Productive use of grid electricity in rural Ethiopia

Current status and prospects in two case-study areas

by Gunther Bensch, Carmen Steinmetz, and Hailemariam Teklewold

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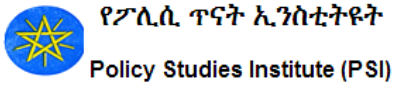
Project partners



Abstract

The agricultural sector is the backbone of large parts of the rural African economy, generating income for a high share of self-employed and employed workers. Ethiopia has ambitious targets to expand the productive use of electricity in agriculture and enjoys favourable conditions through low electricity prices and expanding supply capacities. In this paper, we map current energy use patterns and the scope for additional productive use of electric energy in rural Ethiopia, with an explicit analysis of small-scale irrigation practise and potentials. The analysis relies on quantitative and qualitative data from households, enterprises, and communities in two areas of the country with particular potential for irrigation as identified in previous studies. We find rural productive agricultural energy use to be concentrated in the processing of agricultural products. There is a high willingness among enterprises to modernize their operations, but additional barriers including deficient access to input and output markets limit electricity use also in already electrified areas. The situation is similar for irrigation, which is predominantly fed by diesel motorized pumps so far, and we discuss the prospects and challenges of utilizing grid electricity for irrigation in the given context.

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Introduction

This study explores the scope for the productive use of electric energy from the centralized grid in rural Ethiopia. To do so, this study analyses current energy use patterns in electrified and non-electrified communities and discusses future electricity use potentials. The analysis considers three broad areas of productive use for electricity that are of relevance in this rural setting dominated by smallholder agriculture: non-agricultural use, agricultural use in general and agricultural use for irrigation (see Figure 1). Non-agricultural use concerns private enterprise activities unrelated to agricultural production, such as trade businesses (e.g. selling consumer goods such as local beverages or clothes), service providers (e.g. barber shops or transportation) and manufacturing (e.g. carpentry or welding). Productive electricity use in the agricultural sector includes activities with irrigation and other value-adding activities on agricultural products, such as grain milling, food processing, coffee washing or oil extraction. Electricity can enhance the engagement in productive activities by increasing productivity, by reducing unit costs, or by adding value, both through the creation of new activities or the replacement of traditional forms of energy used for existing activities. The use of electricity for irrigation, for example, can increase the profitability of irrigation by reducing the cost of fetching water, and it can induce more farmers to engage in irrigation, thereby potentially increasing farmers' harvest and revenue through the production of high-value crops and an increased frequency of cropping such as double cropping.

Figure 1: Types of productive use of electric energy

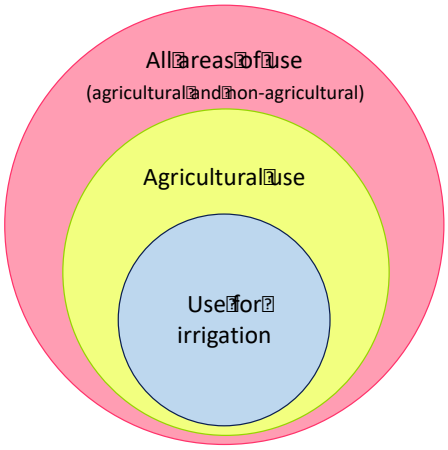


Table 1: Study sample

	Number of respondents
Kebeles	36
Enterprises	244
manufacturing	60
service	105
trade	79
Households	1077
representative sample	771
oversample of irrigating farmers	306
Focus groups	8

Note: Enterprises are often engaged in more than one activity; they are categorized based on the enterprise activity that requires the higher skill level. A more detailed description of the interviewed enterprises can be found in Table A.1 in the Appendix.

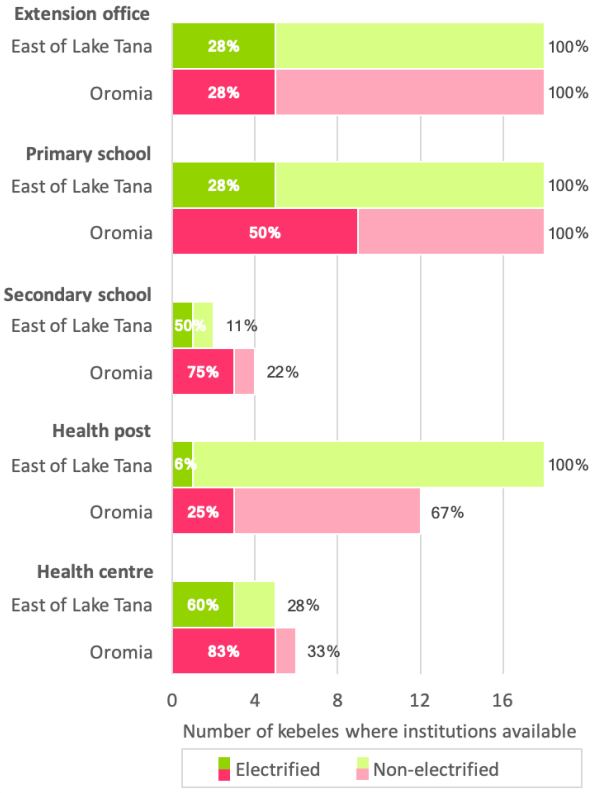
The main basis for the assessments in this report is primary data collected among a range of local actors in April and May 2021. The study is part of a broader research project on electricity demand forecasting in agriculture with a focus on irrigation. For those reasons, as study areas we selected two regions with particular potential for irrigation as identified in previous studies, namely an area east of Lake Tana in the Amhara region and central parts of the Oromia region, each covering around 3.000 km^2. Satellite imagery was used to predict the likelihood of irrigation in these survey areas. Localities were categorized into one of five levels of predicted local irrigation intensity and a total of 36 kebeles – the lowest administrative unit in Ethiopia – were selected in a way that all categories are included in both survey areas. As a consequence, our data is not necessarily population representative for the survey areas, but likely overrepresents localities with more irrigation taking place. Data was collected with representatives of the woreda (district) and the kebele (community), enterprise owners and household heads as well as via Focus Group Discussions (FGD) using structured and semi-structured questionnaires (Table 1). The households surveyed in the kebeles were partly representatively sampled. These households are used to produce statistics that represent the composition of the local communities. Irrigating households were additionally oversampled in order to produce more reliable statistics for this subgroup of households that is of particular interest for this study. Different types of enterprises were interviewed in a more purposive manner. Sampling focused on more energy-reliant enterprises and it was stratified by three enterprise types in order to capture the diversity of existing enterprises. *Trade* is defined as enterprises which sell goods or merchandise that do not involve their transformation, *services* are enterprises which focus on serving the customer directly rather than transforming or just selling physical goods, and *manufacturing* is the production (or maintenance) of merchandise for use or sale using mainly labour and machines or tools. Half of the eight FGDs took place in electrified communities, the other half in non-electrified communities, each of them with ten

