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Rural electrification in an imperfect world: A case study from Mozambique

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ABSTRACT

Electricity is universally recognized as a necessary, although not sufficient, requirement for social and economic development. However, increasing access to electricity in developing countries has proven to be difficult and expensive, particularly in rural areas. In this article, we analyze the dynamics of the relationship between electricity and socio-economic development by means of a cost–benefit analysis of a typical rural electrification project in Mozambique, assessing the impact of electricity on households, education, agro-business, commerce, and the public sector. We show that rural electrification can be commercially viable and cause structural transformation in rural areas within a short period of time. Finally, illustrated by the actual policy practice in Mozambique, we argue that low institutional quality is a key barrier to promote increased access to electricity for the poor.

1. Introduction

Electricity is universally recognized as a necessary, although not sufficient, requirement for social and economic development. However, about one-quarter of the world population—some 1.6 billion people—have no access to electricity. Four out of five people without electricity live in rural areas of the developing world, mainly in South Asia and sub-Saharan Africa (IEA, 2004). Increasing access to electricity in developing countries has proven to be difficult and expensive. In general, investment costs are high while demand is low because people are poor. This is particularly true in rural areas with its combination of low population density and severe and persistent poverty. As a result, rural electrification is generally considered to be a loss-making investment and thus left for finance by governments and the donor community (foreign aid). This practice (implicitly) presumes that in developing countries (i) rural electrification indeed is not a commercially viable investment, and (ii) governments and donors are able to effectively bring electricity to poor people in remote areas.

In this paper, we will challenge these assumptions by providing an insight into the actual practice of rural electrification and energy sector management in Mozambique. In contrast with aggregate (econometric) analyses of the relationship between electricity consumption and economic growth (see, for example, Wolde-Rufael, 2005) we analyze the dynamics of this relationship at the micro-level of a rural area. We do so by providing a cost–benefit analysis of a typical rural electrification project in Mozambique, assessing the impact of electricity on households, education, agro-business, commerce, and the public sector. In addition, we use historical data of the project to develop scenarios to assess future costs and benefits, up to the year 2020. Finally, we draw some lessons to be learned from our case study and confront these with the reality of energy policy making in Mozambique in order to illustrate the actual barriers and challenges to rural electrification in developing countries. We show that rural electrification can be commercially viable and can lead to structural transformation in rural areas within a short period of time. Furthermore, illustrated by the actual policy practice in Mozambique, we argue that weak institutional arrangements constitute an essential component in explaining the generally slow pace of rural electrification in many developing countries, while changing institutions for the better is complex, slow and extremely difficult to influence from outside.

The organization of this paper is as follows. Section 2 provides a brief overview of the rapidly changing Mozambican energy sector, with particular emphasis on electricity. In Section 3, we present cost–benefit calculations for the electrification project under analysis, based on the results over the period 2000–2005. In Section 4, we present a scenario exercise for the period 2005–2020. Section 5 concludes and discusses the lessons to be learned against the background of actual policy making in Mozambique.

2. Mozambique and its energy sector

Mozambique is located in the eastern part of Southern Africa and comprises a land surface of about 800,000 km^2 (roughly three

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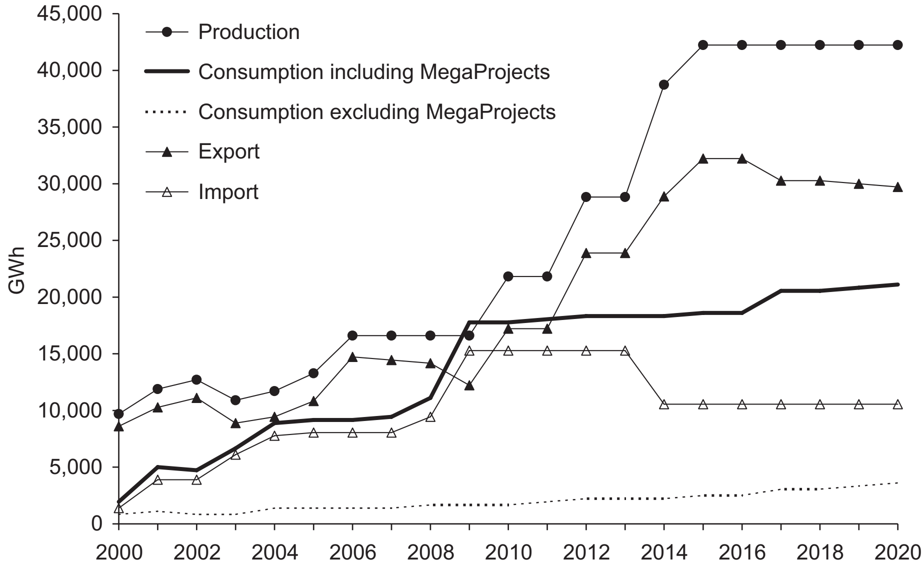

Fig. 1. Electricity sector in Mozambique, 2000–2020.

times the size of the UK) with a 2500 km long coastline as well as borders with Tanzania, Malawi, Zambia, Zimbabwe, South Africa and Swaziland. The country has about 20 million inhabitants. It gained independence from Portuguese colonial rule in 1975, soon to be followed by a protracted and devastating civil war that was ended in 1992. After its first democratic elections in 1994 the country enjoys political stability and rapid economic growth, averaging circa 7.5% over the last decade. Nevertheless it is still one of the poorest countries in the world with a GDP per capita of circa US$350 (US$ PPP 1.100) and a Human Development Index rank of 156 (out of 177 countries). Mozambique is highly dependent on foreign aid, which currently comprises circa half of the government budget.

