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Paying the Price for Unreliable Power Supplies

In-House Generation of Electricity by Firms in Africa

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Abstract

This paper documents the prevalence of in-house generation of electric power by firms in Sub-Saharan Africa and attempts to identify the underlying causes. The analysis is based on two data sources. The UDI World Electric Power Plants Data Base (WEPP), a global inventory of electric power generating units, provides a detailed inventory of in-house generation at the country level. The World Bank's Enterprise Survey Database captures business perceptions of the obstacles to enterprise growth for 8,483 currently operating firms in 25 African countries.

Overall, so-called own generation by firms—which has been on the rise in recent years—accounts for about 6 percent of installed generation capacity in Sub-Saharan Africa (equivalent to at least 4,000 MW of installed capacity). However, this share doubles to around 12 percent in the low-income countries, the post-conflict countries, and more generally on the Western side of the continent. In a handful of countries own generation represents more than 20 percent of capacity.

Rigorous empirical analysis shows that unreliable public power supplies is far from being the only or even the largest factor driving generator ownership. Firm characteristics have a major influence—in particular, the probability of owning a generator doubles in large firms relative to small ones. Our model predicts that the prevalence of own generation would remain high (at around 20 percent) even if power supplies were perfectly reliable, suggesting that other factors, such as emergency back-up and export regulations, play a critical role in the decision to own a generator.

This paper—a product of the African Sustainable Development Front Office, Africa Region—is part of a larger effort in the region to gauge the status of public expenditure, investment needs, financing sources, and sector performance in the main infrastructure sectors for 24 African focus countries, including energy, information and communication technologies, irrigation, transport, and water and sanitation. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at jirving@worldbank.org.

Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa

Vivien Foster and Jevgenijs Steinbuks

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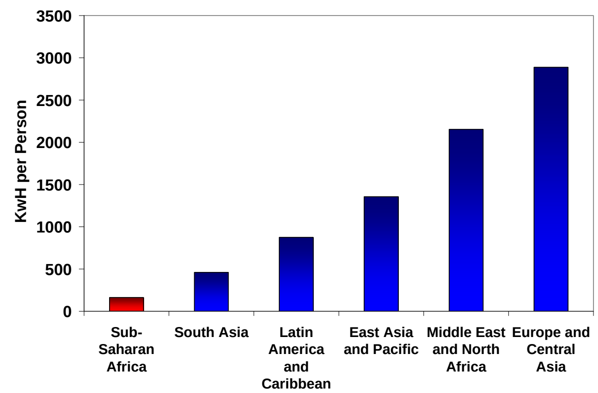
The performance of Africa's power supply sector on the continent is woefully unsatisfactory. Most of the continent's power companies are unreliable sources of supply, inefficient users of generating capacity, deficient in maintenance, erratic in the procurement of spare parts, and unable to staunch losses in transmission and distribution. They also have failed to provide adequate electricity services to the majority of the region's population, especially to rural communities, the urban poor, and small and medium enterprises.

Three-quarters of the electricity produced on the continent comes from South Africa and North Africa; only 26 percent is generated in Sub-Saharan Africa (without South Africa), where power is produced by small, inefficient systems. The problem is not limited to the supply side. Popular demand for power is very low. Net electricity consumption in Sub-Saharan Africa (excluding South Africa) is about 163kWh per capita—about 40 percent of the level in South Asia and 20 percent of the level in Latin America (figure 1).

In response to the endemic unreliability of Africa's national electric power utilities, self-generated electricity has become an increasingly important source of power. Many end users of electricity, from households to large enterprises, now generate their own power by operating small to medium-sized plants with capacities ranging from 1MW to about 700MW (Karekezi and Kimani 2002). For small-scale enterprises, protection against erratic supply from public utilities often means installing small (less than 5MW) thermal generators.

Figure 1 Per capita consumption of electricity, by developing region, 2004



Source: IEA 2007.

These adjustments are not without cost, however. Self-generated electricity is generally more expensive than electricity from the public grid, as we shall see, which limits its potential as a permanent substitute for unreliable public supply. Because it adds to the capital and operating costs of doing business, in-house generation affects the range of investment available to budding entrepreneurs, raises production costs, lowers the competitiveness of local products, and blocks the achievement of economies of scale.

The limitations of own generation do not mean that there are not gains to be had from the decentralization of power generation.

Historically, the generation, transmission, and distribution of electricity have been characterized by increasing returns to scale, and the electric power industry has been viewed as a vertically integrated "natural monopoly," with a sole supplier in each region. Recent econometric studies have shown, however, that scale economies in the generation of electric power level off once the generator reaches a size of about 500 MW.[1] This means that the generation of electric power may be, under some circumstances, a competitive activity, even if transmission and distribution networks are indeed natural monopolies. Moreover, separating transmission and distribution from generation and introducing competition into the generation business may increase the overall efficiency of the electric power sector.

But in no African country have the legal and institutional conditions for decentralized power generation yet reached the point where decentralization can provide an alternative to unreliable supply from monopolistic public providers or to the use of expensive generators at the firm level.[2]

Some 20 African countries are currently initiating some form of power sector reform. Although most are still in the initial phases of privatization and restructuring, the contemplated changes reflect a profound questioning of the principles that have governed the sector since the early 1960s. Some countries, including the Arab Republic of Egypt and South Africa, have had unbundled power sectors for a long time and are now thinking of introducing private participation. Côte d'Ivoire and Ghana introduced reforms (privatization and restructuring) in the early and mid-1990s, respectively (Karekezi and Mutiso 1999).

For the time being, Africa's firms, small and large, must cope with unreliable power supplies.

1 The economic literature on unreliable power

It is fairly settled in the literature that unreliable power supply results in welfare losses (see Kessides 1993 and references therein). But the empirical research on the economic costs of power outages and own generation in developing countries remains limited, owing to the lack of appropriate microeconomic panel data that could be used to infer firms' and households' response to poor provision of electricity supply.[3] Only two studies have recently been done on this subject in Africa. Adenikinju (2005) analyzed the economic cost of power outages in Nigeria. Using the revealed preference approach on business survey data (Bental and Ravid 1982; Caves, Herriges, and Windle 1992; Beenstock, Goldin, and Haitovsky 1997), Adenikinju estimated the marginal cost of power outages to be in the range of \$0.94 to \$3.13 per kWh of lost electricity. Given the poor state of electricity supply in Nigeria Adenikinju (2005) concluded that power outages imposed significant costs on business. Small-scale operators were found to be most heavily affected by the infrastructure failures.[4]

[1] See, for example, Christensen and Greene (1976), Joskow (1987), and Wolak (2001).

[2] Since 1980, when Chile began its radical program of restructuring and privatization, more than 70 countries have introduced reforms of electric power (Besant-Jones 2006). Most of the reforms have sought to promote private ownership and investment, and hence to reduce the dominance of the state-owned, vertically integrated enterprise, which up to that point had been ubiquitous in the sector. These reforms have varied greatly. Some countries have invited private investment in generation only, financed by long-term contracts with state-owned utilities (as in China, India, Indonesia, and Mexico). Some have vertically separated the industry while privatizing only part of it (as in Colombia, El Salvador, Kazakhstan, and New Zealand). Others have privatized the entire industry, creating competitive generation markets, as in Argentina, Chile, and the United Kingdom (World Bank 2004).

[3] Cross-country aggregate data analysis, widely used in the development economics literature, cannot avoid simultaneity between poor infrastructure and welfare.

[4] Lee and Anas (1992) also found that poor infrastructure had a negative effect on small enterprises in Nigeria.

Reinikka and Svensson (2002) analyzed the impact of poor provision of public capital goods on firm performance in Uganda. Using a discrete choice model on business survey data, the authors predicted that unreliable power supply causes firms to substitute complementary capital (for backup generators) for deficient public services. Estimating investment equations on the same data, they found that poor complementary public capital significantly reduced private investment.

Reconciling the results of the two studies is difficult. Both rely on limited datasets from business surveys done in a single country. Both use only a small number of factors among the many that firms might consider in choosing to generate their own power. Neither accounts for effects that may change the provision of power supply. And the estimated marginal costs of electricity and effects of unreliable power supply on firms' investment may be biased because of the failure to address the possible endogeneity in choice of generator, provision of electricity supply, and other observed explanatory variables, such as firms' profitability and access to finance, and the country's industrial structure.

This paper combines the advantages of cross-country data analysis with microeconomic analysis of business survey data. Use of a cross-country dataset can help to identify the effects that affect the provision of power supply, and to some extent, changes in the industrial structure. Microeconomic data can be used to infer firms' and households' response to provision of electricity supply. Because our study relies on cross-sectional data, the bias in estimates cannot be fully avoided. However, cross-country comparisons will still be valid, given the one-dimensional direction of bias.

The central purpose of this study is to examine the national and firm-level costs of unreliable power supplies and own generation in Sub-Saharan Africa. Our specific objectives are:

- To describe power outages and the phenomenon of own generation of electric power in Sub-Saharan Africa.
- To estimate the economic costs of both phenomena at the national and firm levels.
- To explore why firms decide to generate their own power.
- To evaluate the effect of improving the reliability of power supplies on firms' in-house generation.
- To suggest how unreliable power supply might shape the economic structure of Sub-Saharan African economies.

We do not investigate whether the share of own generation is growing in Africa or compare the phenomenon as it is practiced on the continent to own-generation patterns (and their costs and benefits) elsewhere in the world.

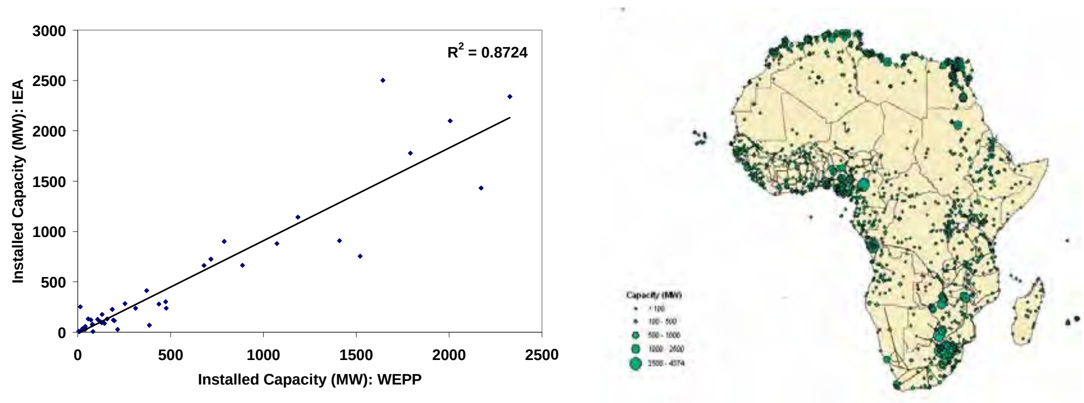
2 The data on self-generated electricity

Our analysis is based on two data sources. The first is the UDI World Electric Power Plants Data Base (WEPP), a global inventory of electric power generating units.[5] WEPP contains design data for

[5] WEPP is issued quarterly by the UDI Products Group of PLATTS, the energy information division of McGraw-Hill. For more information, see the WEPP database manual, available at http://wepp.platts.com.

2,843 plants currently operating and 941 plants under construction of all sizes and technologies operated by regulated utilities, private power companies, and industrial firms that produce their own electricity in 47 Sub-Saharan African countries. WEPP provides highly representative data that account for 87 percent of the variation in total generating capacity in Sub-Saharan Africa (figure 2). A plant-level database that provides rich information on technical and spatial power-supply characteristics, WEPP nevertheless lacks important accounting variables necessary for structural microeconomic analysis.[6] Therefore its primary function here is to provide an aggregate picture of the own-generation phenomenon in Sub-Saharan Africa.

Figure 2 Installed capacity of electrical generating plants in Africa, 2006



Source: UDI World Electric Power Plants Data Base (WEPP).

Our second data source is the World Bank's Enterprise Survey Database, which captures business perceptions of the obstacles to enterprise growth, the relative importance of various constraints to increasing employment and productivity, and the effects of a country's investment climate on the international competitiveness its firms. The database contains data for 8,483 currently operating firms in 25 North and Sub-Saharan African countries sampled from the universe of registered businesses. It uses a stratified random sampling methodology.[7] Because in most countries the number of small and medium enterprises is far greater than the number of large firms, surveys generally oversample large establishments. The main advantage of the Enterprise Survey Database is that it provides both managers' opinions concerning the reliability of power supplies and the accounting data needed for structural microeconomic analysis. However, because enterprise survey data are based on relatively small samples (ranging from 60 to 850 businesses), they are less useful for macroeconomic analysis.

