Batoka Gorge HES are not considered. It is outside the scope of this analysis to consider multiplier effects that may result in expansion of particular sectors. If data were to become available in the future this can be integrated into the model. It is likely this would increase the project's estimated rate of return and lessen its impact on debt sustainability.

The analysis is based on the "three-in-one" split development model endorsed by the Council of Ministers. This includes a publicly financed dam under the Zambezi River Authority (ZRA) and two SPVs that would be used to finance the power stations on the north and south banks. However, there are a range of other potentially viable alternatives that may, for a variety of reasons, become the preferred option. The MAPIO model would provide a useful tool to help the countries consider the relative merits of alternative development models in the future.

It is also outside the scope of the paper to consider the wider impacts of the construction of Batoka Gorge HES in terms of non-economic costs and key sectors. The Mosi-oa-Tunya (Victoria Falls) is an internationally renowned tourism destination with a range of associated adventure activities. While most visitors come to see the Falls, the environmental and social impact assessment estimates that roughly 45 percent of visitors also take part in white water rafting. This creates seasonal employment opportunities for around 200 to 300 people. The creation of the dam, reservoir, and associated infrastructure will also create a range of new tourism opportunities. As a result, the hydraulic backwater effects of the dam have been evaluated to assess the implications. While these effects are likely to be small in relation to the overall costs and benefits of the project. they are an important part of the multi-criteria decision making process and subject to separate assessments and considerations.

3. To estimate the flows on the debt component of the SPV (US$312 million), it is assumed to have an 8 percent interest rate, no grace and a repayment period of 15 years.

The model also makes a number of key assumptions:

- Zimbabwe is currently in arrears with its external public debt to multilateral and bilateral partners. The government has put forward a plan to clear arrears that would enable it to resume much needed financing from international financial institutions. For Zimbabwe's share of the program to be financed on concessional terms, it is assumed that this takes place. It is unlikely Zimbabwe would be able to finance the construction of the program without receiving significant concessional loans from multilaterals.
- Conservative assumptions have been adopted to estimate the benefits of the dam. The feasibility study estimates that with an installed capacity of 2,400 megawatts, the Batoka Gorge HES would generate around 10,215 gigawatt-hours annually after taking into account auxiliary losses and inefficiencies.
- It is assumed that the vast majority of the dam's power (98 percent) would be exported at the current price of around US 6.5 cents per kilowatt-hour and only a small percentage (2 percent) would supplant current generator usage at around US 26.3 cents per kilowatt-hour. Domestic tariffs are assumed to be the same as the export tariff (US 6.5 cents per kilowatt-hour), so that increasing the domestic demand to supplant current generator use would increase economic returns.
- No assumptions are used to estimate the benefits of significantly improving the reliability, quality, and duration of power supplied to the private sector and households.
- It is assumed that ZESCO and ZESA make a margin of around 7.5 percent on total revenues after deducting overheads and flows on the SPVs. This is in line with historical measures.

Chapter 5 Results

5.1. Overall Impact on Zambia and Zimbabwe

The Batoka Gorge Hydroelectric Scheme (HES) generates significant returns under the current assumptions. The total cost of the program equates to around US$2.6 billion for an installed capacity of 2,400 megawatts. The cost of the program is assumed to be apportioned equally between Zambia and Zimbabwe (US$1.3 billion). As a result, the program would generate gross benefits of US$663 million per annum, which after deducting around 8 percent for operation and maintenance costs, would equate to net benefits of US$608 million per annum. This is equivalent to around US$304 million per annum for Zambia and Zimbabwe, respectively.

To examine the findings and provide a detailed assessment of the program's return, two internal rates of return (IRRs)[1] are estimated:

- Financial Internal Rate of Return (FIRR) calculates the interest rate from the flow of costs from the program (including debt flows) minus the revenues it will generate.
- Economic Internal Rate of Return (EIRR) compares the project costs in the year they are incurred and stream of interest costs, with estimated additional GDP effects to calculate the EIRR.

The model estimates the Batoka Gorge HES to have a FIRR of around 16.1 percent and 17.2 percent for Zimbabwe and Zambia, respectively. This confirms the program's extremely high rates of return relative to the investment required. Similarly, the EIRR produces a return of 20.6 percent and 26.7 percent for Zimbabwe and Zambia, respectively (table 5.1).

TABLE 5.1. Model Estimates of the Internal Rates of Return for Zimbabwe and Zambia from the Batoka Gorge HES under the Baseline Scenario
(Percent)

Type	Zimbabwe	Zambia
Financial internal rate of return	16.1	17.2
Economic internal rate of return	20.6	26.7

Source: World Bank data.

5.2. Macroeconomic Impact on Zambia and Zimbabwe

Implementation of the Batoka Gorge HES is estimated to increase aggregate demand during the seven-year implementation period. In particular, demand is expected to increase for the following key sectors: transportation, construction, services, manufacturing, and

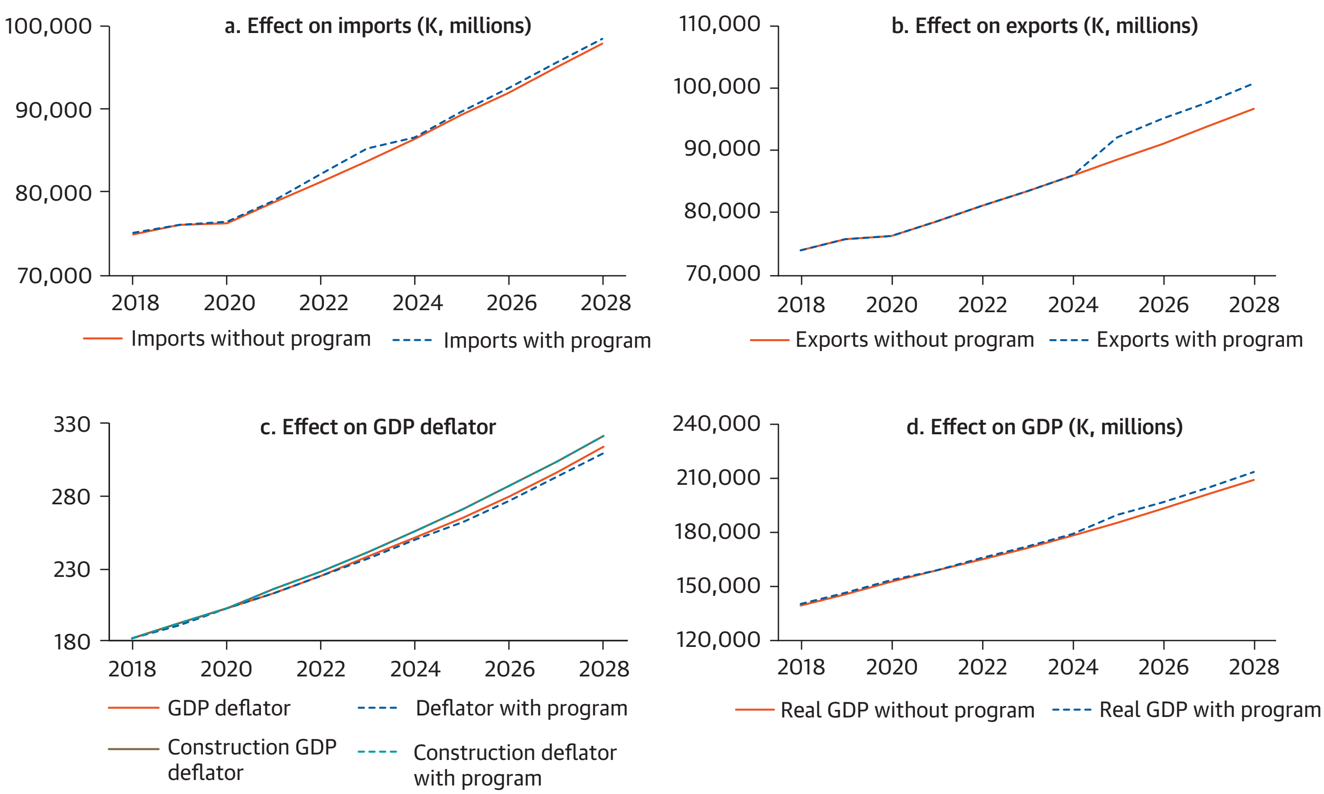
1. To work out internal rates of return, costs and benefits are forecasted forward and the interest rate is calculated for the net present value (NPV) to be zero.
2. To simplify the analysis it is assumed that only these five key economic sectors would be affected by construction of the Batoka Gorge HES. In reality, there are likely to be spillover effects in a number of other sectors. However, estimation of this is outside the scope of the analysis and would not have a major effect on overall benefit estimates.