Mozambique has vast and largely untapped natural resources, including circa 12,500 MW hydro potential, 127 billion m^3 of natural gas reserves, and 13.1 billion tonne of proven coal reserves.[1] Until the end of the 1990s the energy sector was characterized by decline, disruption and initial post-war reconstruction. Since then the energy sector is developing rapidly with a further spectacular growth to be expected during the next decade and beyond. This process has been very much visualized by the 2075 MW Cahora Bassa hydro dam (HCB), commissioned in 1974 by the Portuguese. Its goal to generate electricity for export to South Africa was frustrated for a long time by destruction of the transmission lines during the post-independence civil war. Post-war reconstruction allowed for production to pick-up in 1997, and after prolonged negotiations in 2006 the ownership of HCB has been transferred from Portugal to Mozambique. It may be expected that this will accelerate the realization of other large hydro projects such as the 600 MW HCB–North dam (2010) and the 1300 MW Mphanda Nkuwa dam (2014). In addition, concrete plans exist to build a 700 MW natural gas-fired electricity plant (2011) as well as a 1500 MW coal-fired electricity plant (2012–2015). Large-scale natural gas production (circa 100,000 TJ/year) started in 2004 while large-scale coal mining (circa 14 million tonne/year) is expected to start in 2009.

Access to modern energy services in Mozambique is still very low, with about 80% of the population relying entirely on traditional biomass to meet their energy needs. The domestic electricity market is extremely dual in nature. On the one hand, residential and 'normal' commercial electricity consumption is low (in total 77 kWh/capita/year of which 29 kWh/capita/year residential consumption, in 2006) due to low levels of access (about 8% of the population) and the small scale of the 'normal' commercial sector. On the other hand, Mozambique's natural resource abundance is attracting projects of large dimension in the industry and mining sectors that (will) consume about 5–8 times as much electricity as the rest of the country all together (circa 8 TWh versus 1.5 TWh in 2006). So far, some of these so-called mega projects have been realized, such as the Mozal aluminium smelter (2000) and the Moma mineral sand mining project (2007), while several new projects are planned, including an extension of Mozal (2009), a second mineral sand mine (2010) and the aforementioned large-scale coal exploration (2009).

Another distinguishing characteristic of the Mozambican energy sector is its orientation on export. The vast majority of natural gas and coal resources as well electricity production is aimed for export, with South Africa being the principal destination (except for coal, which will go mainly to the Brazilian steel industry). Moreover, electricity consumption in the southern part of Mozambique—the economically most vibrant part of the country including the large aluminium smelter—has to be wheeled from HCB in the north-west of Mozambique via South Africa, due to lack of direct transmission infrastructure. As a result Mozambique currently exports about as much electricity as it imports. Fig. 1 summarizes these developments, presenting historical data until 2005 as well as the most likely medium growth scenario of the electricity sector until 2020.[2]

To increase access to electricity, the Government of Mozambique has adopted a national Master Plan for electrification that aims for an access ratio of 20% by 2020 (EdM, 2004). The Master Plan comprises a total investment of US$850 million, including circa US$260 million for transmission projects (excluding specific transmission line investments for mega projects) and circa

[1] Source of these and other figures in this section: Ministry of Energy (2007a, b), Yager (2005), feasibility studies of the mentioned projects, and internal communication within the Ministry of Energy. For more details we refer to Mulder (2007). Energy statistics of Mozambique as published by Ministry of Energy (2007a, b) can be downloaded from http://www.petermulder.net.

[2] To this aim we used the software tool LEAP (Long-range Energy Alternatives Planning system), a scenario-based energy–environment modelling tool (see: http://www.energycommunity.org).

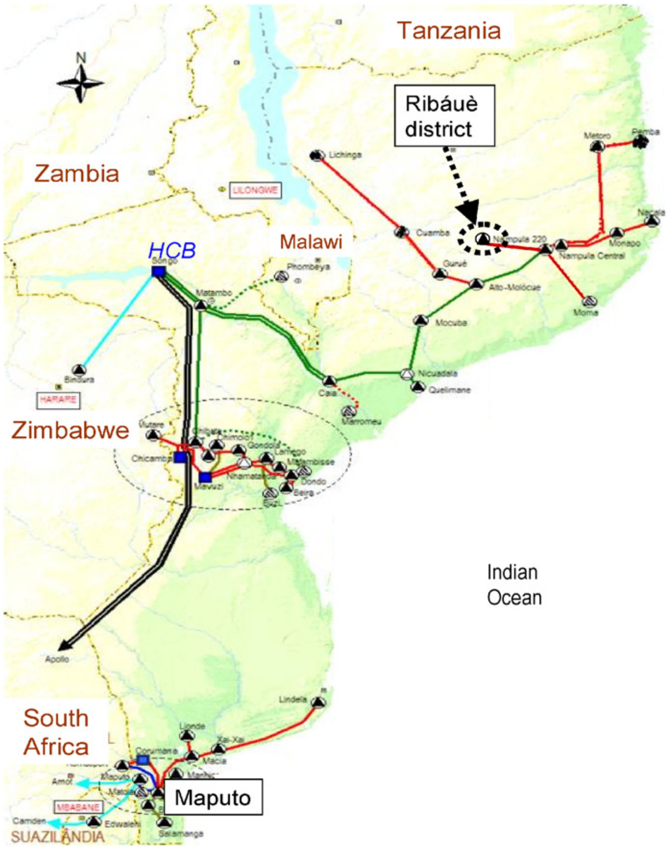

Fig. 2. Mozambique electricity infrastructure. (*Source*: EdM).

US$475 million for distribution projects divided over suburban intensification projects (US$125 million), rural electrification projects (US$200 million) and rehabilitation and ordinary investments (US$150 million). About 30% of these investments will be financed by the national power utility, *Electricidade de Moç ambique* (EdM) itself, while the remaining part has to come from government and donor funding.