Despite obvious sampling differences, there exists some overlap between WEPP and the enterprise surveys. Figures 3–7 provide some consistency checks between the enterprise survey dataset and the WEPP data on industrial firms that produce their own electricity. Figures 3 and 4 show the distributions

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[6] The most important variables for structural microeconomic analysis are the price, sales, and cost data.

[7] Detailed information on the World Bank's Enterprise Survey Database can be found at http://www.enterprisesurveys.org.

of installed generation capacities.[8] It can be seen that WEPP dataset does not take into account the fraction of firms that have the smallest generation capacity (less than 50kW), which are very difficult to detect. On the contrary, the enterprise survey dataset underrepresents the fraction of firms with medium-size and large installed capacities (greater than 5MW), because of the random sampling procedure used to select participating enterprises. The distributions of installed generating capacities fully overlap in the range between 50kW and 1MW, which accounts for 35 percent of participating firms in WEPP dataset and 39 percent of participating firms in enterprise survey dataset.

Figures 5 and 6 show the distributions in observed industrial structure of firms with installed generation capacities between 50kW and 5MW. There are considerable similarities between two datasets. Both comprise a significant share of agricultural industry (23 percent and 29 percent of firms, respectively), metals and mining (14 percent and 26 percent of firms), and chemical products and petroleum (12 percent and 8 percent of firms). Both also have relatively small and significant shares of hotels and restaurants (4 percent and 3 percent of firms), construction and cement (6 percent and 4 percent of firms), and wood and pulp (8 percent and 2 percent of firms). The major differences include a large share of textiles industry in the enterprise survey dataset[9] (20 percent of firms), and a large share of unidentified plants (20 percent of firms) in the WEPP dataset.[10]

Figure 3 Distribution of electrical generating capacity in Africa according to Enterprise Survey Database, 2002–06

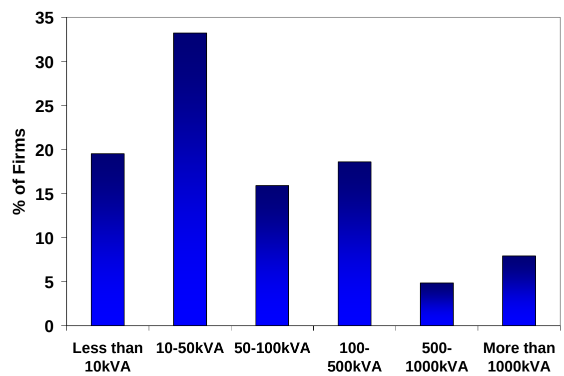
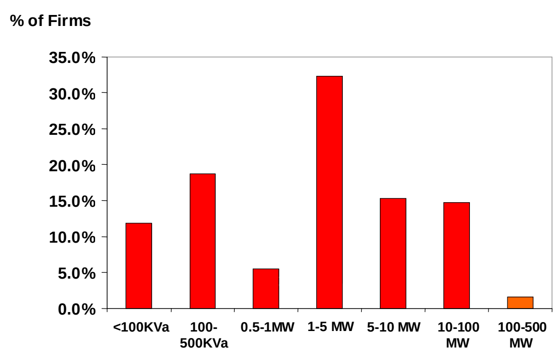


Figure 4 Distribution of electrical generating capacity in Africa according to UDI World Electric Power Plants Data Base (WEPP), 2006



Sources: World Bank, Enterprise Survey Database; UDI World Electric Power Plants Data Base (WEPP).

[8] The enterprise survey does not ask for information on generating capacity, which is estimated at firm level by taking the ratio of the deflated generator's acquisition cost to the average capital cost per kW of the generator's capacity (assuming thermal generation). The data for the capital cost per kW of installed capacity came from the World Bank's Energy and Water Department (2005). The GDP deflator data came from the World Bank's World Development Indicators database.

[9] The textiles industry is oversampled in the enterprise survey dataset for the purpose of international productivity comparisons.

[10] Unidentified industries in the WEPP dataset may comprise multiproduct corporations, and smaller firms that choose not to reveal their commercial activities.

Figure 5 Sectoral distribution of firms in World Bank's Enterprise Surveys, 2002–06

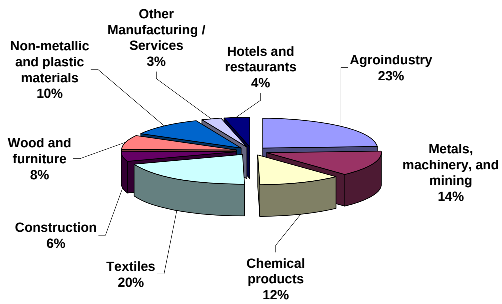
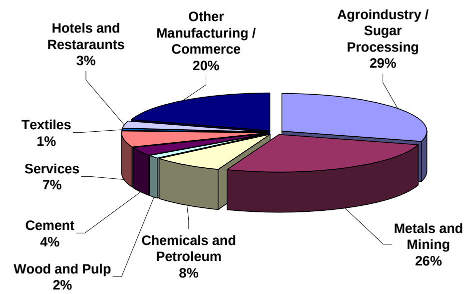


Figure 6 Sectoral distribution of firms in UDI World Electric Power Plants Data Base (WEPP), 2006



Sources: World Bank, Enterprise Survey Database; UDI World Electric Power Plants Data Base (WEPP).

The age distribution of installed generators is generally similar in the two data sources (figure 7), although the enterprise survey dataset has a higher share of recently purchased generators. This finding is not surprising, given that the WEPP dataset comprises a greater share of large generators that have a longer lifespan. Oil and gas are the most common fuels used by commercial and industrial enterprises with generating capacities of 50kW to 5MW (figure 8). The predominance of thermal generation (oil, gas, and biomass) in the WEPP database validates the assumption of thermal generation made in the enterprise survey dataset.

Figure 7 Age of installed generators in Africa, 2002–06

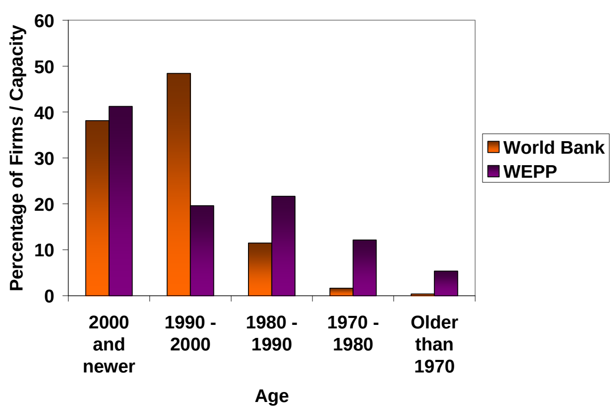
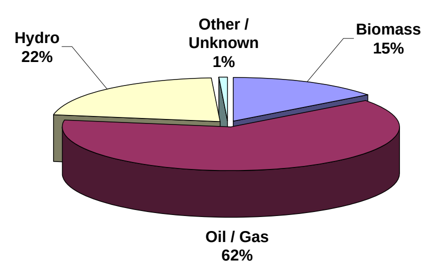


Figure 8 Fuel types used by small producers of electricity, 2006



Sources: World Bank, Enterprise Survey Database; UDI World Electric Power Plants Data Base (WEPP).

We also make use of other sources of information, such as the World Bank's World Development Indicators database, the International Energy Agency's (IEA) *International Energy Annual 2004*, and the United Nation Statistical Division's (UNSD) Commodity Trade (COMTRADE) database.

3 The extent of own generation in Africa

In-house generation of electrical power accounts for only around 6 percent of the installed generating capacity in Sub-Saharan Africa (table 1).[11] This is a bit more than the share in the United States (3.7 percent) and about the same level as in the enlarged European Union (7.3 percent).[12]

There is a considerable variation in the scope and size of in-house generation across Sub-Saharan Africa. The trade-adjusted share of own generation in countries where it exceeds 1 percent is shown in figure 9.[13] In most Sub-Saharan countries, own generation represents less than 10 percent of the installed capacity. In three countries, however, it accounts for more than 25 percent of installed capacity, and for 10–25 percent in nine others.

Table 1 Distribution of installed electrical generating capacity, by region, income group, and conflict status, 2006

Percentage shares of total

			Self-generation, by sector		
	Total MW	Utility / government	Mining	Manufac-turing	Commerce / services
Geographic areas					
Central Africa	5,639.29	92.33	5.33	1.52	0.83
East Africa	2,731.07	92.07	2.95	3.32	1.66
West Africa	14,080.21	82.87	10.62	2.01	6.28
South Africa	50,352.16	97.47	0.99	1.41	0.13
Income groups					
Low Income	26,357.53	88.19	6.82	2.27	3.67
Lower-middle-income	3,971.91	94.23	3.27	1.40	1.09
Upper-middle-income	42,473.29	97.66	1.05	1.21	0.07
Conflict status					
Nonconflict	54,652.76	96.43	2.04	1.43	0.18
Conflict / postconflict	18,149.97	86.86	6.94	2.14	5.21
Africa total	72,802.73	94.05	3.26	1.60	1.43

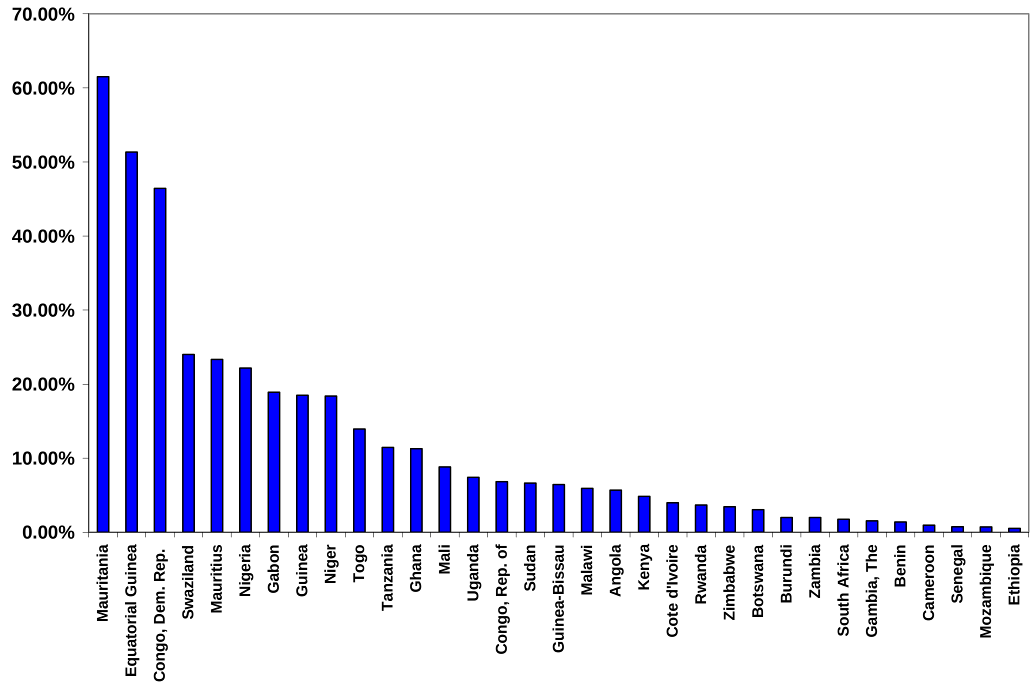
Source: UDI World Electric Power Plants Data Base (WEPP).

[11] The estimates are based on the assumption that 100 percent of installed capacity is functional. In most countries of Sub-Saharan Africa this is not the case, and in many it is as low as 50 percent. Because exact statistics for each country are not available, the size of the observed phenomenon is downward biased. The size of the bias in the share of own-generation capacity in the country's total generation portfolio may vary by half or double.

[12] U.S. Department of Energy, http://www.doe.org; EUROSTAT, http://www.eurostat.europa.eu.

[13] The results reported in figures 9 and 10 are based on the WEPP dataset and hence underestimate the value of small generators (less than 100 kW). The size of the bias is too small (about 250 kW per country) to make any significant changes in the ratios of capacity to GDP and capacity to gross fixed capital formation.