agriculture.[2] Given that it is assumed 90 percent of the cost of the program would be conducted by domestic capital and labor, the domestic demand effects are estimated to be high. Consequently, the investment would positively impact on GDP and the deflator.

After completion of the Batoka Gorge HES, it is expected to continue to generate net benefits. It is conservatively assumed that the majority of these benefits would be in the form of increased exports. However, the resulting increased income in the economy would also increase consumption and investment and result in higher tax revenue.

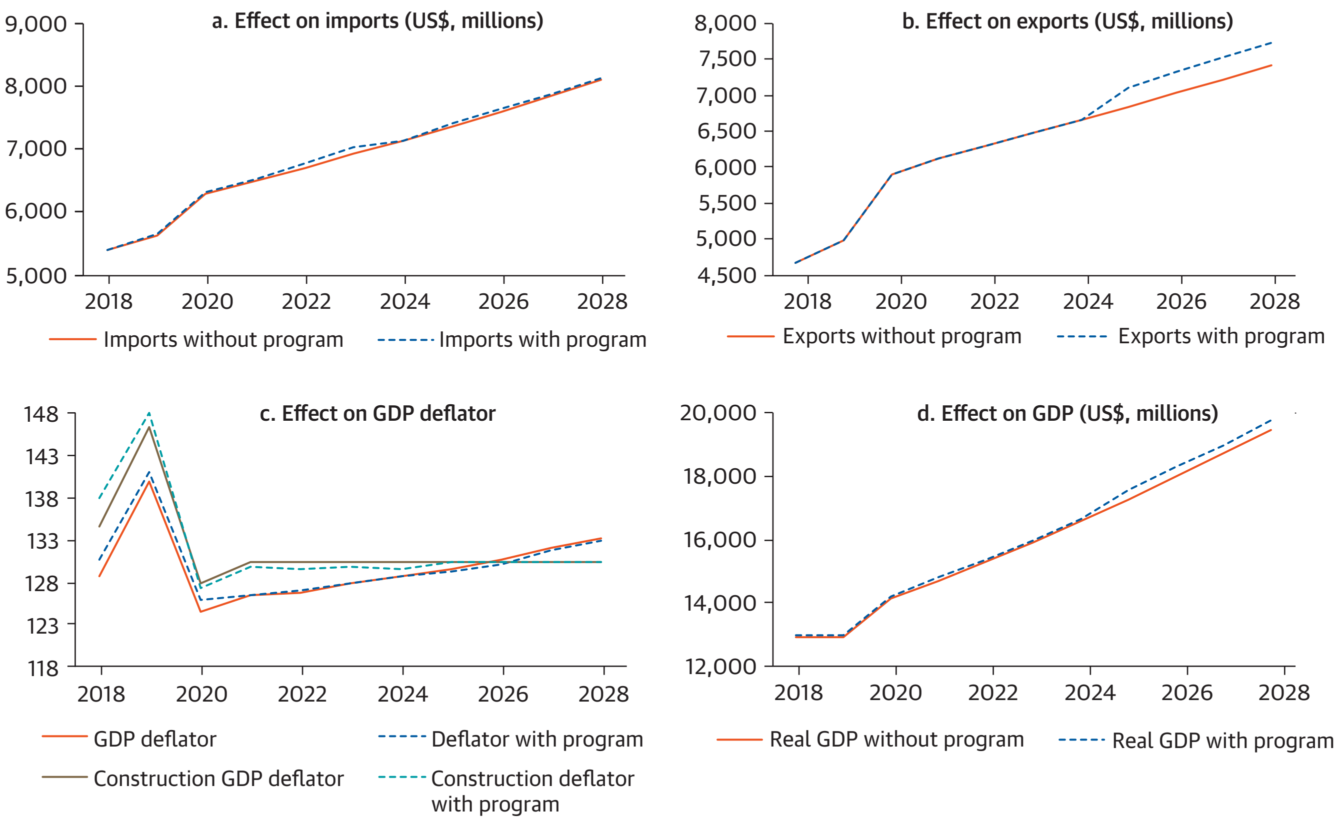
The impact of the Batoka Gorge HES does not noticeably impact on the GDP deflator or the deflator for the construction sector, despite a significant proportion of resources being spent in the country. This is particularly important since the investment constitutes a reasonable proportion of the construction sector in Zambia and Zimbabwe. Based on experience in and across countries for hydropower programs of this scale, the likely initial increase in prices would be limited to around 30 percent for key sectors, particularly construction. This remains a conservative assumption. Work over the implementation period would be subject to procurement contracts, which would serve to lock firms into supplying services at an agreed price. Nevertheless, it's possible that some geographical areas around the

FIGURE 5.1. Model Estimates of the Impact of the Batoka Gorge HES on Zambia Across Macroeconomic Variables, 2018–28, under the Baseline Scenario



Source: World Bank calculations.

FIGURE 5.2. **Model Estimates of the Impact of the Batoka Gorge HES on Zimbabwe Across Macroeconomic Variables, 2018–28, under the Baseline Scenario**



Source: World Bank calculations.

Batoka Gorge HES and key subsectors could experience a temporary increase in prices beyond these levels.

The impact of the Batoka Gorge HES is expected to temporarily lift GDP by around 0.5 percent over the implementation period in both Zambia and Zimbabwe. It is also expected to lift GDP in the construction sector by around 7.7 percent and 1.4 percent in Zimbabwe and Zambia, respectively, and increase GDP in the agriculture sector by around 1.4 percent and 2.6 percent in Zimbabwe and Zambia, respectively. Once the Batoka Gorge HES is completed, GDP is expected to be permanently uplifted by around 2 percent for Zambia and 1.6 percent for Zimbabwe (see figure 5.1, panels a-d, and figure 5.2, panels a-d).