The vast majority of electricity consumption in Mozambique is distributed by the national grid, with virtually all electricity supplied by HCB. By way of illustration Fig. 2 provides a map of Mozambique including its electricity infrastructure. Although plans exist to increase the number of small isolated grids in rural areas, rural electrification in Mozambique is first and foremost a matter of extending the national grid. This is motivated by the availability of existing and future hydroelectricity at relatively low costs. In this article, we therefore focus on national grid-based rural electrification (also still the most important component in other developing countries) and do not consider the potential role of isolated grids and renewable energy technologies like solar and biomass in providing electricity to rural areas.

3. Cost–benefit analysis 2000–2005

The project under analysis comprises the electrification of the Ribáuè district, situated in the northern province of Nampula in Mozambique (see also Fig. 2). Agriculture is the main economic activity in the district and involves almost all households. Ribáuè district is integrated into the provincial trade network. Most trade in the district is based on marketing agricultural surpluses while the district capital serves as the main market for consumer goods. The objective of the electrification project was to promote overall socio-economic development in the region. With electrification, there were expectations that it could boost local industry, trade and employment creation and improve life of the local residents by providing them with access to (improved) education and health facilities, thus contributing to poverty reduction in line with the current poverty reduction strategy for Mozambique.

The electrification project promoted expansion of the existing national grid fed by HCB, and included a 160 km transmission line (from the provincial capital Nampula) as well as a local distribution network. The investment costs amounted US$4 million and were financed through a grant by the Swedish Development Cooperation (SIDA). The line construction started early 1999 and the first consumers were connected in the year 2000. Subsequently, two socio-economic impact studies have been conducted—in 2001 and 2005—to analyze the impact of the project (Åkesson and Nhate, 2002, 2006). Together with a 1997 baseline study of the project (Åkesson et al., 1997), they form the basis for our calculations. Whereas these socio-economic impact studies describe the development of the district and the role of electricity in much detail, we focus on quantifying the benefits of the arrival of electricity over the period 2000–2005 following standard cost–benefit techniques (Kirkpatrick and Weiss, 1996; Layard and Glaister, 1994).

The number of customers has been steadily increasing since the beginning of the project, from about 300 in 2000 to 1900 in 2005, which translates into circa 6% of the local population with access to electricity by 2005. The vast majority of these are small consumers in the category 0–200 kWh/month. This group predominantly consists of families that, in addition to their income from agriculture, have a supplementary income from wage work or permanent self-employment activities. Within this group, 90% consumes less than 85 kWh/household/month. It is to be noted that the number of consumers in 2001 was only about 50% of total clients foreseen (1100) by EdM and SIDA. In the initial period of the project (January–September 2001) 274 (44%) clients were cut off for non-payment, of which 148 (24%) were reconnected. During the same period in 2005 these figures were 459 (24%) and 288 (15%), respectively. Consumers in the private sector, undertaking commercial or semi-industrial activities, the public sector and civil society (churches, NGOs) together account for 6–10% of total consumers. Finally, Ribáuè district has a couple of large consumers, including a cotton fabric, a secondary school and a couple of maize mills. Given the initial investment costs of US$4 million and a total of 1900 clients by 2005, the investment costs per client are about US$2100. Following the growth in the number of clients, electricity consumption within the Ribáuè district has been steadily growing since 2000 to about 2300 MWh in 2005. By 2005, 97% of all consumers were responsible for about 60% of total electricity consumption. These are mainly households in the category 0–200 kWh/month. In addition, the few large consumers account for about 26% of total electricity consumption, of which the cotton fabric in the district is by far the largest electricity consumer.

The principal costs of the project are twofold: initial investment costs, and operating & maintenance costs. The initial investment costs are US$4 million, spent between 1999 and 2000. In our analysis these costs are assumed to fall in the base year 2000. We assume that normal operating and maintenance costs depend on the amount of electricity sold and comprise 20% of the electricity price per kWh. Indirect costs, such as negative impacts on the environment, should be very small, if any, and are therefore not taken into consideration.

The benefits of the project can be divided into direct or private benefits and indirect or social benefits. The *direct benefits* include savings in energy costs and increased productivity from economic activities. The savings in energy costs rise primarily from the fact that the local cotton fabric as well as the maize mills substituted electricity for diesel consumption. The monetary value of this is calculated by multiplying the price differential between diesel and electricity with the respective quantities consumed, given the realized production level. We refer to this as commercial saving of energy costs. In addition, there are household savings resulting from substituting electricity for kerosene to meet demand for lighting services. Likewise household energy savings are calculated as the price differential between kerosene and electricity multiplied by their respective quantities consumed. This latter is based on the realized consumption levels of households with electricity consumption below 85 kWh/month, because it are mainly these households that use electricity predominantly for lighting.

Increased value from economic activity originates in our case mainly from the local cotton fabric that increased both its efficiency as well as the level of production. The use of electricity has allowed the cotton fabric to increase its efficiency with 30%. This led to a more rapid transport chain from producer to the mill and an increased demand for raw cotton. We calculate the monetary value from this straightforwardly from the combination of increased production levels and cotton prices per kg. In addition, the increased number of maize mills working with electric engines provided more regular and efficient service than those relying on diesel engines. As a result, milling charges went down and incomes for its owners went up. We calculate the total value of the consumer surplus on the basis of reported quantities and the milling charge differential, while we assume the producer surplus to be 20% of total turnover (see below). Finally, since electricity arrived, new shops, bars and restaurants have been created, most of them in the informal sector. Of course, here we touch upon the difficult issue of causality: has this been solely due to electrification? We estimate the value of this increased economic activity by combining the reported number of establishments of various types with assumptions on the number of workers per establishment and their salaries, and then assigning an arbitrary 20% of the total value to the electrification project (see below). We assumed the number of workers per establishment to range from 2 (informal mechanical repair shop) to 30 (restaurant), with formal employees earning the official minimum wage while informal workers are supposed to earn 75% of that.[3]