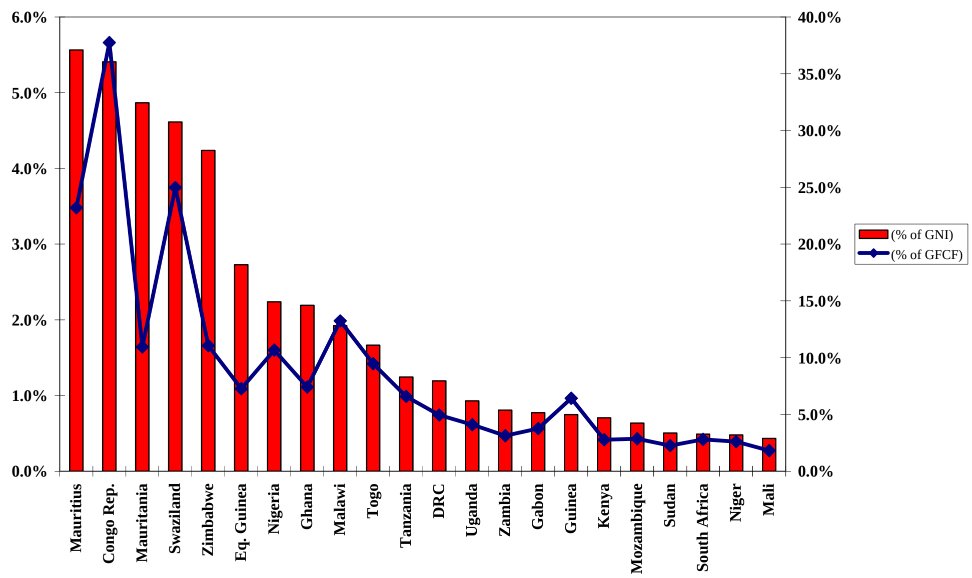
Figure 9 Own-generated electricity as a share of installed generating capacity in Africa, 2005



Source: UDI World Electric Power Plants Data Base (WEPP).Country data on annual electricity imports came from IEA's International Energy Annual 2004. Flow data were converted to generating capacity assuming continuous, uninterrupted annual consumption of imported electricity at an average peak load factor of 0.65.

The estimated startup value of in-house generating capacity, expressed as a percentage of the GNI and gross fixed capital formation (GFCF) in Sub-Saharan African countries is shown in figure 10. For most countries, the value of own generation relative to the size of their economies is not large. However, for five countries (Mauritius, Congo Republic, Mauritania, Swaziland, and Zimbabwe) it is greater than 4 percent of GNI, and for another five countries (Equatorial Guinea, Nigeria, Ghana, Malawi, and Togo) it ranges between 2–3 percent of GNI. Figure 12 also shows that for three countries (Mauritius, Congo Republic, and Swaziland), the value of own generation accounts for more than 20 percent of GFCF, and for five countries (Mauritania, Zimbabwe, Nigeria, Malawi, and Togo) about 10 percent of GFCF.

Figure 10 Value of own generation as share of GNI and gross fixed capital formation, 2005



Source: UDI World Electric Power Plants Data Base (WEPP); World Bank 2005; World Bank, World Development Indicators database.

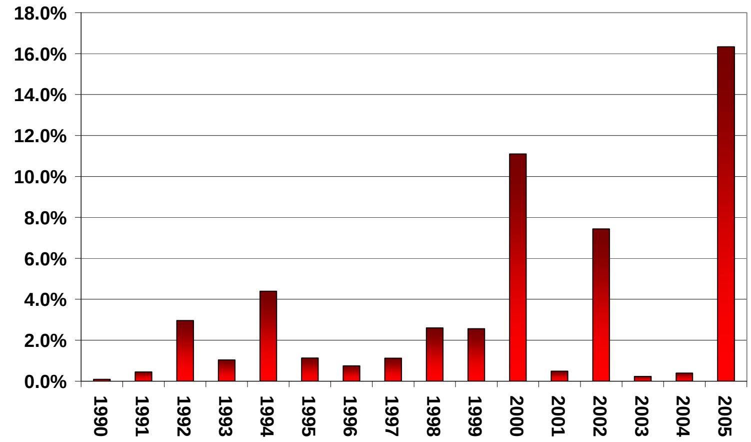
Note: The start-up value of installed capacity was estimated at the individual plant level by the product of the plant's capacity (in kW) and capital cost per kW of installed capacity, and then aggregated at the country level. The data for capital cost per kW of installed capacity (for different technology types) came from the World Bank's Energy and Water Department (2005). The value of own generation as a percentage of GNI is either too small or missing for the countries not reported in the figure.

Annual gross additions to own-generated capacity are shown in figure 11 as a share of total installed own-generation capacity. Consistent with the literature on investment in infrastructure (see, for example, Turvey 2002), the figure illustrates that capacity additions are indivisible, entailing lumpy investment. The largest additions to own-generation capacity occurred in 1994, 2000, 2002, and 2005. These spikes may reflect growing demand, coupled with adverse shocks in the supply of public power, such as economic recessions, armed conflicts, droughts, or increases in oil prices.

The differences in size and scope of own generation in Sub-Saharan Africa can be explained by various factors, including spatial characteristics, economic development, conflict status, and industrial structure (see table 1).

The own-generation phenomenon varies across the geopolitical regions of Sub-Saharan Africa (figure 12). It is significantly more prevalent in the 15-country Economic Community of West African States (ECOWAS).[14] In Mali, Ghana, and Togo own generation accounts for more than 10 percent of installed capacity; in Niger, Guinea, and Nigeria, the share exceeds 20 percent. In the regional context, the high shares of own generation in Nigeria and Ghana—the second- and fourth-largest electricity producers in Sub-Saharan Africa—are especially important.

Figure 11 Additions to own generation as a percentage of gross own-generation capacity, 1990–2005



Source: UDI World Electric Power Plants Data Base (WEPP).

Own-generation is much more prevalent in low-income countries than elsewhere (figure 13).[15] The share of own-generated capacity in low-income countries is 12 percent, twice that of lower-middle-income countries, and five times that of upper-middle-income countries. Of the 12 countries where own generation accounts for more than 10 percent of installed capacity, 8 are low income. Low-income countries account for 74 percent of all own-generation capacity, with upper-middle-income countries accounting for all but 3 percent of the rest.

Figure 12 Own-generation as share of total installed capacity, by subregion, 2006

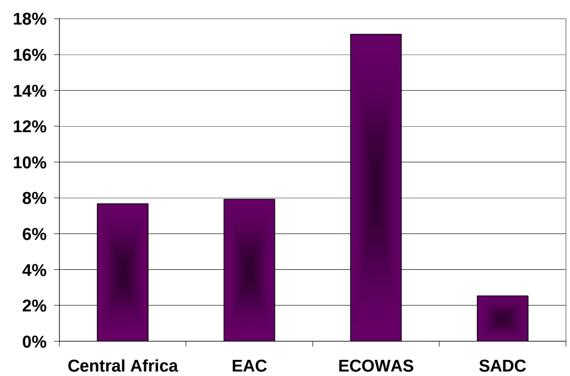
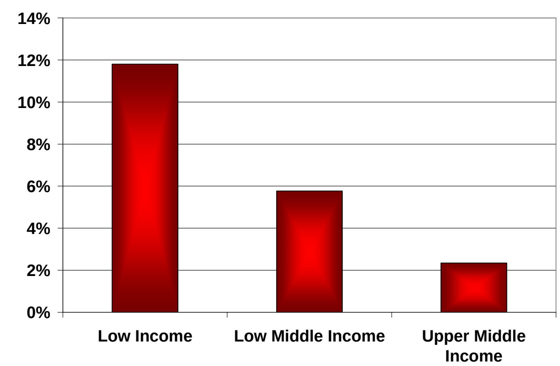


Figure 13 Own-generation as share of total installed capacity, by national income, 2006



Source: UDI World Electric Power Plants Data Base (WEPP).

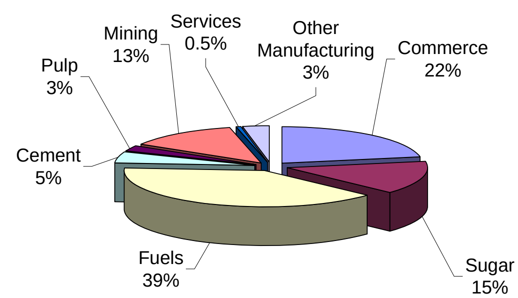
Note: EAC = East African Community; ECOWAS = Economic Community of West Africa States; SADC = Southern African Development Community.

[14] For a complete list of ECOWAS countries, see http://www.ecowas.info/.

[15] The income categories are defined according to the World Bank's classification, available at www.worldbank.org/data/countryclass/classgroups.htm.

Countries that recently experienced or are currently involved in armed conflict have a higher share of own generation (see table 1).[16] Own-generation makes up 13 percent of installed capacity in these countries, compared with less than 4 percent in nonconflict countries. The share of own generation is also about twice as high in manufacturing and about five times as high in commerce in conflict and postconflict countries than in nonconflict countries.

Figure 14 Own-generation as a share of installed capacity, by sector, 2006



Source: UDI World Electric Power Plants Data Base (WEPP).

There is a strong relationship between own generation and industrial structure. Natural-resource industries (oil extraction and mining) account for more than 50 percent of all own-generation capacity (figure 14). The economies of most of the countries in which own generation is prevalent are heavily dependent on natural-resource industries, whether mining (Mauritania, Niger, Guinea, Togo) or petroleum extraction and refining (Equatorial Guinea, Republic of Congo, Gabon, Nigeria). The causality of the relationship is difficult to predict. The high degree of asset specificity in mining and oil extraction industries, coupled with poor contract enforcement in Sub-Saharan African countries, can influence a firm's decision to supply its own power, bundling together generation and extraction facilities (Joskow 1988). On the other hand, poor public provision affects countries' international competitiveness and enhances their specialization in low-value-added industries (Dollar, Hallward-Driemeier, and Mengistae 2005).

Sugar processing accounts for 15 percent of all own generation, reflecting the heavy use of electricity cogeneration agro-based industries. Cogeneration offers substantial opportunities for generating electricity with limited capital investments, while avoiding the negative environmental effects of increased fossil fuel combustion (Karekezi and Kithyoma 2003). Thus, countries with a large domestic sugar industry, such as Swaziland and Mauritius, have high rates of own generation.

Own-generation plants differ from public utilities in technological aspects, such as capacity and fuel type. Public utilities are much larger than own-generation plants (figure 15). About half of the capacity of public utilities is provided by large (500–1,000MW) plants. The average capacity of own-generation plants is about ten times smaller (10–100MW). Most public utilities rely for fuel on coal (in the Southern African Development Community) or hydropower (in East and Central Africa), whereas most own-generation plants, as already noted, are thermal (oil, gas, and biomass) (figure 16).

[16] Information on countries in armed conflicts was taken from Ploughshares' *Armed Conflicts Report* (2006), available at http://www.ploughshares.ca/.

Figure 15 Installed capacity of public utilities and own-generators, by plant size, 2006

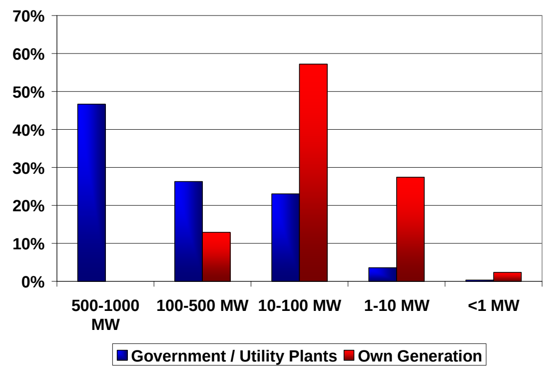
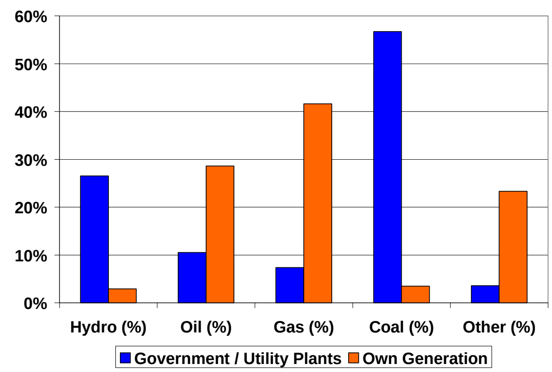


Figure 16 Installed capacity of public utilities and own-generators, by fuel type, 2006



Source: UDI World Electric Power Plants Data Base (WEPP).