Imports are estimated to rise by around 0.4 percent during the program's construction phase, since international capital would be required to construct the dam. Meanwhile, upon completion of the program, exports are expected to increase by around 4 percent for Zambia and Zimbabwe in 2025 because it is assumed that most of the electricity generated is exported out of both countries at current international prices.

5.3. Fiscal Impact

The impact of the Batoka Gorge HES on the fiscal situation is significant. The implementation of the program entails fiscal costs estimated at US$2.6 billion. Of this, most would be concessional financing with the remainder coming from private sector loans and equity financing. Flows for the latter would be accounted for out of total revenues.

Nevertheless, the fiscal impact of the Batoka Gorge HES is manageable within existing public finance constraints. The impact of financing the program would serve to increase the fiscal deficit from 5.5 percent to 6.3 percent of GDP for Zimbabwe in 2018. Similarly, the fiscal deficit would increase from 3.5 percent to 3.9 percent of GDP for Zambia in 2025. However, this fiscal situation is contingent on financing a significant proportion of costs associated with the Batoka Gorge HES on a concessional basis. A sensitivity analysis was conducted to examine the impacts on the program's financial viability if the financing terms were less favorable.

Completion of the Batoka Gorge HES is expected to generate additional revenues. It is assumed these will accrue to the national power utilities in Zambia, ZESCO, and Zimbabwe, Zimbabwe Electricity Supply Authority (ZESA). As a consequence, each central government will receive three-quarters of the increased revenues from its respective utility after taking into account operation and maintenance costs, private equity, and debt flows.[3] Further, the Batoka Gorge HES will permanently increase GDP of the economy, resulting in additional tax revenues. As such, the program is expected to lower Zimbabwe's fiscal deficit by around 0.8 percentage points and Zambia's fiscal deficit by about 0.1 percentage points.

5.4. Scenario Analysis

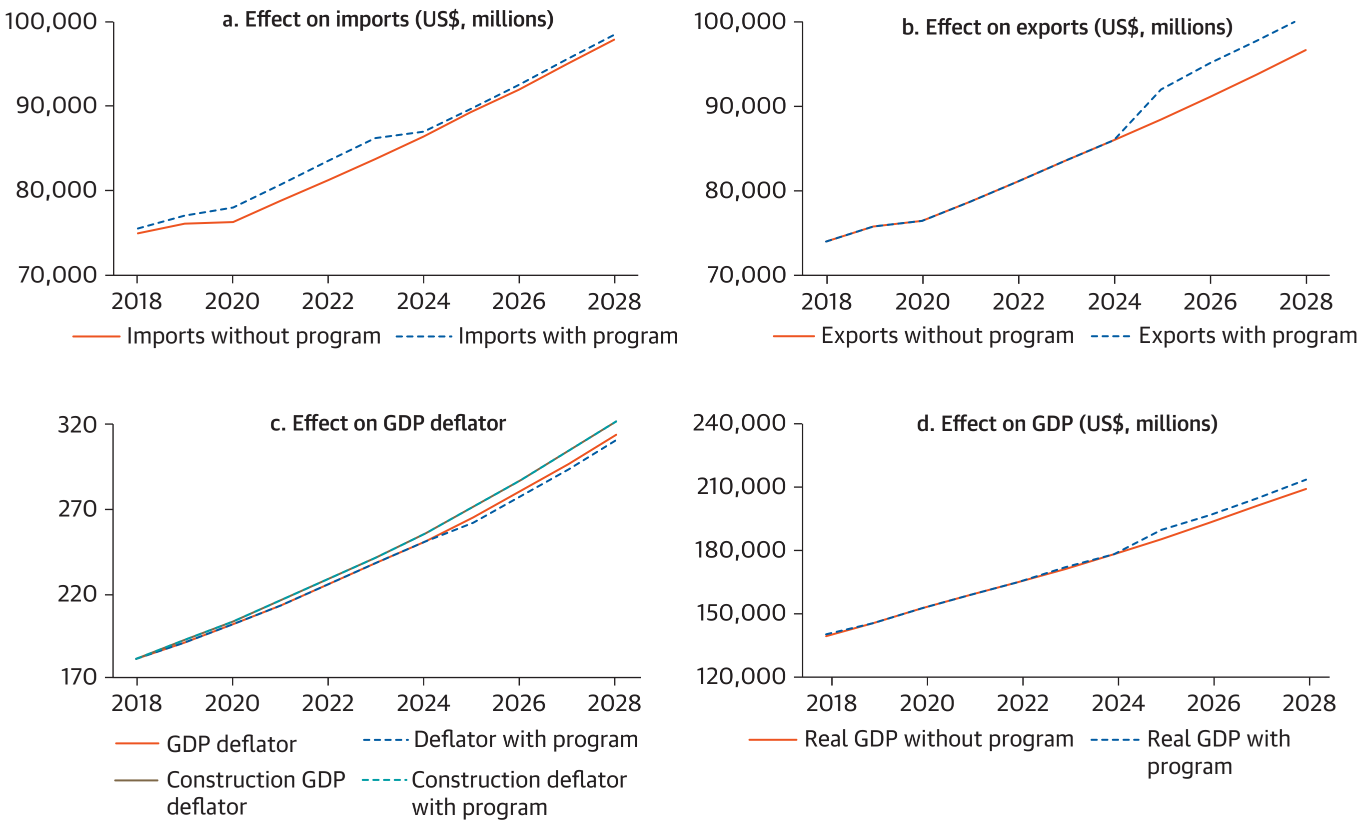
Scenario 1: International Capital and Labor

This scenario examines the impact of the Batoka Gorge HES if a large proportion of the dam were to be implemented by international capital and labor (80 percent of the cost of the program). This would be a typical assumption if the infrastructure program required sophisticated capital, were capital-intensive, required highly skilled personnel, or had to be implemented over a short time period.

The immediate impact of substituting international for domestic resources would be to dramatically reduce the demand effects on the economy during the program implementation period. As a consequence, over the implementation period, it is estimated that there would be no impact on the GDP deflator, GDP, or tax revenue. Moreover, imports over the implementation period increase noticeably in Zambia and Zimbabwe (see figure 5.3, panels a–d, and figure 5.4, panels a–d).

3. While this return is modest, it reflects ZESA's and ZESCO's historic returns after taking into account capital and labor costs and inefficiencies, including wastage.

FIGURE 5.3. Model Estimates of the Impact of the Batoka Gorge HES on Zambia across Macroeconomic Variables, 2018–28, Under Scenario 1: International Capital and Labor



Source: World Bank calculations.

Scenario 2: Limited Supply Response

The MAPIO model assumes implementation of the Batoka Gorge HES would primarily result in an increased supply response due to the increased demand rather than a notable price effect. While unrealistic, Scenario 2 assumes the resulting increase in demand leads to a significant price effect[4] to test price sensitivity to the construction of the dam. The impact on other macroeconomic variables is minimal and therefore excluded from the analysis.