The *indirect benefits* include improved educational and health services, increased tax revenues for the local government and various other benefits like more and better channels of communication (radio, TV) and improved security due to public lighting. The impact of electrification on education is threefold. The introduction of electricity enabled the schools to offer night classes, which led to an increased number of students. Secondly, the promotion rates at day classes improved because of better study conditions (at night). Finally, the participation of female students increased, due to night classes and increased facilities such as a boarding school. Because of methodological difficulties we did not estimate the impact of the last effect. To quantify the other two effects we estimate the aggregate returns to education by multiplying the increased number of students finishing school with the so-called wage premium. The wage premium indicates the degree of higher wages earned when having a certain schooling level, and is obtained by applying a Mincer-type of wage regression (see, for example, Pritchett (2006) and Schultz (1999) for a detailed discussion). We took wage premium factors from Jones (2006) and Fox et al. (2005), which are derived from the 2003 national household survey in Mozambique. These values correct for various relevant factors, including the rural/urban dichotomy.

The tax income for the local government in the Ribáuè district increased with 90% between 2001 and 2005. The majority of revenues originate from fees on local commerce. Since commerce has increased significantly due to the availability of electricity we arbitrarily assume that 50% of the revenue increase is due to the electrification project (see below).

Electricity also led to improved health services: the hospital now offers 24 h emergency attendance and improved equipment allows for increased and better treatment of patients. Measuring welfare from health improvement requires finding appropriate "prices" to value health status. There is a voluminous literature on the value of fatalities prevented, with best estimates ranging from US$0.6 million to US$13.5 million per fatality prevented (Viscusi, 1993). Unfortunately, for the Ribáuè district we do not have appropriate data on the prevention of general fatalities that can be attributed to the availability of electricity via improved emergency attendance or treatment. We do know that in 2005 the hospital had to transfer 3 emergency cases per month to the hospital of the provincial capital (Nampula) against 30 cases in 2001 and that maternal mortality had reduced from 16 in 2004 to 6 in 2005. However, according to the hospital itself this drop in fatalities and in maternal mortality is due to improved skills of personnel, a better informed population and the availability of an ambulance (Åkesson and Nhate, 2006, p. 64). As a result we feel it is difficult to assign the improved healthcare to electrification, and hence we decided not to include the health effects in our cost–benefit analysis. Admittedly, this is a serious drawback because the monetary benefits of improved health care are substantial, given the aforementioned estimates of the value of fatalities prevented.

In addition, with electricity the district also got access to public lighting that improved the sense of security of inhabitants, in particular of women. Finally, electricity led to improved access to modern communication means like radio and TV. Unfortunately, lack of data as well as methodological problems prevented us from quantifying these effects.

Throughout the calculations we use constant prices and a constant 2000 PPP exchange rate to convert values in different currencies to US dollars (US$). Furthermore, we assume an economic lifetime of 20 years, exactly covering the period under analysis (2000–2020) and thus leaving no residual value. Finally, we apply a baseline discount rate of 5% to calculate the net present value of future costs and benefits. One could argue in favour of higher opportunity costs of capital over the lifetime of the project—also given the fact that interest rates in Mozambique are in the order of 15%—and thus implying that a higher discount rate would be more appropriate. However, the main investments done were financed by a grant from SIDA, meaning that the majority of the capital for this project has been made available at a zero interest rate. To balance the different capital flows we work with a standard 5% and check the robustness of our results by providing a sensitivity analysis of the cumulative net benefits against a range of discount rates.

In Table 1, we present the main results of our calculations. From the table it can be seen that annual benefits are positive and increasing, while the cumulative net benefits have just become positive by 2004. As indicated before, the costs comprise initial investment costs of US$4 million as well as operating and maintenance costs. The break down of total benefits of the project per year shows that the majority of the benefits results from commercial energy savings and improved processing of cotton. Since also the majority (70–80%) of commercial energy savings originates from the cotton fabric, this leads to the conclusion that the cotton fabric is the principal source of benefits in this

[3] Based upon local expert opinion we assume the official minimum wage to be a sufficiently appropriate indication of opportunity costs of unskilled labour within the Ribáuè district, and thus refrained from estimating shadow prices including specific wage-premiums.

Table 1
Costs and benefits, 2000–2005

	Total	2000	2001	2002	2003	2004	2005
Costs and benefits, 1000US$							
Costs	4639	4114	66	76	108	124	151
Benefits	6336	458	732	842	1132	1435	1737
Net benefits	1698	−3656	665	766	1025	1311	1586
Cumulative net benefits		−3656	−2991	−2224	−1200	112	1698
Decomposition of benefits							
Saving energy costs—commercial (%)	55.9	68.3	57.7	53.3	56.3	56.2	52.5
Saving energy costs—residential (%)	7.3	0.9	2.7	4.1	5.7	8.1	13.1
Processing of cotton (%)	24.4	22.7	30.4	30.9	25.2	22.3	20.3
Electric maize mills (%)	0.3	0.0	0.2	0.3	0.3	0.3	0.3
Other business (%)	8.8	8.1	7.6	8.7	9.5	8.9	8.8
Education (%)	2.6	0.0	0.4	1.6	2.3	3.5	4.3
Tax income (%)	0.7	0.0	0.9	1.0	0.8	0.7	0.7

electrification project. It is to be noted that the absolute value of the energy cost-saving component grew substantially as of 2003, due to increased cotton production as well as increased diesel prices. Increased production on its turn was stimulated by increased cotton prices. In addition, the estimated benefits from increased private sector activities ('other business') are considerable, while the value of improved education is gradually emerging. Finally, average domestic energy savings have been increasing considerably as of 2003 due to a relatively strong increase of the price of kerosene for lighting, following international oil price increases. As a result households have increasingly been able to save on energy costs by substituting electricity for kerosene.