4 What drives firms to generate their own power?

To explain why own generation is more prevalent in some countries than in others, we estimated a cross-country linear regression model. The share of own generation was expressed as a function of wealth (GNI per capita), public capital (gross fixed capital formation), power sector characteristics (total access to electricity, energy intensity, share of electricity generated by hydroelectric plants, and diesel fuel price), economic structure (share of manufacturing, agriculture, and services in GNI), conflict status, and regional controls. The results are reported in table 2.

Table 2 Share of own generation in national installed capacity

Linear regression results

Variable	Estimated coefficient	P-value
GNI per capita (USD, log)	–0.058*	0.07
Gross fixed capital formation (% GNI)	–0.005	0.13
Total access to electricity (% population)	0.002	0.25
Energy intensity, (btu / USD, log)	0.024	0.37
Price of diesel fuel (USD / liter)	–0.001	0.41
Share of hydro plants in total generation (percent)	0.058	0.55
Share of agriculture in GNI (percent)	–0.003	0.27
Share of manufacturing in GNI (percent)	0.005***	0.01
Region: SADC	–0.064	0.30
Region: ECOWAS	–0.022	0.65
Region: EAC	0.038	0.64
Conflict or postconflict country (1="Yes")	–0.100**	0.04
Constant	0.369	0.30
F-Statistic	2.58***	0.01
R^2	0.49	
N	45	

*** statistically significant at 1 percent level; ** statistically significant at 5 percent; level; * statistically significant at 10 percent level

The estimated regression has an acceptable goodness of fit (the R^2 is equal to 49 percent), and is significant overall (the p-value associated with the F-statistic is 0.01). Although almost all estimated coefficients have the expected signs, only three statistically significant relationships were found. GNI per capita and conflict status were found to be negatively related to the share of own generation. The share of manufacturing in GNI was positively associated with the degree of own generation.[17]

The World Bank's enterprise surveys offer clues to why firms elect to generate their own power. Because deficiencies in the provision of public power impede business operations, firms install their own generating equipment to protect themselves against power outages.[18]

Power outages have a significant effect on business operations. Firms that experienced few power outages (fewer than 30 days per annum) tended to declare that electricity was not an obstacle or was only a minor obstacle for the operation and growth of their businesses. On the other hand, firms that suffered frequent outages (more than 60 days per annum) tended to believe that electricity was a major or very severe obstacle for the operation and growth of their businesses.

Frequent power outages result in significant losses for enterprises in terms of forgone sales and damaged equipment. Firms experiencing frequent power outages (more than 60 days per year) lose 10–12 percent of their sales (figure 17). This is about twice as high as the figure for firms that have few outages (less than 15 days per year). Equipment damage traceable to power outages is about twice as high for firms that suffer frequent outages as for firms that suffer few outages (1 percent of sales compared to 0.5 percent of sales) (figure 18).

Figure 17 Sales lost owing to power outages

Percent

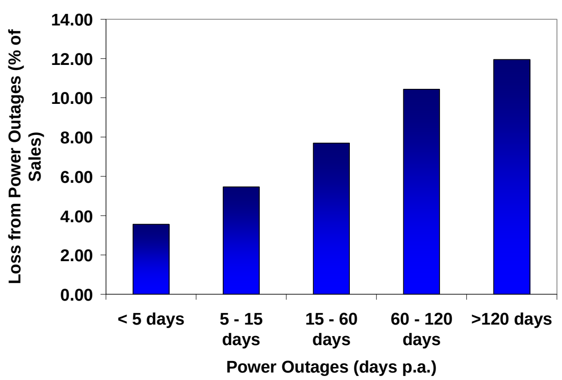
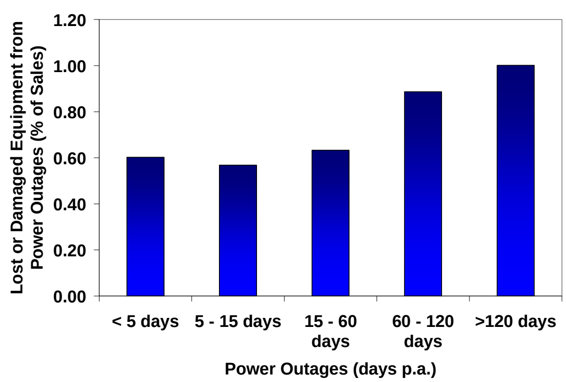


Figure 18 Equipment losses resulting from power outages

Percent



Source: World Bank, Enterprise Survey Database.

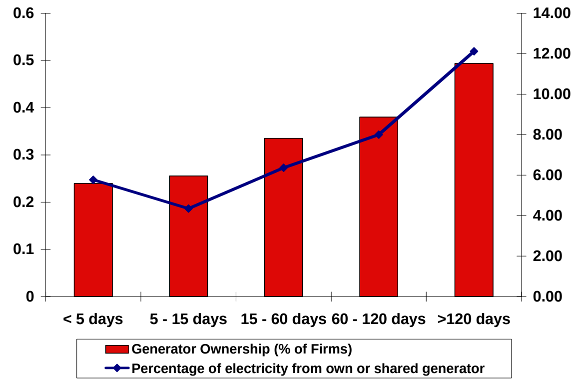
The size and the scope of own generation is higher for firms that experience frequent power outages. Firms that experience frequent power outages are about twice as likely to have their own generator as firms that have few power outages (figure 19). The share of electricity produced in-house increases sharply among firms that have frequent power outages (8–14 percent), compared with other firms (4–6 percent).

[17] The estimated coefficients reflect correlations, not causalities. Further analysis of the estimated relationship is impeded by the simultaneity of the choice of own-generation and the explanatory variables.

[18] Statistics from the Enterprise Surveys on power outages and the adoption of own-generation appear in appendix 1, tables 2a to 2f.

Other characteristics also affect the likelihood that a firm will choose to generate its own electricity. Size is one such characteristic. Larger firms are more likely to have their own generator and are more likely to have a generator of high capacity. Around half of medium size and large firms (those with 50 or more employees) have their own generator, compared with just 10 percent of small firms and micro enterprises (less than 10 employees) (figure 20). The average capacity of the generators used by small firms is about one-third of those used by enterprises of medium size (10 to 100 employees) and one-quarter of those used by large enterprises (more than 100 employees).

Figure 19 Generator ownership by firms and share of electricity generated in-house, by frequency of power outages



Source: World Bank, Enterprise Survey Database.

Figure 20 Generator ownership, by firm size

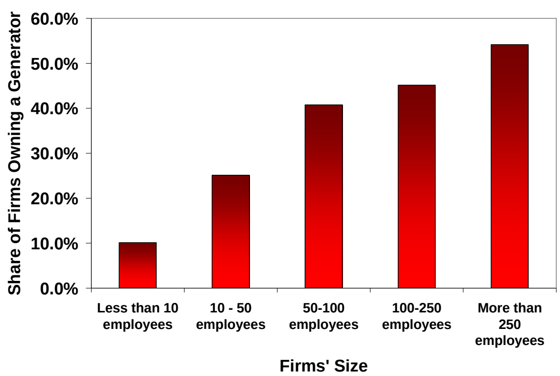
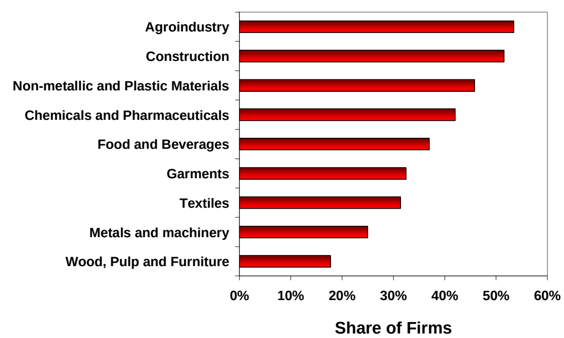


Figure 21 Probability of having a generator, by industry



Source: World Bank, Enterprise Survey Database.

The share of firms possessing their own generators varies significantly across manufacturing industries (figure 21).[19] In agriculture and construction, more than half of firms own a generator; in chemicals and nonmetal materials industries, the percentage is not far behind (between 40 and 50 percent). Own-generation is also more prevalent among exporters and foreign-owned firms (appendix 1, tables 1d and 1e). In nonmanufacturing industries, the share of firms owning a generator is very high in tourism, as one might expect (appendix 1, table 1f), and low in other service industries, such as wholesale and retail sales, as well as in IT services (appendix 1, table 1b). The share of firms owning a generator is especially low (about 5 percent) among informal enterprises (appendix 1, table 1f).

To evaluate the extent to which reliability of power supply and firm characteristics affect the decision to generate electricity in-house, we employed the methodology laid out by Reinikka and Svensson (2002). We began with a stochastic specification,

$$\Pr\left(Y_i = 1\right) = \Phi\left(\alpha_1 x_i, \alpha_2' Z_i\right), \tag{1}$$

where Y_i is the estimated probability that firm i invests in a generator, Φ is the standard normal distribution function, x_i is the frequency of power outages, and Z_i is a vector of controls, including country and firm characteristics.

Equation (1) is estimated using the probit method. Selected estimated parameters are presented in table 3, with the complete set appearing in appendix 1, table 2. Consistent with the analysis above, the reliability of power supply and various firm characteristics—age, size (as measured by number of employees), and export orientation) all have a significant positive impact on the estimated probability of investing in generating capacity. However, the impact of a firm's size is much larger than that of power-supply reliability. The size of the estimated coefficient on employment is about 6 times higher than that on the number of days of power outages.

The probability that a firm will own a generator can be expressed as a function of the reliability of power supply and the firm's size. The probability of finding a generator on the premises increases by nearly 50 percent as one moves from small firms (less than 10 employees) to very large ones (more than 500 employees) (figure 22). The probability of having a generator remains high (about 20 percent) even where power supply is completely reliable. For large firms the probability of having a generator in the absence of power outages is even higher (about 50 percent).

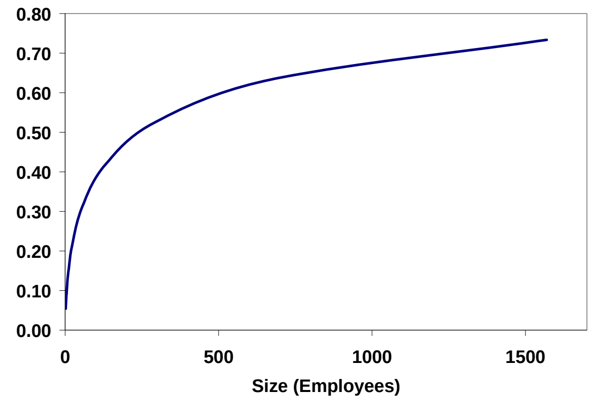
Table 3 Probit regression results (generator ownership)

Variable	Estimated coefficient	P-value	Elasticity
Days of power outages (log)	0.06***	0.01	0.02
Age (log)	0.06**	0.03	0.02
Employment (log)	0.37***	0.00	0.12
PKM (log)	–0.001	0.31	0.00
Size1 * lost days (log)	–0.14***	0.00	–0.04
Size2 * lost days (log)	–0.04	0.14	–0.01
Size4 * lost days (log)	0.001	0.99	0.00
Size5 * lost days (log)	–0.06**	0.05	–0.02
Exporter	0.29***	0.00	0.10

*** statistically significant at 1 percent level; ** statistically significant at 5 percent level

[19] The impact of industrial structure on own-generation is discussed in greater detail later in this paper.

Figure 22 Probability that a firm will own a generator, by number of employees



Source: World Bank, Enterprise Survey Database.

The evidence thus suggests that generator ownership is greatly affected by firm characteristics, such as size, sector, corporate structure, and export orientation. Large firms that operate 24 hours per day are more likely than smaller firms to install backup generation capacity compared to smaller firms, which operate only during daylight hours and therefore are less affected by evening blackouts. Mining firms tend to require own power to keep elevators, air pumps, and other safety devices fully operational regardless of the power supply from public grid. Petroleum firms have very sensitive and delicate equipment that must be protected from damage stemming from power outages. Exporters may need to generate their own power to meet ISO standards (e.g., relating to cold chains). Informal firms may be unable to accumulate significant generating capacity because of security concerns, which may include police raids, unstable land or lease tenure, and other factors.