The impact on prices is only significant for Zimbabwe's construction sector (figure 5.5, panels a–b), reflecting that it is considerably smaller than that in Zambia. Even then, the shock dissipates very quickly once the implementation period has ended. The impact on the overall deflator and other sector deflators are minimal. This reflects the relative size of the investment compared to other hydropower programs that provide a comparable level of energy.

4. Of the initial increase in demand, 90 percent is supposed to result in increased prices, and 10 percent is expected to result in increased supply.

FIGURE 5.4. **Model Estimates of the Impact of the Batoka Gorge HES on Zimbabwe across Macroeconomic Variables, 2018–28, under Scenario 1: International Capital and Labor**

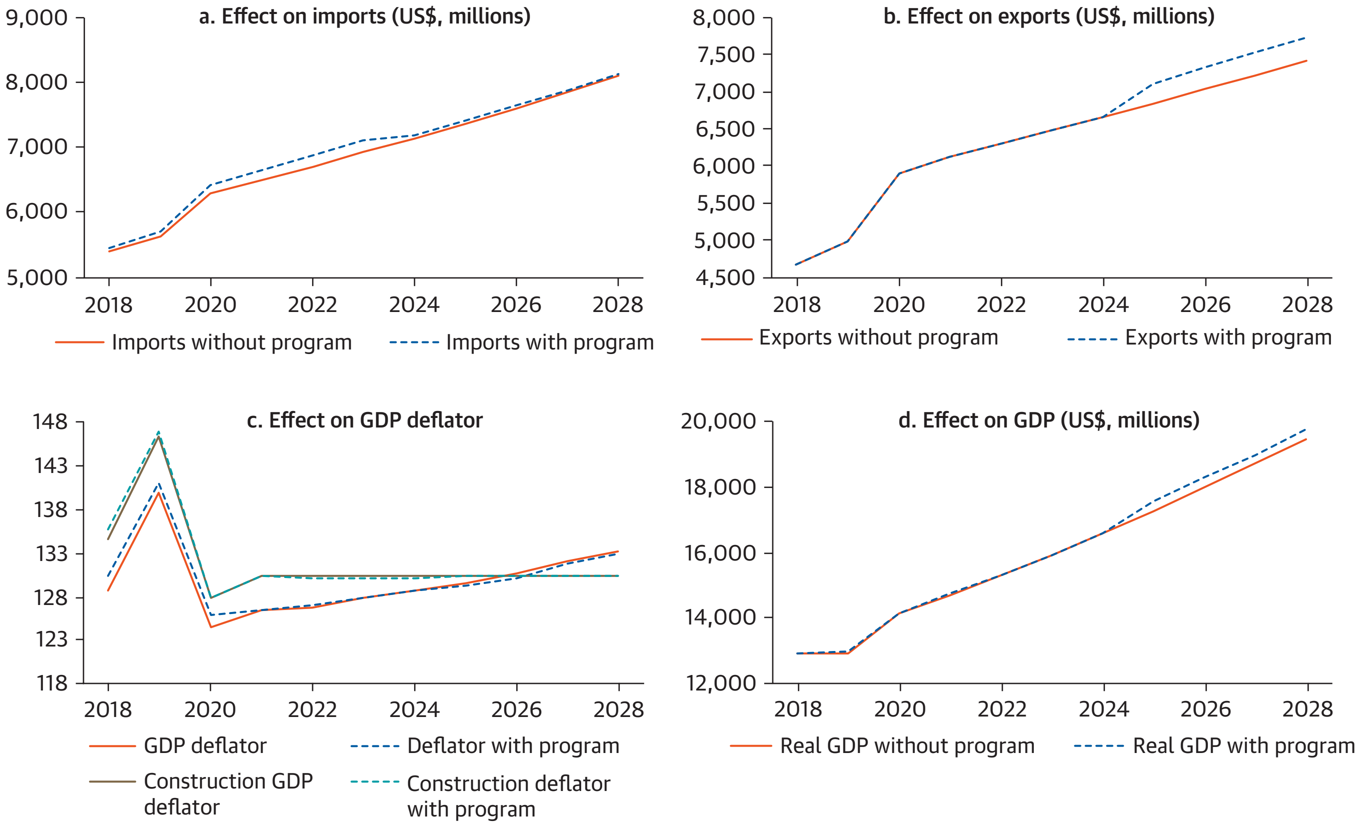
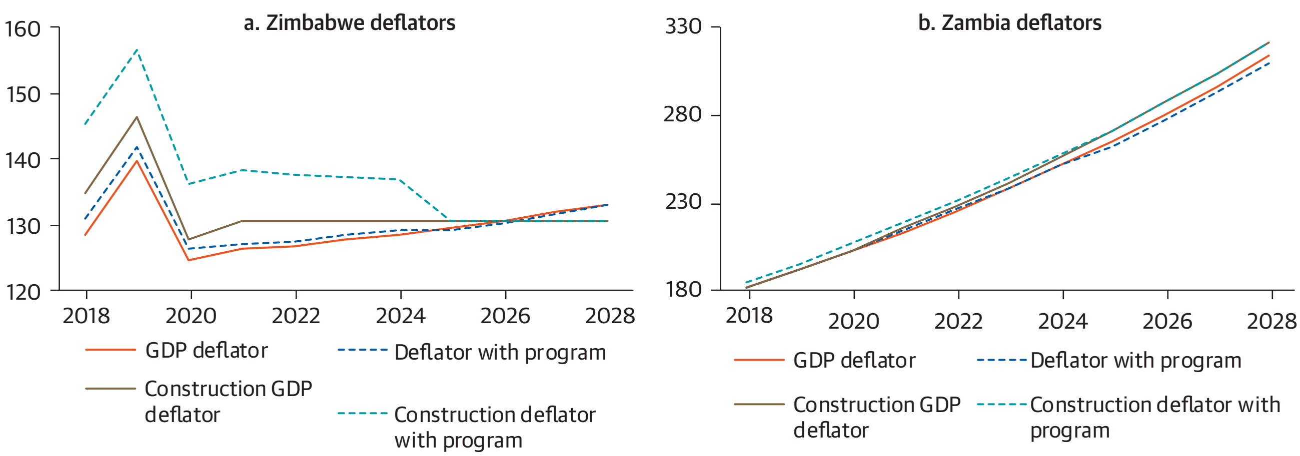


FIGURE 5.5. **Model Estimates of the Impact of the Batoka Gorge HES on GDP and Construction Sector Deflators in Zimbabwe and Zambia, 2018–28, under Scenario 2: Limited Supply Response**



Source: World Bank calculations.

Scenario 3: Sensitivity to Financing Terms

The baseline scenario assumes that the majority of the Batoka Gorge HES would be financed through concessional borrowing (around 54 percent). Moreover, required private sector borrowing from the market would be around 8 percent with a 20-year repayment period. This scenario examines the likely impact of the Batoka Gorge HES if both countries were required to borrow at significantly harder terms. In this context, the financing terms in the model are assumed to include a 10 percent interest rate with a 20-year repayment period.

If Zambia and Zimbabwe were required to take on significant external debt at harder terms to finance development of the Batoka Gorge HES, it would have a negative impact on their public debt and a change in the external financing terms would impact the fiscal accounts. However, for the purpose of the model it is assumed that this would not result in a change in the governments' fiscal policy (increasing taxes, reducing public spending) thereby impacting on the macroeconomy. It is not part of the analysis to presuppose government policy, particularly since such costs would be partly offset by higher revenues upon completion. Therefore, this scenario estimates there is no impact on GDP, the GDP deflator, exports, or imports. Indeed, the impacts on most macroeconomic variables are negligible and are not shown here.