As discussed above, these results are driven by a number of assumptions, most of which are straightforward. Three assumptions, however, are highly arbitrary: (i) the producer surplus from increased performance of maize mills is 20% of total value, (ii) 20% of the total value of increased economic activity of small businesses can be assigned to the electrification project, and (iii) 50% of increased tax revenues are due to the electrification project. Therefore we performed a sensitivity analysis, reproducing the benefits of the project under different values regarding these assumptions. We adopted a high and low scenario, changing the aforementioned percentages (20%, 20% and 50%) in {40%, 40%, 80%} and {5%, 5%, 20%}, respectively. The results indicate that the overall picture does not change: while the exact numbers change somewhat, the cotton fabric remains to dominate the results accordingly to the breakdown shown in Table 1. Obviously, the reason is to be found in the relatively small percentage contribution of these 3 components to total benefits. This is particularly true for the benefits from improved milling and tax income with a percentage contributing varying between 0.2% and 1.3%, while the percentage contribution of other business varies from 2% in the low scenario to 14% in the high scenario.[4]

4. Scenarios 2005–2020

Based on the cost–benefit analysis presented above, we develop three scenarios for the period 2005–2020. These scenarios reflect optimistic, average and pessimistic assumptions about the future costs and benefits. Table 2 summarizes the main assumptions underlying the three scenarios—labeled as high, medium and low—in relation to the values for the period 2000–2005. These assumptions are based on modelling the historical developments as well as additional calculations and assumptions on the development of key indicators.

Table 2
Assumptions for the 3 scenarios, annual % change or growth rate

	2000–2005	High	Medium	Low
Operating costs	10	8	10	12
Commercial energy saving	27	7	4	1
Production	3.5	5	3	1
Diesel price	23.6	3	1	−1
Electricity price	1.2	1.5	0.95	0.05
Domestic energy saving	50	12	8	4
Kerosine price	22.2	3	1	−1
Electricity price	0.3	1.5	0.95	0.05
Number of electricity consumers	34.6	15	10	5
Improved processing of cotton	18	8	5	2
Production	3.5	5	3	1
Cotton price	13.8	5	3	1
Electric maize mills	37	30	20	15
Production	36.8	30	20	15
Other business	35	15	10	5
Income	6.8	10	5	1
People involved formal sector	38.7	15	10	5
People involved informal sector	22.7	15	10	5
Education	86	25	20	15
Inflation rate	13.0	10	8	6
Average number of new students	16.8	12	8	4
Tax income	24	25	15	5

It is to be noted that the assumptions on commercial energy costs saving and processing of cotton are deliberately conservative since they already constitute the major part of the benefits (see Table 1). The same applies to the emerging benefits from other business activities and education. On the other hand, assumptions on electric maize mills and tax income are deliberately positive. Furthermore, it is to be noted that the annual increase in diesel and kerosene prices is assumed to be limited or even slightly negative, because their prices at the end of 2005 were already high—based on a price of about 60 US$/barrel.

Given these assumptions, our model enabled us to make projection of total costs and benefits up to 2020. The resulting cumulative net benefits of the 3 scenarios are summarized in Fig. 3.

The figure shows that in all 3 scenarios the cumulative net benefits will continue to increase considerably. In the most optimistic scenarios, total net benefits are estimated to reach circa US$40 million by 2020, while in the most pessimistic scenario this is still about US$20 million. Hence, it can be

[4] We refer to the working paper version of this article for details (Mulder and Tembe, 2006).

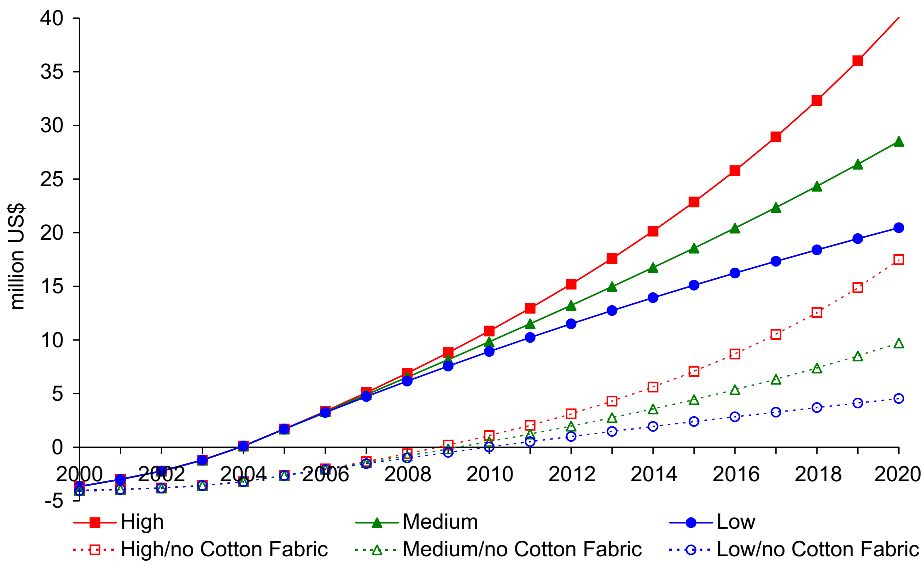

Fig. 3. Cumulative net benefits, 2000–2020.

concluded that overall the project realizes a high pay-off over time. To further illustrate the crucial role of the cotton fabric, in Fig. 3, we also present the estimated cumulative net benefits of the electrification project excluding the cotton fabric. From the figure it can be seen that without the cotton fabric total cumulative net benefits by 2020 would range between circa US$4 and 17 million (depending on the scenario), and would have become positive only after 2009/2010.