The composite effect of size and reliability of power supply is generally not significant across firms, except for small firms and microenterprises (table 3). The significant negative coefficient on the product of small firms and large power outages indicates that small firms suffer the most from unreliable power supply, since they lack the resources to invest in own generation.[20]

5 The costs and benefits of own generation

Costs

We use the revealed preference approach to analyze the economic costs of own generation.[21] This approach is based on the presumption that rational, profit-maximizing firms will insure themselves against the risk of frequent power outages. Because insurance contracts for unreliable power supply are not available in developing countries, the only way to minimize losses is to acquire backup generating power. The firm's problem is to choose the optimal amount of backup power that minimizes the sunk costs incurred by acquiring generation capacity as well as the damage that unsupplied power would cause.

A competitive, risk-neutral firm will maximize expected profits by equating at the margin the expected cost of generating a kWh of its own power to the expected gain due to that kWh. That gain consists of the continued production (even if partial) that the self-generated electricity makes possible,

[20] Further discussion of this subject becomes complicated because access to electricity and access to finance are frequently simultaneous. For example, in Nigeria small firms may lack internal funds to obtain a generator, and owning a generator may be a prerequisite to secure loan from the bank.

[21] See earlier citations to the revealed preference approach in the first section of this paper.

and the avoided damage to equipment that would have been caused by a power failure. Under profit-maximizing conditions, the expected marginal gain from a self-generated kWh is also the expected marginal loss from the kWh that is not supplied by the utility. Therefore the marginal cost of self-generated power may serve as an estimate for the marginal cost of an outage.

The cost to the firm of generating its own power consists of two elements. The first is the yearly capacity cost of the generator and other capital outlays. Following earlier literature, that cost will be denoted by $b(Kg)$, where Kg is the generator's capacity measured in kW. The second is the variable cost per kWh—chiefly fuel cost, which is practically constant.[22] If the generator is used to capacity during power cuts, the variable cost per year will then be $v \cdot H \cdot Kg$, where v is the fuel cost per kWh, and H is the expected total duration of outages, measured in hours per year. The total expected yearly cost per kW of backup generating power is then

$$C(Kg) = b(Kg) + v \cdot H \cdot Kg \tag{2}$$

The expected respective marginal cost is

$$C'(Kg) = b'(Kg) + v \cdot H \ , \tag{3}$$

and the expected marginal cost of a kWh generated is simply given by

$$C'(Kg)_{kWh} = \frac{b'(Kg)}{H} + v \tag{4}$$

Applying equation (4) to the enterprise survey data allows us (using reasonable assumptions) to estimate the (marginal) cost of own generation from observed information about the acquisition and running costs of in-house generating capacity, and from data on the frequency of power outages.[23] For these purposes, values for b', H, and v must be obtained.

The operating cost, v, is calculated as a product of the unit cost of fuel and the generator's fuel efficiency (fuel consumption per kWh). Assuming that most firms in the enterprise survey dataset rely on thermal generation, the unit cost of fuel is approximated by an average price per liter of diesel fuel.[24] Fuel efficiency data was obtained from the Web sites of leading manufacturers of generators.[25] Fuel efficiency improves sharply after graduating from the smallest generators but becomes almost flat once capacity reaches 100MW (figure 23). The estimated operating costs and capacities of in-house generators in Africa, gleaned from the enterprise surveys, are summarized in appendix 1, table 3.

[22] This measure does not account for other variable costs, such as maintenance, wages, and salaries.

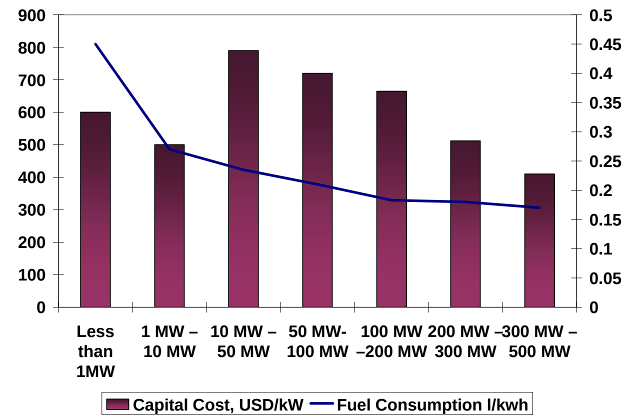
[23] This measure of marginal cost does not account for incomplete backup that may result in additional losses such as destruction of raw materials and damage to equipment. These losses are inversely related to the percentage of backup and the reliability of the firm's backup equipment.

[24] The fuel prices came from GTZ International Fuel Prices 2005, available at http://www.gtz.de/fuelprices

[25] These manufacturers included Wärtsilä (http://wartsila.com) and Cummins (http://cumminspower.com).

The unit capital cost of self-generated electricity, *b'*, depends on price schedules for generators, tax and depreciation rules, and the interest rates. Original price schedules (in national currencies) and data on year of acquisition are reported in the enterprise surveys. We converted the original price schedules into current U.S. dollars. First, we deflated the price schedules, applying the corresponding value of the country's GDP deflator and then converting into dollars at the prevailing exchange rate.[26] The data for capital cost per kW of installed capacity (in 2004 dollars, assuming thermal generation, no tax rules, and an internal rate of return of 10 percent[27]) came from the World Bank's energy department (2005).

Figure 23 Capital and operating costs of diesel generators of various sizes



Sources: World Bank's energy department (2005); authors' estimates.

The capital cost per kW of installed generator capacity is nonlinear. It decreases up to 10MW threshold, and then rises sharply, reflecting the change in generating technology, before beginning to decrease again owing to economies of scale (see figure 24). The unit capital cost of own electricity was annualized assuming linear depreciation and an average generator life of 20 years.

Our data on the duration of power outages, *H*, came from the enterprise surveys. Data on the average duration of power outages were generally not available. We assumed a value of eight hours per day.[28]

In most of the countries of Africa, the average cost of generating electricity in-house is significantly higher then the cost of electricity from the public grid (table 4). This finding reflects the differences in efficiency between the small backup generators used by commercial firms and the large plants that produce electricity for the public grid. The major exceptions are the countries in which fuel is heavily subsidized (Algeria, Arab Republic of Egypt, and Eritrea), where the average cost of self-generated electricity is close to the cost of the electricity from the public grid.

[26] The GDP deflator and nominal exchange rates came from the World Bank's World Development Indicators database. Nominal exchange rates were adjusted for price volatility using the World Bank *Atlas* method. See http://econ.worldbank.org for more information.

[27] The results from the enterprise surveys show that most firms in Africa rely on internal rather than external financing. Therefore, given limited access to finance, the internal rate of return is preferred to interest rates.

[28] Other assumptions about the duration of power outages were considered, including 4 and 12 hours. It follows from equation 4 that under these assumptions the estimates of the unit capital cost of self-generated electricity will vary within the 50 percent confidence interval.

Table 4 The comparative costs of self-generated and publicly supplied electricity, and the effect of own generation on the marginal cost of electricity, in Africa

Country	Average variable cost of own electricity (A)	Average capital cost of own electricity (B)	Average total cost of own electricity (C=A+B)	Price of kWh purchased from public grid (D)	Weighted average cost of electricity (E=∂C+(1-∂)D)
Algeria	0.04	0.11	0.15	0.03*	0.05
Benin	0.36	0.10	0.46	0.12*	0.27
Burkina Faso†	0.42	0.32	0.74	0.21*	0.23
Cameroon†	0.41	0.04	0.46	0.12*	0.16
Cape Verde†	0.46	0.04	0.50	0.17*	0.26
Egypt, Arab Rep.	0.04	0.26	0.30	0.04*	0.12
Eritrea	0.11	0.03	0.13	0.11	0.12
Kenya	0.24	0.06	0.29	0.10	0.14
Madagascar	0.31	0.08	0.39	—	—
Malawi	0.46	0.03	0.50	0.05*	0.09
Mali	0.26	0.26	0.52	0.17	0.21
Mauritius	0.26	0.35	0.61	0.14*	0.25
Morocco	0.31	0.32	0.62	0.08*	0.15
Niger†	0.36	0.04	0.41	0.23*	0.26
Senegal	0.25	0.09	0.34	0.16	0.18
Senegal††	0.28	0.40	0.68	0.16	0.30
South Africa	0.18	0.36	0.54	0.04	0.05
Tanzania	0.25	0.04	0.29	0.09	0.13
Uganda	0.35	0.09	0.44	0.09	0.14
Zambia	0.27	0.18	0.45	0.04	0.06

† Tourism industry (hotels and restaurants sector) only.
†† Survey of informal sector
∂ Share of total electricity consumption coming from own generation
* Data not reported in the enterprise surveys (obtained from the public utilities).
— = data not available.

The second column of table 4 reports the first term of equation (4), the estimated average capital cost of self-generated electricity, adjusted by the frequency of power outages. As might be expected, the average capital cost of self-generated electricity is higher in countries with a reliable power supply (Egypt, Mali, Mauritius, Morocco, South Africa), and in the informal sector, which uses inefficient low-capacity generators (Senegal).

The third column of table 4 shows the average total cost of self-generated electricity, calculated as a sum of the average capital cost and the average variable costs. Overall, the average total cost of self-generated electricity is about five times the price of electricity purchased from the public grid and can be as much as ten times more (in Malawi, South Africa, and Zambia). Eritrea is the only country in which the average total cost of self-generated electricity is comparable to the price of purchasing electricity from the public grid.

The last column of table 4 shows the weighted average cost of consumed energy, taking into account the share of self-generated electricity reported in the enterprise surveys.[29] It can be seen that while the average total cost of own generation is very high, its effect on the weighted average cost of power for most countries is not very large, owing to limited use of own generation. The impact of own-generation costs is higher in countries where electricity from public utilities is subsidized (Egypt, Malawi, Morocco), where the supply of public power is reliable (Egypt, Mauritius, Morocco), and where the share of own generation is large (Benin, informal sector in Senegal).

Benefits

Our analysis of the economic benefits of own generation takes two paths. The first follows the literature on the reliability of electricity supply (see, for example, Kariuki and Allan 1995) and computes the value of lost load, defined as the value an average consumer puts on an unsupplied kWh of energy. The value of lost load is represented by the customer damage function

$$y = f(X) \tag{5}$$

According to equation (5), the value of lost load (y) measured in dollars per hour depends on variety of parameters (X), including costs and frequency of outages, seasonal characteristics, and advance notice. Because data on seasonal characteristics and advance notice were not available, the lost load value was based on the costs and frequency of power outages. Lost load values were computed separately for firms with and without their own generators. For firms owning a generator the lost load value was calculated as

$$y = v \cdot Kg\ , \tag{6}$$

where v is the generator's operational cost (in dollars per kWh), as described earlier, and Kg is generator's capacity in kW. For firms without a generator the lost load value was calculated as

$$y = \frac{Z}{t}\ , \tag{7}$$

where Z is reported sales lost from power outages and t is reported frequency of power outages, multiplied by their average duration.[30] The economic benefit of owning a generator is thus expressed as the reduced loss per interrupted kW. The average values of lost load for firms with and without generators are reported in table 5. In all countries, except Uganda, the lost load is considerably higher for firms without a generator, especially in countries with infrequent (Mauritius, South Africa) or costly (Malawi) power outages.

The second way to determine the benefit of own generation is to estimate the marginal benefit of owning a generator by regressing the percentage of sales lost from power outages against the duration of power outages, generator ownership, and salient characteristics of countries and firms.[31] Selected

[29] This indicator is based on the assumption that the electricity tariffs charged by the utilities are set according to marginal-cost pricing schedules.

[30] Power outages were assumed to last eight hours on average.

[31] An attempt to estimate the marginal benefit of owning a generator with respect to physical capital losses on a smaller sample of firms did not yield significant results. For details, see appendix 1, table 5.

estimated parameters of such a regression are reported in table 6; the complete set of parameters appears in appendix 1, table 4. The estimated parameters are jointly statistically significant (the p-value associated with the computed F-statistic is less than 0.01), and account for 20 percent of the variance in the response variable. As expected, the sign of the coefficient for duration of power outages is negative and significant, and the sign of the coefficient for generator ownership is positive and significant. The size of the estimated coefficient for generator ownership suggests that, when controlling for other factors, owning a generator decreases losses from power outages by approximately 1 percent of a firm's sales.