The increase in the financing costs results in a decrease in the FIRR for Zambia from 17.2 percent to 13 percent. Meanwhile, Zimbabwe experiences a decrease in the FIRR from 16.1 percent to 9 percent. Moreover, if the scenario were to be run assuming interest rates of 12 percent, then the FIRR would become negative for Zimbabwe, while still being financially viable for Zambia.

The results illustrate the financial viability of the Batoka Gorge HES. Interest rates on market-based debt would be required to reach around 1,200 basis points to make it financially unviable for Zimbabwe. At such levels the program would remain financially viable in Zambia with a return of 7.1 percent (table 5.2). Finally, the fact that economic internal returns would remain highly positive provides a compelling argument for the government to finance the program.

Scenario 4: Sensitivity to Implementation Delays

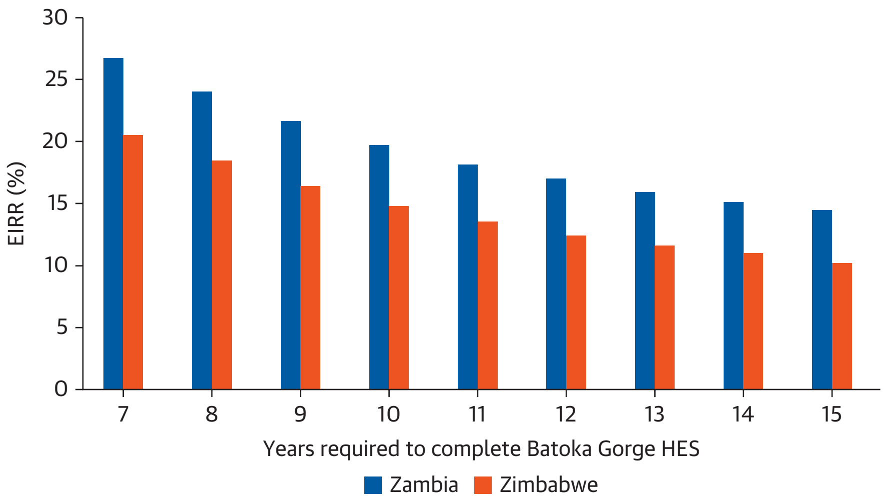
This scenario examines the impact on the EIRR if implementation of the project were to increase. Under the baseline it is assumed that the Batoka Gorge HES could be completed within seven years. However, given the complexity of the program, certain factors could result in the program being completed over a longer period. Scenarios have been assessed ranging from the base case scenario of seven years up to 15 years. This reflects evidence that suggests that large dam projects experience delays in implementation of 44 percent (Ansar et al. 2014).

TABLE 5.2. Model Estimates of the Financial Internal Rates of Return for Zimbabwe and Zambia from the Batoka Gorge HES under Different Market Interest Rates

Market Interest Rate	Zimbabwe	Zambia
8 (baseline scenario)	16.1	17.2
10	9	13
12	n.a.	7.1

Source: World Bank calculations.

FIGURE 5.6. Model Estimates of the Economic Internal Rates of Return for Zambia and Zimbabwe from the Batoka Gorge HES under Different Implementation Periods



Source: World Bank calculations.

While the EIRR is gradually reduced with the extended implementation period it remains highly positive (figure 5.6). The EIRR for Zambia falls from around 26.7 percent in the base scenario of completion within seven years to around 14.5 percent if it is completed over 15 years. The results are more pronounced if implemented over 15 years, with a fall from 20.6 percent in the base scenario to 10.2 percent. This scenario demonstrates the project is robust and resilient to delays in implementation beyond the estimated seven-year period.

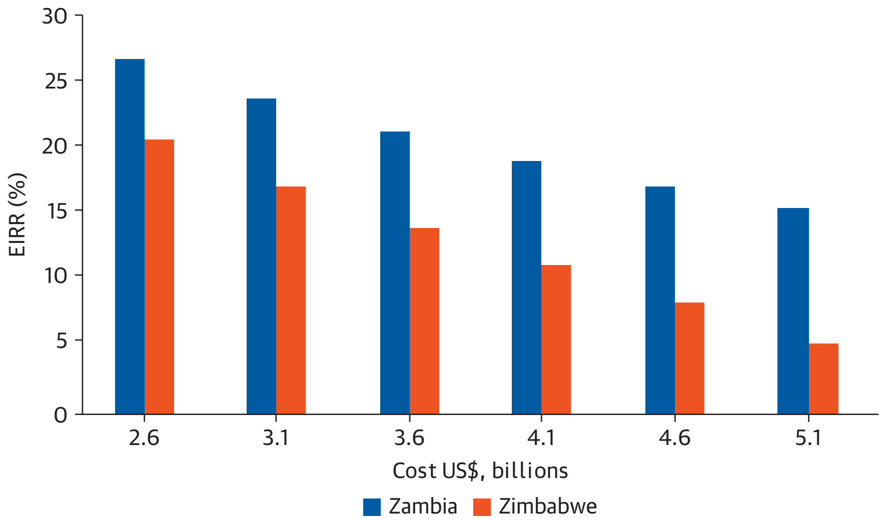
Scenario 5: Sensitivity to Cost Increases

This scenario examines the effect on economic impact associated with cost escalations. The baseline scenario assumes the cost of the Batoka Gorge HES to be US$2.6 billion. However, evidence demonstrates that complex hydropower programs can experience cost overruns as high as 96 percent (Ansar et al. 2014). Such cost escalations can dramatically affect the overall impact of the program.

Five alternative cost scenarios for the project have been assessed. These are based on half a million cost increments over the baseline of US$2.6 billion to give a range of scenarios culminating in almost double the initial base cost estimates.

The cost escalations have a significant impact on EIRR but remain positive (figure 5.7). A steady decline in the EIRR is observed as costs increase. However, even with a doubling of the total cost to US$5.1 billion, the EIRR remains positive at around 15.4 percent for Zambia and 5.2 percent for Zimbabwe. This reflects imposition of a higher deflator in Zambia compared to Zimbabwe, which leads to widening in the rates of return between the countries as costs are escalated further and further.