In Fig. 4, we demonstrate a breakdown of the benefits over time. The figure shows that the cotton fabric remains to be the main driver of the results, both in terms of saving energy costs and improved performance of its production process. At the same time, the benefits from education are emerging as a considerable share of total benefits, resulting from an ever-increasing cumulative number of students over time. Obviously, since we measure the benefits from education by means of the wage premium to higher education levels, there is an inherent time lag when it comes to materialize these benefits.

So far, all our calculations are based on applying a discount rate of 5%. As discussed before, one may question the appropriateness of this choice and thereby our results, particularly in the long run. Therefore, we test the robustness of our results by conducting a sensitivity analysis of total cumulative net benefits of the project under different discount rates. The results of this analysis are provided in Fig. 5. From the figure it can be seen that even at a high discount rate of 20% by 2020 the cumulative net benefits of the project would be positive, albeit small (around US$4–6 million). If we exclude the cotton fabric, in the high scenario total cumulative net benefits in 2020 would be very small (US$0.06 million) while in the low and medium scenarios total cumulative net benefits by 2020 remain only positive at discount rates up to 13% and 16%, respectively.

5. Conclusions and discussion

Our simple cost–benefit analysis of a typical rural electrification project in a developing country, Mozambique, shows that in spite of the high costs (about US$2100 per realized customer in 2005) the project has led to positive cumulative net benefits within 4 years. This result is to be explained mainly from the improved performance of existing productive capacity of the local cotton fabric, further helped by an exogenous increase in diesel and cotton prices. Increased other (informal) economic activities also have had a considerable impact. In contrast, the monetized benefits for households have been small. In addition, a scenario exercise showed that the electrification project is likely to raise substantial positive benefits over the coming years, making it a successful project from an economic point of view. However, this future success is again highly dependent on the continued positive economic performance of the cotton fabric. At the same time, education emerges as a potentially important source of benefits over a longer time span, resulting from the wage premium to higher education levels. The direct economic benefits for households remain limited, and only pay-off the initial investment costs after a very long period of time.

These results lead to the conclusion that rural electrification projects in principle can be commercially viable on the condition that they include at least one key customer, like the cotton fabric in our case, which could generate a considerable return on investment. Without such a key customer, rural electrification projects indeed are likely to be commercially unviable. From an economic point of view a rural electrification strategy should thus look for potential or existing productive capacity that access to electricity can help to realize or increase, respectively.

One could argue that if successful rural electrification projects require the existence of a key private customer, it might not be appropriate to subsidize these projects with public funds (be it from donors or the government) since it are the considerable private benefits of the key customer that make these projects commercially viable. However, rural electrification generates substantial positive externalities, originating from spillovers generated by increased productivity in the private sector (like, in our case, improved economic conditions of the local farmers supplying the cotton fabric), freeing up time and labour for education and/or income generating activities, and improved environmental, health and safety conditions—which will particularly benefit women.[5] Given the high costs of rural electrification and the existence of considerable positive external benefits,

[5] It is to be noted that, due to limited data availability, we have not been able to quantify all these benefits and thus our results underestimate the social benefits of rural electrification in Ribáuè district.

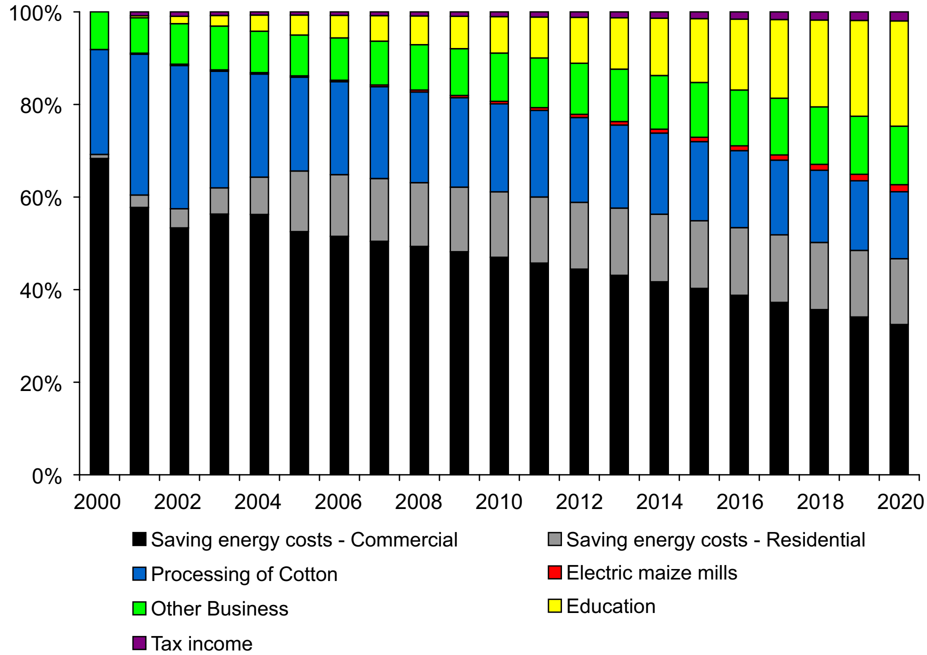

Fig. 4. Decomposition of benefits, 2000–2020.