Table 5 Losses due to outages ("lost load") for firms with and without their own generator

Country	Lost load (no generator, $/hour)	Lost load (with generator, $/hour)
Algeria	155.8	52.2
Benin	38.4	23.1
Burkina Faso†	114.1	13.0
Cameroon†	403.6	12.3
Cape Verde†	177.7	36.4
Egypt, Arab Rep.	201.5	30.4
Eritrea	31.9	10.2
Kenya	113.1	37.1
Madagascar	434.5	153.0
Malawi	917.3	401.4
Mali	390.3	9.5
Mauritius	468.6	13.9
Morocco	377.5	22.9
Niger†	81.3	22.6
Senegal	166.0	19.2
Senegal††	12.9	1.9
South Africa	1140.1	66.1
Tanzania	—	444.3
Uganda	27.6	191.4
Zambia	286.6	39.2

† Survey of tourism sector; †† Survey of informal sector. — = data not available.

Table 6 Marginal benefit of owning a generator

Reduction in lost sales

Variable	Estimated coefficient	P-value
Days of power outages (log)	1.94***	0.00
Generator ownership	–1.16***	0.01
Constant	–1.71	0.11
F-statistic	26.25***	0.00
R^2	0.21	
N	4,254	

*** statistically significant at 1 percent level.

Costs vs. benefits

With no improvement in quality of public power supply

Here we summarize the costs and benefits of own generation by integrating them at the firm level, assuming no improvement in quality of public power supply. The costs are computed as the sum of the annualized fixed costs of acquiring a generator and the net annual operating costs of generation. The fixed costs of own generation were annualized assuming linear depreciation. The net annual operating costs were calculated as the product of the firm's consumption of self-generated electricity and the difference between the costs per kWh of self-generated electricity and of electricity from the public grid.[32]

The benefits of own generation were computed as the product of the share of firms owning a generator and the marginal benefit of owning a generator, as estimated from the regression analysis discussed in the previous section.[33] Both costs and benefits of owning a generator are expressed as percentages of sales. The resulting difference between the benefits and costs of own generation (the benefit-cost margin) was tested for statistical significance from zero using the Student's *t* test. The results are summarized in tables 7a–c below.

In five countries (Benin, Egypt, Eritrea, Morocco, and Zambia), the costs of own generation significantly outweigh the benefits (table 7a). Only in Mali and Mauritius do the benefits outweigh the costs. In most cases the negative difference between benefits and costs is not statistically significant from zero, implying that investment in in-house generation allows firms to break even.

Table 7a Cost-benefit analysis of own generation, by country

Percent

Country	Investment costs	Own-generation costs	Total costs	Reduced sales losses	Benefit-cost margin
Algeria	3.12	—	—	0.26	.
Benin	0.43	1.62	2.05	0.22	–1.83**
Egypt	2.34	0.86	3.20	0.21	–2.99***
Eritrea	1.54	0.41	1.95	0.48	–1.47**
Kenya	0.14	—	—	0.80	—
Madagascar	0.28	—	—	0.21	—
Malawi	0.09	0.78	0.87	0.52	–0.35
Mali	0.31	0.17	0.48	0.56	0.08
Mauritius	0.17	0.01	0.18	0.54	0.36***
Morocco	0.06	0.39	0.45	0.18	–0.27**
Senegal	0.32	0.50	0.82	0.70	–0.12
Senegal††	0.98	—	—	0.13	—
South Africa	0.10	0.09	0.19	0.13	–0.06
Tanzania	0.43	1.01	0.94	0.47	–0.47
Uganda	0.45	0.49	0.94	0.45	–0.49
Zambia	3.02	0.95	3.96	0.26	–3.70**

†† Survey of informal sector.
*** statistically significant at 1 percent level.
** statistically significant at 5 percent level.
— = data not available.

Under less restrictive assumptions than those used so far, the benefits of own generation can compensate for the losses even for countries where the difference between benefits and costs is negative and statistically significant. First, the fixed costs of own generation can be sunk or depreciated

[32] Total consumption of self-generated electricity was estimated using the "electricity approach" discussed in appendix 2.
[33] This measure probably represents a lower bound estimate of the own-generation benefits given the various considerations not related to reliability of power supply as described in section 4 of this paper.

nonlinearly. In three of these countries (Egypt, Eritrea, and Zambia) the result is driven by fixed costs.[34] Second, the analysis presented above does not account for other potential gains from own generation, such as reductions in damaged equipment. This is especially important in Benin, where the average losses from damaged equipment account for 1.5 percent of sales.[35] Third, the results of the analysis do not incorporate the option value of lost load due to future shocks to power supply (e.g. unexpected draughts or power infrastructure damages).[36]

The costs and benefits of own generation differ according to firm size (table 7b). The total costs of own generation vary nonlinearly by firm size, being most efficient for medium-sized firms. For small firms own generation imposes relatively low fixed costs but higher variable costs. Larger firms have relatively high fixed costs, and increasing variable costs. The total benefits of own generation increase linearly with firm size, reflecting the higher share of generator owners among larger firms. The difference between the costs and benefits of own generation is negative across all size categories but is statistically significant only for small and very large firms. The difference is insignificant or marginally significant for microenterprises, medium, and large firms.

Table 7b Cost-benefit analysis of own generation, by size of firm

Percent

Size	Investment costs	Own-generation costs	Total costs	Reduced sales losses	Benefit-cost margin
Micro	0.49	0.67	1.16	0.17	–0.62
Small	1.19	0.51	1.71	0.24	–1.24***
Medium	0.43	0.36	0.78	0.44	–0.35*
Large	1.64	0.77	2.41	0.50	–2.10*
Very large	1.20	1.22	2.42	0.60	–2.01**

*** statistically significant at 1 percent level.

** statistically significant at 5 percent level.

* statistically significant at 10 percent level.

The costs of own generation vary significantly across industries (table 7c). The costs are highest in chemicals, nonmetal and plastic materials, and mining, and lowest in light industries, such as textiles and wood. Chemicals and construction have the highest fixed costs of own generation, whereas nonmetal and plastic materials and mining have the highest operational costs. The highest gains from own generation are observed in mining, construction, and food and beverages. The difference between the costs and benefits of own generation is negative across all industries, but the result is not statistically significant or just marginally significant, except for food and beverages and textiles.

[34] The difference between the gains from own-generation and the net operational costs of own-generation is positive for Eritrea.

[35] See appendix 1, table 2a.

[36] The authors thank David Newberry for making this point.

Table 7c Cost-benefit analysis of own generation, by sector

Percent

Industry	Investment costs	Own-generation costs	Total costs	Reduced sales losses	Cost-benefit ratio
Textiles	0.42	0.29	0.71	0.23	–0.48**
Food and beverages	0.79	0.77	1.56	0.53	–1.03***
Metals and machinery	1.08	0.13	1.21	0.26	–0.95*
Chemicals	2.92	0.14	3.06	0.43	–2.63
Construction	2.08	0.46	2.54	0.57	–1.97
Wood and furniture	0.42	0.37	0.79	0.20	–0.59
Nonmetallic and plastic materials	0.91	2.30	3.20	0.36	–2.84*
Mining and quarrying	0.11	3.10	3.22	0.62	–2.60

Source: World Bank, Enterprise Survey Database.
*** statistically significant at 1 percent level.
** statistically significant at 5 percent level.
* statistically significant at 10 percent level.

With improvements in quality of public power supply

The results of the probit model discussed earlier can be used to evaluate the extent to which an improvement in the reliability of power supply will affect generator ownership. The marginal effects of the probit model (equation 1) suggest that the probability of a firm's owning a generator is not very sensitive to power supply reliability. Reducing power outages by half the mean outage reduces generator ownership by less than 2 percent (table 8). It appears that thoroughly reliable power would reduce generator ownership by no more than 12 percent.

Table 8 Simulated change in generator ownership

Variable	Mean	Change in probability that firm will own a generator		
		Min>Max	½ mean change	½ std change
Days of power outages	37.9	0.12	0.02	0.03
Age	18.3	0.16	0.02	0.02
Employment	111.7	0.87	0.12	0.16
Exporter	0.19	0.10	n.a.	n.a.

Source: World Bank, Enterprise Survey Database.
Note. Exporter is a binary variable, therefore ½ mean change and ½ std change statistics are not reported.
n.a. = not applicable.

The predictions of the probit regression are extended to individual countries in appendix 1, table 6. Raising the reliability of power supply to the level of South Africa results in a mere 3–5 percent reduction in generator ownership.

Although the regression results suggest that improving the reliability of power supply would have a relatively small effect on generator ownership, there are several reasons to expect that the effect would be greater. First, the regression analysis does not account for unobserved explanatory variables, such as firms' access to finance and productivity, which may bias the regression results downward. Second, because investment in in-house generation is irreversible, reductions in generator ownership will occur with a lag as public power supply is improved. The cross-sectional data analysis conducted in this study does not capture these dynamics. Third, the gains to be had by improving the reliability of power supply may be greater if the effects of unreliable power supply on observed industrial structure and external competitiveness are taken into account. Because energy-intensive industries require more stable power supplies, improving reliability will diversify country's production base and result in additional economic gains.

6 Conclusions and policy implications

This paper aims to deepen our understanding of the widespread phenomenon of own generation of electric power by firms, as well as its relationship to unreliable public power supplies in the African context. It does so by triangulating across a number of different sources of evidence covering more than 26 countries across Africa. First, the UDI World Electric Power Plants database provides a detailed inventory of (at least the largest cases of) own generation at the country level, giving an impression of the overall extent of the own generation phenomenon. Second, the World Bank's Enterprise Survey Database provides a detailed set of attitudinal and behavioral information about decisions relating to own power generation at the firm level; at least for the case of larger formal sector manufacturing enterprises. Third, both sources are complemented by engineering data from generator manufacturers and other sector sources that help to capture the cost structure of generating power on-site.

Overall, own generation by firms accounts for about 6 percent of installed generation capacity in Sub-Saharan Africa adding an additional 4,000 MW to the total available plant. However, this share doubles to around 12 percent in the low-income countries, the post-conflict countries, and more generally on the Western side of the continent. Moreover, there emerge around a dozen countries for which own generation represents more than 10 percent of their installed generation capacity, and even more than 20 percent in some cases (DRC, Equatorial Guinea, Mauritania, Nigeria, and Swaziland). Moreover, in these cases the value of the capital stock tied-up in own-generation assets can be as high as 4 percent of one year's national income or 20 percent of one year's gross domestic fixed capital formation. Relative to generation plant owned by public utilities, on-site generation tends to be smaller in scale (by as much as an order of magnitude), and much more heavily skewed towards diesel and gas as opposed to coal and hydro. Historic trends suggest that the growth in own generation has been particularly high in recent years.

The decision of a firm to maintain its own-generation capability is driven by a variety of factors. In firm surveys, firms in countries reporting more than 60 days of power outages per year tend to identify power as a major constraint to doing business, and present relatively high rates of generator ownership. However, more rigorous empirical analysis shows that unreliable public power supplies is far from being the only or the largest factor driving generator ownership. Firm characteristics such as size, age, industrial sector and export orientation all have a major influence. In particular, the probability owning a generator doubles in large firms relative to small ones. Moreover, the behavioral model predicts that the percentage of firms owning their own generators would remain high (at around 20 percent) even if power supplies were perfectly reliable, suggesting that other factors such as emergency driven back-up requirements or export driven quality regulations play a critical role in the decision to own a generator.

The costs of own generation are high, driven mainly by the variable cost of diesel fuel. In most cases they fall in the range US$0.30-0.70 per kilowatt-hour, which is often three times as high as the price of purchasing electricity from the public grid; although the latter is typically subsidized. Nevertheless, in most cases, this does not hugely affect the overall weighted average cost of power to firms given that own generation is only used during a relatively small percentage of the working year.

At the same time, the survey evidence shows that the benefits of generator ownership are also substantial. Considering only lost sales resulting from periods of power outages, firms with their own generators report a value of lost load of typically less than US$50 per hour, which is only a fraction of the value of lost load in excess of US$150 per hour that is reported by firms in the same country that do not have their own generators.