FIGURE 5.7. Model Estimates of the EIRR for Zambia and Zimbabwe from the Batoka Gorge HES under Different Cost Scenarios

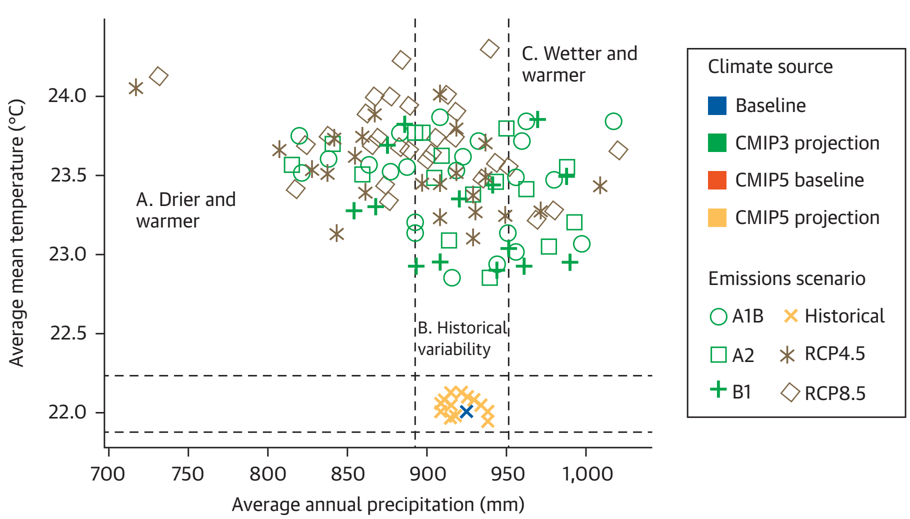


Note: EIRR = economic internal rates of return.

Scenario 6: Sensitivity to Allocative Inefficiencies

This scenario examines the effect of the introduction of allocative inefficiencies of the Batoka Gorge HES, which have the potential to reduce returns. Such allocative inefficiencies would likely take the form of negative externalities due to costs imposed on the environment. This could include the potential negative impacts associated with future changes in climate. The future climate is unlikely to be similar to the historical climate. An analysis of future climate scenarios in the Zambezi River Basin (Cervigni et al. 2015) shows a range of scenarios with potentially significant impacts on hydrology (figure 5.8).

FIGURE 5.8. Climate Futures in 2050 for the Zambezi River Basin



Source: Cervigni et al. 2015.

TABLE 5.3. Model Estimates of the Economic Internal Rates of Return for Zambia and Zimbabwe from the Batoka Gorge HES Assuming Different Allocative Inefficiencies

EIRR (%)	Country	
Allocative inefficiency	Zimbabwe	Zambia
5	19.6	25.7
10	18.4	24.5
15	17.2	23.3
20	15.9	22.1
25	14.5	20.7

For the purpose of the Macroeconomic Assessment of Public Investment Option (MAPIO) assessment, a range of scenarios are included to reflect as much as a 25 percent reduction in energy production. While the Zambezi River Basin program supports a series of detailed assessments, the preliminary indications are that this scenario corresponds to as much as a 40 percent reduction in runoff due to potential future changes in climate. The results show that while there is a noticeable drop in the EIRRs as allocative inefficiencies increase, they remain positive in both countries (table 5.3).

Scenario 7: Export Sensitivities

The baseline scenario assumes that around 98 percent of power from Batoka Gorge HES is exported. This scenario explores the implications if exports are decreased to 50 percent, with the balance consumed domestically. With all other conditions remaining the same, it is assumed that domestic tariffs for electricity would equate to international prices, particularly because of the ease with which electricity is traded between countries in Sub-Saharan Africa. However, under this scenario it is assumed that the use of additional power domestically would involve a larger proportion of users relying on generators to switch to use of electricity. Overall, the scenario makes a conservative assumption that 5 percent of the additional power would replace generator use compared to the counterfactual. Given the significantly higher costs of generators, the economic internal rates of return increase substantially for both countries compared to the baseline scenario, with the model estimates of the Economic Internal Rates of Return 28.2 percent for Zambia and 22.1 percent for Zimbabwe.

Chapter 6 Conclusions and Recommendations

The hydropower resources of the Zambezi River Basin have the potential to provide a sustainable, low carbon source of energy to sustain economic growth and improve the quality of life of those in the basin. The region is historically characterized by inadequate generation capacity, limited electrification, low power consumption, unreliable services, and high costs. These have adverse consequences for the regional economies and the potential to undermine many of the gains in economic growth and productivity.

Expanding electricity supply in line with projected demand growth over time and to meet the significantly increased rates of access involves a major scale-up of generation. The challenge for many countries in Southern Africa is that the most efficient option often relies on large investments on a scale that cannot be justified based on national demand alone. Arranging such investments as regional projects that accommodate demand from multiple countries is therefore important to making them economically viable.

The Macroeconomic Assessment of Public Investment Options (MAPIO) model shows that the Batoka Gorge Hydroelectric Scheme (HES) provides a robust financial and economic investment option. The analysis suggests that the project would generate significant financial and economic returns with limited impacts on prices and imports. The impact on the governments' fiscal accounts is expected to be modest, due to the concessional nature of the debt and the introduction of an innovative special purpose vehicle (SPV) model. The estimates are considered conservative given that the findings do not take into account cross-sectoral spill-overs occurring as a result of the investment. For instance, there are potential linkages developed with international labor and capital allowing the diffusion of skills and knowledge.

The net benefits estimated from the Batoka Gorge HES are expected to exceed potential costs and to have a net positive impact on the national economies of both Zambia and Zimbabwe. The model base case assumptions generate an Economic Internal Rate of Return (EIRR) for the Batoka Gorge HES of 20.6 percent for Zimbabwe and 26.7 percent for Zambia, with the Financial Internal Rate of Return (FIRR) estimated at 16.1 percent and 17.2 percent, respectively. The returns from the Batoka Gorge HES remain robust when subjecting the model to extreme assumptions to test the sensitivity of the results. Nevertheless, the impact of the Batoka Gorge HES on public finances for Zambia and Zimbabwe would be pronounced, and there is a need to continue to interrogate the underlying assumptions, analytical sensitivities, and cumulative impacts of different permutations, such as that of a delay in implementation and an increase in the cost of financing.

While the MAPIO model provides a simple, cost-effective, and robust framework, it is important to acknowledge its limitations. Accurate and timely information are required for the program and the key macroeconomic indicators, while informed judgments should be exercised on the assumptions. For Zambia and Zimbabwe, the estimation of benefits is solely based on estimated power generation and current international prices. The model does not include an analysis of non-economic benefits, costs, or impacts on other sectors. Therefore, any decision to proceed with a project of this type and magnitude should be based on a multi-criteria assessment and decision-making process. The combined effects of different variables on the overall returns should also be incorporated into the sensitivity analysis.

The development of water resources infrastructure within a transboundary context, such as the Batoka Gorge HES within the Zambezi River Basin, and the projected benefits are susceptible to a number of externalities and risks. The returns generated by the MAPIO Model reflect the unique geographical features associated with the project and that the Batoka Gorge HES provides a substantive opportunity to install significant additional power (2,400 megawatts) at a significantly lower cost (US$2.6 billion) than projects of a comparable scale. By contrast, the application of the MAPIO model to the Kandaji Dam in Niger (Beguy et al. 2015) generated a FIRR of 4 percent and an EIRR of 17 percent. However, the transboundary nature of Africa's water resources presents additional challenges to effectively, equitably, and sustainably harness its socio-economic benefits. Issues of sovereignty, historical tensions, difficulty in determining reasonable and equitable use, and differences in the technical and financial capacity of the Riparian States introduce inherent complexity to transboundary water resources development. Accentuating these challenges is a lack of confidence that greater economic benefits can be gained from cooperation, and that benefits can be equitably distributed. These often culminate in long project development timelines and high transaction costs involved in cooperative approaches.