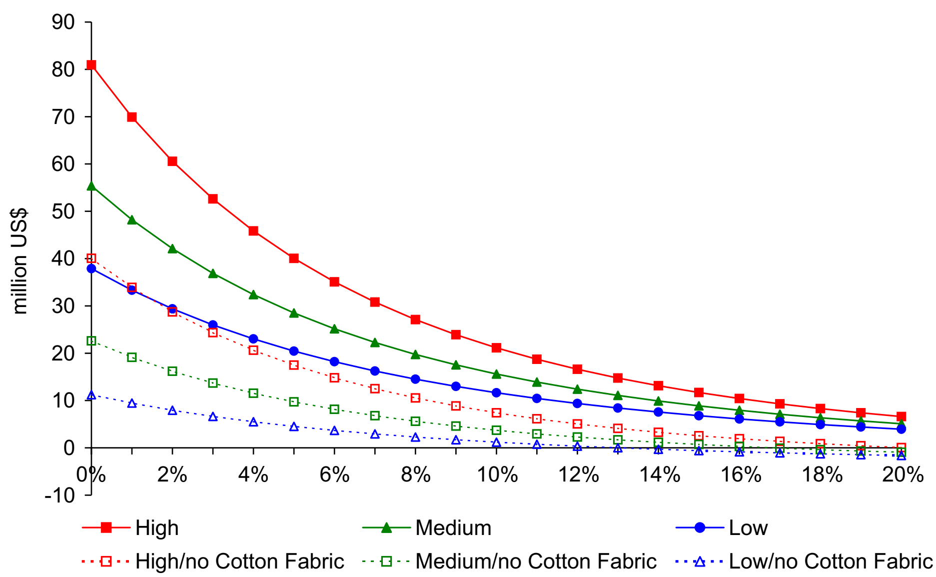

Fig. 5. Cumulative net benefits, in 2020 at different discount rates.

commercial finance alone is likely to lead to underinvestment in the national grid from a welfare point of view.

In effect, a strategy to search for key private customers is very similar to the idea underlying the macroeconomic strategy of the Government of Mozambique (GoM) to attract mega projects (see Section 2). These 'anchor projects' are supposed to create economic dynamics by establishing linkages with other sectors, thus initiating 'trickle down effects'. While the mega projects attract a great deal of attention, their sustainable impact on the Mozambican economy is very limited because their capital-intensive character in fact prevents the creation of many cross-sectoral linkages in a predominantly low-skilled agricultural society (Anderson, 2001; Carlos-Branco and Goldin, 2003). By contrast, relatively small anchor projects in the area of agro-processing, like the cotton fabric in the Ribáuè district, do establish linkages across the local economy and contribute to increasing agricultural productivity and other grass-root economic development in rural areas, thereby potentially generating substantial positive long-term macroeconomic effects.

This is not to say that Mozambique is not benefiting from the presence of mega projects. The benefits from mega projects for rural electrification could in principle be substantial if we take into account their investments in (long-distance) transmission lines that might well serve as important backbones for extending and reinforcing the national grid, thus facilitating rural electrification in remote areas. Of course this requires careful planning of transmission infrastructure given (potentially) diverging views on the optimal route and voltage of transmission lines resulting from the discrepancy between private and social benefits.

Mega projects could also considerably promote rural electrification through cross-subsidies. The Mozambican national power utility EdM currently applies a cross-subsidy scheme consisting of two components: (i) a progressive electricity tariff and (ii) a uniform tariff structure across the country notwithstanding local and regional costs differences. Effectively this means that the availability and affordability of electricity in rural areas is predominantly subsidized by electricity consumers in urban centres. Thus far mega projects are not part of the cross-subsidy system, while the implementation of the national electricity Master Plan implies that the scheme will come under great pressure over the coming years because of the increasing number of small (poor) customers in rural areas. Inclusion of the mega projects into the cross-subsidy scheme may generate annual funds up to US$35 million whereas the implied minor price increase will by no means jeopardize the commercial viability of the mega projects (Bucuane and Mulder, 2007).[6]

Investments in transmission infrastructure for mega projects are highly profitable while a certain number of electrification projects, such as the one in Ribáuè, also are commercially viable. At the same time, ambitious rural electrification schemes pose a heavy burden on national power utilities in developing countries. As mentioned in Section 2, increasing access to electricity in Mozambique to 20% by 2020 will cost approximately US$850 million. Because of the weak financial position of the national power utility EdM this implies a sizeable need for government and donor funds to finance rural electrification—notwithstanding the existence of commercially viable projects. This makes EdM highly dependent on the whims of donors for a very long time. Furthermore, if donor funds for rural electrification come in the form of loans at positive rates, its financial health is further undermined. Therefore, to fully realize the potential of existing commercial opportunities it has been suggested to transform the national power utility into a holding with two legally and financially separated entities: a commercially viable entity and a commercially non-viable component.[7] The present fully integrated structure of EdM makes its performance look artificially bad when measured by conventional financial ratios while "ring-fencing" its commercially viable activities allows EdM to plan and finance their profitable investments (like the one in Ribáuè) independent of donor development priorities, thus enabling them to act as an efficient commercial player on the (regional) power market. Such a construction assures commercial lenders that the government cannot undermine the financial viability of the company by imposing a loss-making rural electrification programme onto it. Donors on the other hand have the advantage that they can grant finance to loss-making electrification projects from a social point of view without major discussions and uncertainties about what rural electrification projects are commercially viable and which ones are not. Our analysis supports the underlying assumption that it should be possible to distinguish between commercially viable and unviable electrification projects, with the first category comprising electricity intensification projects in (sub-) urban areas as well as electrification projects in some rural centres and towns (such as Ribáuè), while the last category will mainly include scattered small rural communities.

The Ribáuè electrification project also made clear that in spite of the arrival of electricity, the development of commercial activity in the district is very much hampered by lack of complementary infrastructure like good roads, telecommunication, water and irrigation networks, banks and credit facilities, etc. (Åkesson and Nhate, 2002, 2006). Electricity alone will not trigger much development and therefore rural electrification programs should not be implemented in isolation but become integrated with investments in complementary infrastructure.