Nevertheless, when costs and benefits are considered side by side, the balance is not found to be significantly positive; a pattern which holds across countries, industrial sectors, and business scales. This may simply be because the analysis is only able to capture one dimension of the benefits of generator ownership – namely reduction in lost sales – but fails to capture many other important aspects – such as reduced damage to equipment, higher quality of production, and meeting reliability criterion for access to export markets.

A number of policy implications emerge from these findings.

First, while the overall scale of own generation in Africa is not that substantial overall, it plays a very important in a number of countries in the region, including some of the larger countries (to wit DRC and Nigeria). This suggests that there may be some strategic value for these countries to think about the role that this significant additional generating capacity could play in national power supply. In many countries, own-generators are not allowed to sell power into the grid, even though this could make a valuable contribution to improving the availability of power in the country as a whole.

Second, while improvements in the reliability of public power supplies would reduce the extent to which own generators were used and hence the level of variable costs incurred, it would in many cases not alter the firm's basic decision to maintain its own back-up generation facilities. The reason is that there are other important motivations for holding these assets, including meeting international quality standards for participation in export markets, and dealing with critical sensitivities in the production process (for example, maintaining ventilation of mines).

Third, through own generation the majority of large formal sector enterprises are able to effectively insulate themselves from the impact of unreliable power supplies. Although the cost of running such generators is high (typically US$0.25–0.45 per kilowatt-hour), given that outages are only intermittent, the overall impact on the weighted average cost of power supply to these firms is relatively small: of the order of a few cents per kilowatt-hour. The major victims of unreliable power supply are in the informal sector, where the limited survey evidence available suggests that generator ownership is an order of magnitude less prevalent than in the formal sector. The other major casualties are the formal sector firms that simply never open-up in countries where power supply is a constraining factor.

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Appendix 1 Electrical generating capacity in Sub-Saharan Africa

Table 1a Summary statistics from the enterprise survey data, by country

Country	Electricity cited as business constraint (% firms)	Power outages (days)	Power outages (% sales)	Equipment destroyed by outages (% sales)	Generator owners (% firms)	Power from own generator (%)	Generator capacity (KW)	Cost of KWH from public grid (US$)
Algeria	11.47	12.32	5.28	—	29.49	6.22	322	—
Benin	69.23	56.12	7.79	1.54	26.90	32.80	35	—
Botswana	9.65	22.29	1.54	—	14.91	17.57	—	—
Burkina Faso	68.97	7.82	3.87	—	29.82	6.52	31	—
Burundi	79.56	143.76	11.75	—	39.22	25.28	—	—
Cameroon	64.94	15.80	4.92	—	57.79	7.62	25	—
Cape Verde	70.69	15.18	6.87	—	43.10	13.53	23	—
Egypt	26.46	10.40	6.12	—	19.26	5.87	353	—
Eritrea	37.66	74.61	5.95	—	43.04	9.31	103	0.11
Ethiopia	42.45	44.16	5.44	—	17.14	1.58	—	0.06
Kenya	48.15	53.40	9.35	0.34	73.40	15.16	78	0.10
Madagascar	41.30	54.31	7.92	0.91	21.50	2.23	190	—
Malawi	60.38	63.21	22.64	—	49.06	4.44	50	—
Mali	24.18	5.97	2.67	1.36	45.33	5.09	43	0.17
Mauritania	29.66	37.97	2.06	—	26.25	11.75	—	—
Mauritius	12.68	5.36	4.01	0.42	39.51	2.87	37	—
Morocco	8.94	3.85	0.82	—	13.81	11.16	58	—
Namibia	15.09	0.00	1.20	—	13.21	13.33	—	—
Niger	26.09	3.93	2.72	—	27.54	14.74	73	—
Senegal	30.65	25.64	5.12	0.62	62.45	6.71	31	0.16
South Africa	8.96	5.45	0.92	—	9.45	0.17	64	0.04
Swaziland	21.43	32.38	1.98	—	35.71	10.33	—	—
Tanzania	60.24	63.09	—	0.81	59.05	12.28	70	0.09
Uganda	43.85	45.50	6.06	0.74	38.34	6.56	31	0.09
Zambia	39.61	25.87	4.54	0.28	38.16	5.13	51	0.04
Conflict	51.52	53.91	7.74	73.93	24.06	5.56	50	0.08
Nonconflict	29.99	21.79	6.22	65.90	28.58	6.74	125	0.09

Source: World Bank, Enterprise Survey Database.
Note: — = data not available.

Table 1b Summary statistics from the enterprise survey data, by sector

Sector	Electricity cited as business constraint (% firms)	Power outages (days)	Power outages (% sales)	Equipment destroyed by outages (% sales)	Generator owners (% firms)	Power from own generator (%)	Generator capacity (KW)	Cost of KWH from public grid (US$)
Agroindustry	40.15	35.10	5.26	0.65	57.14	10.92	48	0.10
Beverages	37.04	42.10	3.33	—	55.56	3.35	79	0.06
Chemicals	26.02	27.52	5.26	0.40	39.71	6.90	138	0.09
Construction	29.17	26.31	4.78	0.61	47.11	10.85	138	0.11
Electronics	8.89	5.59	0.39	—	33.33	3.35	75	0.07
Food	43.09	29.24	8.83	0.31	31.85	8.61	133	0.06
Garments	28.78	25.11	7.88	0.42	13.54	5.92	98	0.08
IT services	24.24	23.07	2.78	—	18.75	0.69	—	—
Leather	17.14	22.59	4.43	0.84	14.35	3.14	192	0.08
Metals and machinery	29.06	21.60	6.93	0.92	25.36	4.57	154	0.09
Mining	40.91	20.24	2.80	0.20	45.45	15.50	10	0.03
Nonmetallic and plastic products	28.16	21.24	6.97	0.65	29.45	7.39	201	0.08
Paper	34.41	26.08	6.37	0.62	28.74	4.66	80	0.09
Retail and wholesale	29.90	12.80	3.78	0.86	6.25	1.43	.	0.05
Textiles	32.49	18.96	7.17	0.43	20.67	5.15	127	0.09
Wood and furniture	39.65	32.84	5.36	1.01	16.00	3.39	58	0.08

Source: World Bank, Enterprise Survey Database. *Note*: — = data not available.

Table 1c Summary statistics from the enterprise survey data, by size of firm

Size of firm (number of employees)	Electricity cited as business constraint (% firms)	Power outages (days)	Power outages (% sales)	Equipment destroyed by outages (% sales)	Generator owners (% firms)	Power from own generator (%)	Generator capacity (KW)	Cost of KWH from public grid (US$)
< 10	42.43	28.16	9.21	1.47	9.75	3.65	51	0.10
10–50	31.68	26.18	6.06	0.75	24.05	4.97	112	0.10
50–100	26.00	28.22	5.03	0.48	38.73	8.00	112	0.08
100–250	26.24	25.27	5.36	0.40	41.07	8.56	128	0.07
> 250	30.02	28.81	4.25	0.38	51.54	11.49	160	0.06

Source: World Bank, Enterprise Survey Database.

Table 1d Summary statistics from the enterprise survey data, by export status

Export status	Electricity cited as business constraint (% firms)	Power outages (days)	Power outages (% sales)	Equipment destroyed by outages (% sales)	Generator owners (% firms)	Power from own generator (%)	Generator capacity (KW)	Cost of KWH from public grid (US$)
Nonexporter	32.08	31.13	5.90	0.72	26.07	5.36	130	0.08
Exporter	26.36	23.57	4.22	0.48	37.52	9.36	99	0.08

Source: World Bank, Enterprise Survey Database.

Table 1e Summary statistics from the enterprise survey data, by firm ownership

Ownership	Electricity cited as business constraint (% firms)	Power outages (days)	Power outages (% sales)	Equipment destroyed by outages (% sales)	Generator owners (% firms)	Power from own generator (%)	Generator capacity (KW)	Cost of KWH from public grid (US$)
Domestic	28.14	25.63	5.74	0.72	26.09	5.33	133	0.09
Foreign	32.08	37.43	5.80	0.51	47.73	9.48	80	0.08

Source: World Bank, Enterprise Survey Database.

Table 1f Summary statistics from the enterprise survey data, by country and by survey sector

Country	Survey	Electricity cited as business constraint (% firms)	Power outages (days)	Power outages (% sales)	Generator owners (% firms)	Power from own generator (%)
Burkina Faso	Manufacturing	68.63	8.20	3.87	24.00	6.51
	Tourism	71.43	2.67	—	71.43	6.60
Burundi	Manufacturing	80.79	137.41	11.30	39.22	25.28
	Tourism	73.33	170.48	13.56	—	—
Cameroon	Manufacturing	65.55	8.60	4.92	61.34	6.89
	Tourism	62.86	33.50	—	45.71	12.84
Cape Verde	Manufacturing	65.96	10.60	6.87	34.04	9.98
	Tourism	90.91	24.67	—	81.82	34.38
	Informal	55.77	6.25	8.69	—	—
Kenya	Manufacturing	48.15	52.35	9.32	70.86	14.90
	Tourism	.	62.00	9.65	94.12	17.54
	Informal	75.00	7.68	31.31	3.36	34.86
Malawi	Manufacturing	60.38	63.21	22.64	49.06	4.44
	Informal	44.83	9.39	22.53	—	—
Mauritania	Manufacturing	28.57	38.12	2.02	26.25	11.75
	Tourism	36.36	37.16	2.28	—	—
Niger	Manufacturing	21.60	3.90	2.72	24.80	14.59
	Tourism	69.23	4.60	—	53.85	15.42
Senegal	Manufacturing	30.65	25.64	5.12	62.45	6.71
	Informal	42.74	2.92	5.67	10.57	29.44
South Africa	Manufacturing	8.97	5.44	0.92	9.47	0.17
	Informal	17.17	0.71	—	—	—
Tanzania	Manufacturing	58.89	59.64	—	55.35	12.28
	Tourism	66.13	72.98	—	74.24	.
Uganda	Manufacturing	44.48	46.85	6.25	36.00	6.78
	Tourism	37.04	31.63	3.43	65.38	3.26
	Informal	61.93	11.28	15.75	5.77	19.27

Source: World Bank, Enterprise Survey Database.
Note: — = data not available.

Table 2 Probit regression results (generator ownership)

Variable	Estimated Coeff.	P-value	Elasticity
Days of Power Outages (log)	0.06	0.01	0.02
Age (log)	0.06	0.03	0.02
Employment (log)	0.37	0.00	0.12
PKM (log)	-0.001	0.31	0.00
Size1 * Lost Days (log)	-0.14	0.00	-0.04
Size2 * Lost Days (log)	-0.04	0.14	-0.01
Size4 * Lost Days (log)	0.001	0.99	0.00
Size5 * Lost Days (log)	-0.06	0.05	-0.02
Exporter	0.29	0.00	0.10
Algeria	1.53	0.00	0.55
Benin	1.57	0.00	0.57
Botswana	1.09	0.00	0.41
Burkina Faso	1.43	0.00	0.53
Burundi	2.37	0.00	0.71
Cameroon	2.17	0.00	0.69
Cape Verde	2.11	0.00	0.68
Egypt	0.98	0.00	0.35
Eritrea	1.62	0.00	0.58
Ethiopia	1.2	0.00	0.45
Kenya	2.47	0.00	0.73
Madagascar	0.91	0.00	0.34
Malawi	1.49	0.00	0.54
Mali	2.16	0.00	0.69
Mauritania	1.5	0.00	0.55
Mauritius	1.53	0.00	0.56
Namibia	0.89	0.01	0.34
Niger	1.69	0.00	0.60
Senegal	2.42	0.00	0.73
Swaziland	1.37	0.00	0.51
Tanzania	2.24	0.00	0.70
Uganda	1.8	0.00	0.63
Zambia	1.14	0.00	0.43
Food and beverages	0.8	0.00	0.28
Metals and machinery	0.32	0.00	0.11
Chemicals and pharmaceutics	0.65	0.00	0.24
Construction	0.68	0.00	0.25
Wood and furniture	0.19	0.03	0.06
Non-metallic, plastic materials	0.61	0.00	0.22
Other manufacturing	0.52	0.00	0.19
Other services	0.18	0.65	0.06
Hotels and restaurants	1.11	0.00	0.42
Mining and quarrying	0.53	0.11	0.19
Constant	-4	0.00	0.02

Source: World Bank, Enterprise Survey Database.