While acknowledging the benefits derived from the development of large hydropower projects such as the Batoka Gorge HES and their contributions to society at large, it is also important to recognize that these projects embrace a broad range of complex social, environmental, and political choices on which the human aspiration to development and improved well-being depend (World Commission on Dams 2000). Their development therefore needs to be part of an overall system for water management and energy development that is integrated within basin and regional planning. This planning needs to be embedded within a process that engages a diverse group and complete set of stakeholders to consider the range of available options and alternatives. Managing the complex interdependencies among these factors requires strategic tools and careful planning, along with a clear, transparent, and predictable process. There are several available tools, such as the Hydropower Sustainability Assessment Protocol (HSAP) (World Bank 2018), that when coupled with sound, timely, and robust assessments can facilitate balanced outcomes that provide countries with significant economic benefits, while managing environmental impacts, enhancing social development, and mitigating investment risks.

Appendix A Existing and Potential Hydropower Projects and Reservoirs in the Zambezi River Basin

TABLE A.1. Existing Hydropower Projects and Reservoirs in Zambezi River Basin

Name	Utility	River	Country	Type	Capacity (MW)
Victoria Falls	ZESCO	Zambezi	Zambia	Run-of-river	108
Kariba	ZESCO, ZESA	Zambezi	Zambia, Zimbabwe	Reservoir	1,470
ltezhi Tezh	ZESCO	Kafue	Zambia	Reservoir	n/a
Kafue Gorge Upper	ZESCO	Kafue	Zambia	Reservoir	990
Mulungushi	ZESCO	Mulungushi	Zambia	Reservoir	20
Lunsemfwa	ZESCO	Lunsemfwa	Zambia	Reservoir	18
Lusiwasi	Private	Lusiwasi	Zambia	Pondage	12
Cahora Bassa	HCB	Zambezi	Mozambique	Reservoi	2,075
Wovwe	ESCOM	Wovwe	Malawi	Pondage	4.35
Nkula Falls A&B	ESCOM	Shire	Malawi	Pondage	124
Tedzani	ESCOM	Shire	Malawi	Pondage	90
Kapichira stage I	ESCOM	Shire	Malawi	Pondage	64

Source: World Bank, 2010.
Note: MW = megawatt.

TABLE A.2. Potential Hydropower in Zambezi River Basin, by Country

Country	River	HP/Reservoir	Capacity (MW)	Study stage
Angola	Lumbage	1	1	n/a
Angola	Zambezi	2	4	n/a
Angola	Zambezi	3	2	n/a
Angola	Luvua	4	1	n/a
Angola	Luizavo	5	11	n/a
Angola	Ludevu	6	3	n/a
Angola	Lumache	7	1	n/a
Angola	Lufuige	8	2	n/a
Angola	Macondo	9	3	n/a
Malawi	Shire	Kapichira II	64	Feasibility
Malawi	Shire	Kholombidzo High	240	Prefeasibility
Malawi	Shire	Kholombidzo Low	217	Prefeasibility
Malawi	Shire	Mpatamanga	263	n/a
Malawi	S. Rukuru/N. Rumphi	Lower Fufu	100	n/a
Malawi	South Rukuru	Lower Fufu North	70–170	n/a
Malawi		High Fufu	85–175	n/a
Malawi		Henga Valley	20–40	n/a

table continues next page

TABLE A.2. continued

Country	River	HP/Reservoir	Capacity (MW)	Study stage
Malawi	Lake Malawi/Niassa/Nyasa	Pumped storage	>1,500	n/a
Malawi	Songwe	Manolo	55–125	n/a
Malawi	Bua	Mbongozi	25–55	n/a
Malawi	Bua	Malenga	30–65	n/a
Malawi	Bua	Chizuma	110–170	n/a
Malawi	Bua	Chasonmbo	25–55	n/a
Malawi	Ruo	Zoa Falls	20–40	n/a
Malawi	Dwambazi	Chimgonda	20–50	n/a
Malawi/Tanzania	Songwe	Songwe	340	Feasibility
Mozambique	Zambezi	HCB North Bank	850	Feasibility
Mozambique	Zambezi	Mphanda Nkuwa	2,000	Financing
Mozambique	Zambezi	Boroma	444	Prefeasibility
Mozambique	Zambezi	Lupata	654	n/a
Mozambique	Zambezi	Ancuaze-Sinjal I	330–600	n/a
Mozambique	Zambezi	Chemba	1,040	n/a
Mozambique	Revubue	1	36	n/a
Mozambique	Revubue	2	110	n/a
Mozambique	Revubue	3	85	n/a
Mozambique	Luia	4	267	n/a
Mozambique	Capoche	5	60	n/a
Tanzania	Ruhuhu	Masigira	118	n/a
Tanzania	Rumakali	Rumakali	256	n/a
Zambia	Kabompo	Kabompo Gorge	34	Reconstruction
Zambia	Kabompo	Chikata Falls	3.5	Reconstruction
Zambia	Lunga	West Lunga	2.5	Reconstruction
Zambia	Zambezi	Chavuma Falls	10–20	Reconstruction
Zambia	Zambezi	Katombora	n/a	Prefeasibility
Zambia	Zambezi	Victoria Falls Extension	390	n/a
Zambia	Zambezi	Kariba North Extension	360	Feasibility
Zambia	Kafue	Kafue Gorge Lower	750	Financing
Zambia	Kafue	Itezhi Tezhi	120	Financing
Zambia	Lusiwasi	Lusiwasi Extension	40	n/a
Zambia and Zimbabwe	Zambezi	Batoka Gorge	1,600	Feasibility
Zambia and Zimbabwe	Zambezi	Devils Gorge	1,200	Reconstruction
Zambia and Zimbabwe	Zambezi	Mupata Gorge	640–1,200	Reconstruction
Zimbabwe	Zambezi	Victoria Falls (Zimbabwe)	300	Prefeasibility
Zimbabwe	Zambezi	Kariba South Extension	300	Feasibility

Source: World Bank, 2010.
Note: HP = hydropower; MW = megawatt; n/a = not applicable.

Appendix B Constructing the Macroeconomic Assessment of Public Investment Options Model

Step 1: Producing baseline accounts for the Macroeconomic Assessment of Public Investment Options (MAPIO) model

First, projections are developed for the macroeconomic accounts.

- The gross domestic product (GDP) deflator is disaggregated on a sectoral basis and projected from 2016 to 2050 on the basis of historical trends.
- Real GDP is projected from 2014-32 by sector based on simple assumptions. The sectors are totalled to provide us with real GDP. Real GDP by sector is multiplied by its respective GDP deflators to obtain nominal GDP.
- After growth forecasts are obtained, projections are made for the demand components of GDP: imports, exports, investment, consumption, and savings. These projections are later refined following more detailed projections of imports, exports in the balance of payments, and government consumption and investment in the fiscal accounts.
- Projections are made for the balance of payments based on assumptions, such as historical trends or shares. Minor increases are assumed for the capital and financial accounts due to small increases in other public investment.[1]
- Forecasts of revenues and grants are based on conservative projections with the assumption that deficit is covered by domestic borrowing.
- Finally, reserve money growth is calculated assuming a precise relationship with the balance of payments and fiscal accounts.