In sum, our evaluation of a typical electrification in Mozambique leads to a list of recommendations, most of which can be summarized as: creating appropriate institutional frameworks and economic incentives. Apart from the peculiarities of the Mozambican context, this conclusion is not new (see, for example, Barnes and Foley, 2004). Effectively, this is a plea for improved performance of the government, who should maximize benefits from mega projects, promote small anchor projects, reorganize and better regulate the national power utility to improve its financial and operational performance, and assure investments in complementary infrastructure. Unfortunately, like in many developing countries, the government in Mozambique is far from being a strong institutional player that can effectively manage and enforce change for the better. 'The' government consists of many institutional entities and individuals, each with their vested interests and dependencies, while government effectiveness is further hindered by low levels of human capital, a patronage-like human resource policy and lack of effective democratic control mechanisms. As a result often a discrepancy exists between official policies and competence at the senior policy level on the one hand and actual behaviour of (lower ranked) officials in executive positions on the other hand. In addition, the government depends to a large extent on the donor community, foreign investors and consultants, which adds another degree of complexity to effective policy formulation and implementation. Hence, recommending improved institutional frameworks and incentives is much more easily said than done, and we think it is here that we have to look for the deeper causes of the generally slow pace of rural electrification in many developing countries.

For example, the negotiations between the various mega projects and the GoM are to be characterized as a multi-party game in a second-best world including uncertainty and asymmetric information, with the different projects (electricity generation and consumption) depending not only on the government but also on each other, foreign capital and export agreements. Under these conditions, it is no surprise that in practice it is very difficult for a highly understaffed Ministry of Energy to define the optimal strategy that maximizes social benefits from mega project investments. In addition, extension of the existing cross-subsidy scheme so as to include mega projects is likely to meet resistance, not only from the mega projects but also from senior government officials and other members of the ruling party who enjoy benefits from these projects. In the recent past, the mega projects have shown to be able to negotiate extremely preferential tax regimes while the government policy in this respect is characterized by lack of transparency.[8] At the same time, promoting relatively small anchor projects in order to sustain commercially viable rural electrification projects requires a considerable improvement of the currently very difficult business environment in Mozambique,[9] a task that obviously goes beyond the realm of the energy sector.

[6] This result is particular due to the combination of large benefits from exploring natural resources and the low level of current electricity prices they pay (1–2.7 US$c/kWh).

[7] We are indebted to Wolfgang Mostert for sharing this idea with us.

[8] For example, it has been estimated that in 2006, the GoM lost over US$100 million in revenues from income tax incentives granted to the Mozal aluminium smelter alone, which is equivalent to circa 10% of the state's total revenue (Kuegler, 2007).

[9] Mozambique ranks 140 out of 175 countries at the 2006 World Bank 'Ease of doing business' ranking, particularly due to red tape (on average 113 days are required to start a business, 364 days to obtain licenses), high costs of import and

As regards the simultaneous investment in rural electrification and complementary infrastructure, this requires an integrated planning practice ideally coordinated by the recently created Ministry of Planning and Development (MPD). However, MPD highly depends on collaboration of the different sector ministries, all of them being no exception to the rule that well-staffed first-class government bodies are scarce in developing countries. On top all different ministries depend to a large extent on a wide range of donor organizations, each with their own priorities, programs, time horizons, bureaucracies and political headquarters back home. In practice, this means little effective long-term policy implementation. It has to be noted that in many other developing countries this situation might be worse, since by international standards Mozambique receives a substantial part of foreign aid in the form of direct budget support and often is regarded as an example of excellent donor coordination and harmonization.

Reorganizing and regulating the national power utility EdM in order to improve its financial and operational performance has proven to be very difficult given strong vested interests, protected by its near-monopoly position on electricity distribution as well as historical close connections with the Ministry of Energy. In such a context it is also typically impossible to buy reform with financial and technical assistance provided by donors. For example, in the 1990s, the World Bank imposed power sector reforms on the GoM, amongst others by the creation of an electricity market regulator (CNELEC). While existing by law, the GoM has so far effectively blocked implementation of this regulator by not providing funds. Moreover, increased accountability as well as improved commercially viable decision making within the national power utility is in practice difficult to realize, not only because of regular political interference but also because of the high willingness to pay among donors for the very visible (rural) electrification projects. This is not to say that no progress is made concerning the performance of EdM. For example, while since the end of the 1990s for many years the number of annual new connections fluctuated around 30,000, since 2006 EdM realizes each year around 70,000 new connections. However, also at this pace it will, given the expected population growth, take decades before over 50% of the population have access to electricity (Mulder, 2007).

Understandably, many have argued in favour of a key role for the market at the expense of government intervention in bringing modern energy to the poor. Without wanting to deny the blessings of the market mechanism, invoking the market to buy out government failures is often a flight rather than a solution for the very reason that well-functioning markets require a sound institutional framework and frequently also active government involvement (for example, to control for monopoly power, which typically comes together with new and small-scale markets as is often the case in developing countries). For example, the GoM is currently actively involved in helping to establish markets for new vehicle fuels like LNG and biodiesel, justified by excessive monopoly power practices and underinvestment, respectively. Concerning electricity, in the spirit of the so-called Washington consensus regarding economic reform, the World Bank in the 1990s tried in vain to sell private concessions for electricity distribution in rural areas in Mozambique: except for one isolated grid-distributing electricity generated from local natural gas, there was no interest from the private sector.

(*footnote continued*)
export, and huge difficulties in enforcing contracts (on average 38 procedures, 1010 days).

In conclusion, our cost–benefit analysis underlines the existence of promising opportunities for rural electrification programs. They are not by definition commercially unviable and can lead to structural transformation in rural areas within a short period of time. Widening the scope and increasing the pace of rural electrification, however, requires in general better institutional arrangements than currently are in place in developing countries like Mozambique. Relatively little is known about the ultimate determinants of institutional quality and this might be especially true for those most actively involved in the energy field: engineers and economists. We consider more attention for and a better understanding of the dynamics of institutions in developing countries an essential component of strategies to increase access to modern energy services for the poor. Institutional quality determines ultimately the effectiveness of available economic and technical solutions, and is therefore a key issue in bringing about change—a general conclusion that is not less true for rural electrification.

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