Note: Base country: South Africa; base industry: Textiles

Table 3 Operating costs of own generation in Sub-Saharan Africa

Country	Fuel price (USc/l)	Price of kwh				
		<5kVA	5–100kVA	100kVA–1MW	1MW–10MW	Grid
Algeria	0.10	0.08	0.05	0.03	0.03	0.03*
Benin	0.72	0.58	0.32	0.22	0.19	0.12*
Botswana	0.61	0.49	0.27	0.18	0.16	0.04*
Burkina Faso	0.94	0.75	0.42	0.28	0.25	0.21*
Burundi	1.08	0.86	0.49	0.32	0.29	n.a.
Cameroon	0.83	0.66	0.37	0.25	0.22	0.12*
Cape Verde	0.81	0.65	0.36	0.24	0.22	0.17*
Egypt	0.10	0.08	0.05	0.03	0.03	0.04*
Eritrea	0.25	0.20	0.11	0.08	0.07	0.11
Ethiopia	0.32	0.26	0.14	0.10	0.09	0.06
Kenya	0.56	0.45	0.25	0.17	0.15	0.10
Madagascar	0.79	0.63	0.36	0.24	0.21	n.a.
Malawi	0.88	0.70	0.40	0.26	0.24	0.05*
Mali	0.55	0.44	0.25	0.17	0.15	0.17
Mauritania	0.59	0.47	0.27	0.18	0.16	n.a.
Mauritius	0.56	0.45	0.25	0.17	0.15	0.14*
Morocco	0.70	0.56	0.32	0.21	0.19	0.08*
Namibia	0.65	0.52	0.29	0.20	0.18	0.04*
Niger	0.91	0.73	0.41	0.27	0.25	0.23*
Senegal	0.53	0.42	0.24	0.16	0.14	0.16
South Africa	0.40	0.32	0.18	0.12	0.11	0.04
Swaziland	0.73	0.58	0.33	0.22	0.20	0.05*
Tanzania	0.61	0.49	0.27	0.18	0.16	0.09
Uganda	0.70	0.56	0.32	0.21	0.19	0.09
Zambia	0.60	0.48	0.27	0.18	0.16	0.04

Table 4 Marginal benefit of generator ownership (lost sales)

Variable	Estimated Coeff.	P-value
Days of Power Outages (log)	1.94	0.00
Generator Ownership	-1.16	0.01
Algeria	2.20	0.04
Benin	0.74	0.56
Botswana	-3.31	0.09
Burkina Faso	0.56	0.79
Burundi	3.24	0.03
Cameroon	1.21	0.39
Cape Verde	1.85	0.36
Egypt	2.12	0.03
Eritrea	-1.21	0.45
Ethiopia	-0.70	0.52
Kenya	3.62	0.00
Kenya (informal)	28.68	0.00
Madagascar	1.70	0.14
Malawi	15.76	0.00
Mali	0.60	0.68
Mauritania	-3.39	0.03
Mauritius	1.78	0.19
Morocco	-0.95	0.41
Namibia	-3.24	0.18
Niger	-0.64	0.75
Senegal	0.84	0.48
Senegal (informal)	3.75	0.01
South Africa	-1.25	0.25
Swaziland	-3.01	0.09
Uganda	0.54	0.63
Uganda (informal)	10.63	0.00
Agroindustry	0.84	0.13
Metals And Machinery	2.20	0.00
Chemicals And Pharmaceutics	0.18	0.81
Construction	-0.08	0.94
Wood And Furniture	0.04	0.94
Non-Metallic And Plastic Materials	1.02	0.15
Other Manufacturing	0.06	0.95
Other Services	1.80	0.34
Hotels And Restaurants	1.69	0.39
Mining And Quarrying	-0.77	0.79
Micro	1.40	0.05
Small	0.85	0.12
Large	0.96	0.17
Very Large	-0.16	0.82
Constant	-1.71	0.11
F-Statistic	26.25	0.00
R^2	0.21	
N	4254	

Source: World Bank, Enterprise Survey Database.
Note: Base country: Zambia; base industry: textiles; base size category: medium size (50–100 employees).

Table 5 Marginal benefit of generator ownership (damage to physical capital)

Variable	Estimated coefficient	P-value
Days of power outages (log)	0.05	0.15
Generator ownership	0.03	0.79
Benin	0.73	0.00
Kenya	-0.11	0.51
Madagascar	0.70	0.00
Mali	0.65	0.01
Mauritius	0.21	0.34
Senegal	0.26	0.11
Uganda	0.22	0.24
Agroindustry	0.15	0.32
Metals and machinery	0.21	0.24
Chemicals and pharmaceutics	0.01	0.95
Construction	0.06	0.76
Wood and furniture	0.14	0.41
Non-metallic and plastic materials	0.18	0.43
Other manufacturing	0.62	0.02
Mining and quarrying	0.09	0.82
Small	0.79	0.00
Medium	0.21	0.12
Large	0.00	0.98
Very large	-0.13	0.43
Constant	0.001	0.99
F-Statistic	6.06	0.00
R^2	0.2	
N	540	

Note: Base country: Zambia; base industry: textiles; base size category: medium size (50–100 employees),
Source: World Bank, Enterprise Survey Database.

Table 6 Simulated change in generator ownership from improved reliability of power supply

Country	Power outages	Predicted generator ownership	Simulated generator ownership (no power outages)	Simulated generator ownership (outages at South African average)
Algeria	13.96	0.28	0.21	0.25
Benin	74.73	0.20	0.11	0.14
Botswana	24.86	0.19	0.11	0.13
Burkina Faso	20.42	0.26	0.17	0.20
Burundi	130.09	0.44	0.32	0.36
Cameroon	30.36	0.59	0.55	0.59
Cape Verde	27.30	0.46	0.39	0.43
Egypt	17.23	0.18	0.12	0.14
Eritrea	110.15	0.46	0.35	0.39
Ethiopia	60.63	0.19	0.07	0.09
Kenya	82.03	0.69	0.65	0.69
Madagascar	74.15	0.19	0.11	0.13
Malawi	76.88	0.46	0.36	0.40
Mali	14.28	0.47	0.42	0.47
Mauritania	65.65	0.27	0.16	0.19
Mauritius	7.49	0.41	0.37	0.41
Namibia	15.00	0.20	0.11	0.14
Niger	38.35	0.41	0.34	0.38
Senegal	29.15	0.61	0.56	0.60
South Africa	5.95	0.09	0.05	0.09
Swaziland	34.87	0.38	0.27	0.30
Tanzania	70.15	0.57	0.49	0.53
Uganda	61.38	0.34	0.24	0.27
Zambia	36.34	0.38	0.30	0.33

Table 7 Impact of power situation on observed industrial structure and foreign trade

Country	Key exports	Days of power outages	Energy intensity (IEA, Btu / USD)	Energy intensity (ICA / DOE Index)
Algeria	Petroleum	13.99	5,441	0.99
Benin	Cotton, meat, fruits	73.86	3,147	0.94
Botswana	Diamonds, ores	24.56	4,319	1.00
Burkina Faso	Cotton	20.08	1,095	0.96
Burundi	Coffee, gold	143.76	1,739	0.98
Cameroon	Petroleum, wood	30.05	1,871	0.96
Cape Verde	Apparel	13.27	1,015	0.92
Egypt	Diverse	17.46	7,721	1.02
Eritrea	Sugar	93.89	3,255	1.07
Ethiopia	Coffee, leather, vegetables	60.30	1,644	1.00
Kenya	Oil, tea, vegetables	64.96	4,125	1.03
Madagascar	Spices, fish	77.99	2,510	1.00
Malawi	Tobacco, sugar	54.83	2,532	0.94
Mali	Gold	14.55	706	0.94
Mauritania	Iron ore, fish, gold	48.28	10,710	0.98
Mauritius	Sugar, apparel	7.76	2,767	0.97
Morocco	Diverse	7.28	2,996	1.07
Namibia	Fish, gems	15.20	4,965	0.98
Niger	Uranium, food	25.15	1,437	0.97
Senegal	Oil, chemicals	18.64	3,402	0.94
South Africa	Diverse	4.60	12,477	0.97
Swaziland	Chemicals, apparel	35.11	4,573	1.00
Tanzania	Gold, fish, coffee	72.27	3,466	0.96
Uganda	Fish, gold, coffee	43.93	1,440	1.00
Zambia	Copper nonferrous metals	37.21	11,773	0.95

Appendix 2 Methodologies for estimating average costs of self-generated electricity

The results of the two approaches detailed below were not significantly different.

Fuel approach

Makes it possible to estimate the average cost of self-generated electricity without knowing the reported price of electricity from the public grid (which is missing for some countries).

- Calculated annual fuel consumption by dividing reported fuel expenditures by fuel prices from country-level data from GTZ.
- Calculated the ratio of average consumption of fuel for firms with and without generators by country, sector, and size.
- Calculated the total amount and expenditures on fuel used for own generation by multiplying annual fuel consumption on the ratio of average consumption of fuel for own generation.
- Calculated the total amount of self-generated electricity by multiplying the estimated amount of fuel used for own generation by the generator’s fuel transformation coefficient as provided by electrical engineering experts (measured in liters per kWh).
- Calculated the total amount of electricity consumed from public grid using the estimated amount of self-generated electricity and the reported share of electricity from public grid.
- Calculated total expenditures on electricity from the public grid by multiplying estimated consumption from the public grid by the reported price of electricity from the public grid.
- Calculated the average costs of electricity from own generation and the electricity from public grid by dividing electricity expenditures by electricity consumption.

Electricity approach

Advantage of methodology: simple, requires fewer iterations, possibly more precise.

- Calculated annual electricity consumption from public grid by dividing reported electricity expenditures by reported price of electricity from the public grid.
- Calculated the total amount of self-generated electricity using the estimated amount of self-generated electricity and the reported share of electricity from the public grid.
- Calculated the total expenditures on self-generated electricity by multiplying the estimated amount of self-generated electricity by the projected average cost of own generation (the product of the generator’s fuel transformation coefficient and the fuel price).

- Calculated the average costs of electricity from own generation and electricity from the public grid by dividing electricity expenditures by electricity consumption.

About AICD

This study is part of the Africa Infrastructure Country Diagnostic (AICD), a project designed to expand the world's knowledge of physical infrastructure in Africa. AICD will provide a baseline against which future improvements in infrastructure services can be measured, making it possible to monitor the results achieved from donor support. It should also provide a more solid empirical foundation for prioritizing investments and designing policy reforms in the infrastructure sectors in Africa.

AICD will produce a series of reports (such as this one) that provide an overview of the status of public expenditure, investment needs, and sector performance in each of the main infrastructure sectors, including energy, information and communication technologies, irrigation, transport, and water and sanitation. The World Bank will publish a summary of AICD's findings in November 2009. The underlying data will be made available to the public through an interactive Web site allowing users to download customized data reports and perform simple simulation exercises.

The first phase of AICD focuses on 24 countries that together account for 85 percent of the gross domestic product, population, and infrastructure aid flows of Sub-Saharan Africa. The countries are: Benin, Burkina Faso, Cape Verde, Cameroon, Chad, Congo (Democratic Republic of Congo), Côte d'Ivoire, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Uganda, and Zambia. Under a second phase of the project, coverage will be expanded to include additional countries.

AICD is being implemented by the World Bank on behalf of a steering committee that represents the African Union, the New Partnership for Africa's Development (NEPAD), Africa's regional economic communities, the African Development Bank, and major infrastructure donors. AICD grew from an idea presented at the inaugural meeting of the Infrastructure Consortium for Africa, held in London in October 2005.

Financing for AICD is provided by a multi-donor trust fund to which the main contributors are the Department for International Development (United Kingdom), the Public Private Infrastructure Advisory Facility, Agence Française de Développement, and the European Commission. A group of distinguished peer reviewers from policy making and academic circles in Africa and beyond reviews all of the major outputs of the study, with a view to assuring the technical quality of the work.

This and other papers analyzing key infrastructure topics, as well as the underlying data sources described above, will be available for download from www.infrastructureafrica.org. Freestanding summaries are available in English and French.

Inquiries concerning the availability of datasets should be directed to vfoster@worldbank.org.