Second, an estimate is made the impact of the program compared to the counterfactual, i.e., what would have happened if the program had not taken place. Therefore, baseline accounts have to be constructed to remove the likely impact of the program from all the main accounts.

- Estimates are made on the likely impact of the program, and these effects are removed from the macroeconomic accounts.
- The likely impact of the program is estimated from the output accounts (see step 2).

Step 2: Producing Output Sheets

The output sheets attempt to capture the impact attributable to the Batoka Gorge HES. It makes a series of conservative assumptions on the resource flows and their impact on different factor groups and economic sectors to ascertain the additional impact on the macroeconomic accounts: balance of payments, monetary, fiscal, and national accounts.

1. It is assumed that the balance of payments (deficit or surplus) is exclusively financed by net foreign assets.

The output sheets makes the following assumptions:

- On the likely financing of the program and its financing terms to model loan repayment terms.
- To assess the likely impact of the program on factor groups and economic sectors. In addition, assumptions are made on the composition of spending of resource types across savings, investment, consumption, and taxes.
- Moreover, the impact of the program is apportioned on prices and supply across five selected economic sectors—construction and public works, transport, manufacturing, agriculture, and services. A number of assumptions are made:
  - The demand effects are assumed to be constant throughout the period. It is assumed that suppliers are rational and will increase their supply based on average program flows over the financing period 2018-24.
  - The supply response in year one occurs when implementation of the program commences.
  - It is assumed that upon commencement of the demand effect, suppliers will start investing, and the supply response in subsequent years will improve.
  - It should be noted, that since this analysis looks solely at the impact of the program from 2018-24, it is assumed the supply response disappears in 2025 upon the completion of the Batoka Gorge HES.[2]

Step 3: Producing Macroeconomic Accounts

The output sheets form the basis for the calculation of the macroeconomic accounts, which can then be compared to the baseline accounts, enabling us to compare the program's impact on key macroeconomic variables. In addition, it enables costs and benefits to be generated and an analysis of the Internal Rate of Return to estimate the following:

- The financial internal rate of return (FIRR);
- The fiscal economic internal rate of return (EIRR); and
- The fiscal economy wide internal rate of return (EWIRR).

A number of key assumptions have been made to estimate the impact of the program on the macroeconomic accounts from 2018-50, including the following:

- It is assumed that the benefits of the program would accrue from 2025 onward.
- The increased GDP would be in the form of higher exports, investment, consumption and taxes.

2. The price effects are a proportion of the demand effects. For simplicity, the price effects and supply effects equal 100 percent. For instance, in year one (or 2014 in this model), price effects are 90 percent for the construction sector, while supply effects are 10 percent. In subsequent years, the price effects are expected to fall, while supply effects rise. It is assumed the price effect persists due to inefficiencies.

Constructing GDP by Demand Component

i. Consumption

- Private consumption is projected on the basis of a simple growth rate.
- Public consumption is derived from current expenditure in the fiscal accounts.

ii. Investment

- Public investment is derived from capital expenditure in the fiscal accounts.
- Private investment is calculated by subtracting gross domestic investment and the current account balance from gross national savings.

iii. Imports and exports

- Imports and exports of goods and services are taken from the balance of payments plus respective service credits and service debits.

iv. Gross national disposable income (GNDI)

- GNDI is estimated by adding gross domestic product (GDP) to transfers and income in the balance of payment. This estimation is revised, once the balance of payments projection has been finalized.

v. Gross national savings (GNS)

- GNS is obtained, by deducting total consumption from GNDI.
- Public national savings were estimated by adding grants in the balance of payments) to public domestic savings.
- Private national savings are estimated as GNS minus public national savings.

vi. Comparisons can be made between GDP plus imports, and exports plus consumption and investment. The figures should roughly match. This can provide a useful check against estimates of GDP by sector (supply). There should be a coherent story between the two.

References

Ansar, A., B. Flyvberg, A. Budzier, and D. Lunn. 2014. "Should We Build More Large Dams? The Actual Costs of Hydropower Megaproject Development." *Energy Policy* (March): 1-14.

Beguy, O., S. Dessus, A. Garba, J. Hayman, and J. Herderschee. 2015. "Modeling the Impact of Large Infrastructure Projects: A Case Study from Niger—Macroeconomic Assessment of Public Investment Options." MFM Global Practice Discussion Paper 7. World Bank, Washington, DC.

Cervigni, R, R. Liden, J. E. Neumann, and K. M. Strzepek. 2015. *Enhancing the Climate Resilience of Africa's Infrastructure: The Power and Water Sectors*. Africa Development Forum. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/21875.

Eberhard, K. G., E. Morella, and P. Antmann. 2016. *Independent Power Projects in Sub-Saharan Africa: Lessons from Five Key Countries*. Directions in Development—Energy and Mining. Washington, DC: World Bank.

Foster, V, and C. Briceno-Garmendia. 2010. *Africa's Infrastructure: A Time for Transformation.* Africa Development Forum. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/2692

Subramanian, Ashok, Bridget Brown, Aaron Wolf. 2012. "Reaching Across the Waters: Facing the Risks of Cooperation in International Waters." Water Papers, World Bank, Washington, DC. http://documents.worldbank.org/curated/en/2012/03/16588090/reaching-across-waters-facing-risks -cooperation-international-waters.

NEXANT. 2008. *SAPP Regional Generation and Transmission Expansion Plan Study*, *Volume 2A*. Southern African Power Pool (SAPP) Coordination Center, Harare, Zimbabwe.

PM News. 2017. "Chinese Companies Get Record-Breaking $5.8 Billion Nigeria Power Project. PM News (blog), September 15. https://www.pmnewsnigeria.com/2017/09/15/chinese-companies-get-record-breaking-5-8-billion-nigeria-power-project/amp/.

SADC (Southern African Development Community), SARDC (Southern African Research and Documentation Centre), ZAMCOM (Zambezi Watercourse Commission), GRID-Arendal, and UNEP (United Nations Environment Programme). 2012. *Zambezi River Basin: Atlas of the Changing Environment*. Gaborone, Botswana: SADC/SARDC.

World Bank. 2009. *Zambia—Managing water for sustainable growth and poverty reduction : a country water resources assistance strategy for Zambia (English)*. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/297971468170957020/Zambia-Managing-water-for-sustainable-growth-and-poverty-reduction-a-country-water-resources-assistance-strategy-for-Zambia.

World Bank. 2010. *The Zambezi River Basin: A Multi-Sector Investment Opportunities Analysis*. Vol 1, Summary Report. Washington, DC: Water Resources Management, World Bank Africa Region.

——. 2015. *Powering the Zambian economy*. Zambia economic brief; no. 6. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/551761468197338422/Powering-the-Zambian-economy

——. 2018. *Batoka Gorge Hydroelectric Scheme*. Working Paper 123272, World Bank, Washington, DC. http://documents.worldbank.org/curated/en/574651518042899815/Batoka-Gorge-Hydroelectric-Scheme.

World Commission on Dams. 2000. *Dams and Development: A New Framework for Decision-Making*. London, U.K., and Sterling, VA: Earthscan Publications.

CIWA

WORLD BANK GROUP

W18005