agricultural producers who are part of the farming community in their kebele and have experience in the use of irrigation in agricultural production.

Current level of electricity access

A brief depiction of the electricity access situation at community level provides some background for the subsequent productive use analysis. Communities refer to kebeles in the Ethiopian context, which have on average around 1200 households in the sample. Kebeles in the survey area east of Lake Tana are slightly less populated as compared to those in the Oromia region, while there is no substantive difference in population sizes between electrified and non-electrified kebeles. Figure 2 depicts basic infrastructure in the sampled kebeles: extension offices and primary schools are available in all kebeles and health posts provide basic health services in most of them. Few kebeles in the sample also have secondary schools or better equipped health centres. District offices and hospitals are not available in any of the kebeles and are therefore not shown in the figure. The figure also shows grid connection rates of these institutions. These rates primarily depend on the availability of and proximity to the grid of the state-owned Ethiopian Electric Power (EEP) utility. In addition, the more basic institutions with typically lower energy requirements have lower connection rates: this is the case for extension offices, primary schools, and health posts. The more specialized institutions that require electricity to be able to provide more advanced public services such as secondary schools and health centres are connected in more than half of the kebeles where they are available.

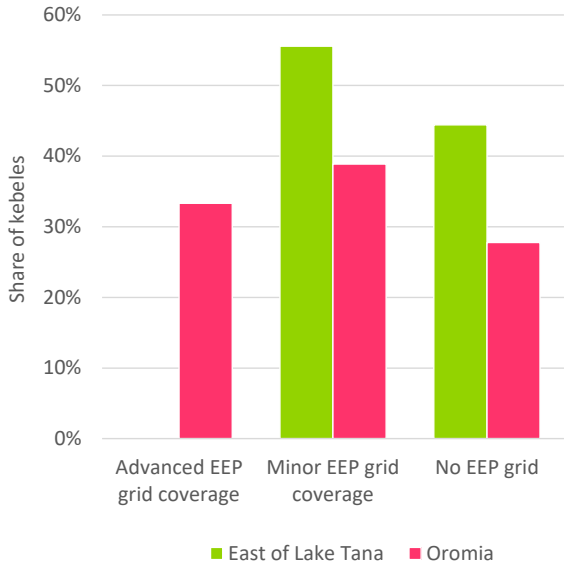
Figure 2: Availability of public institutions and their grid connection status (by survey area)

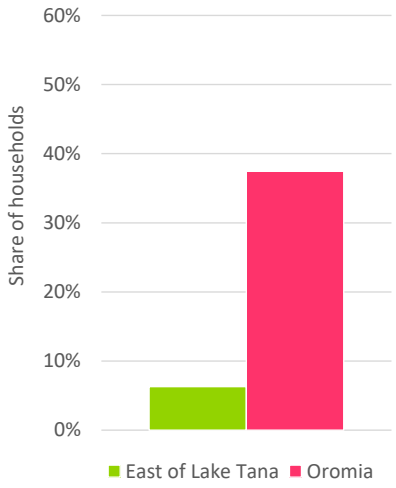


The regional differences in connection rates among institutions most likely originate from the stark regional differences in grid coverage. This can be taken from Figure 3 and Figure 4. Figure 3 divides the electrification status of kebeles into three categories according to the share of grid-connected households: advanced EEP grid coverage, minor EEP grid coverage and no EEP grid. A kebele belongs to the category of minor grid coverage when less than 25 percent of households are connected to the EEP grid, either directly or via a neighbour. Kebeles with a larger share of households connected to the grid belong to the category of advanced EEP grid coverage.

Figure 3: Grid electrification of kebeles (by survey area)

Figure 4: Household connection rates (by survey area)





Advanced EEP grid coverage is only found among kebeles in Oromia region (33 percent), whereas both regions see some level of minor grid coverage. These regional differences in grid coverage of kebeles also translate into lower connection rates among the sample households (Table 2). 37 percent of households in the Oromia sub-sample have access to the EEP grid, whereas the share of connected households in the east of Lake Tana sub-sample remains low at 7 percent.

Table 2 shows that households in kebeles with minor or no grid coverage have higher access rates to off-grid electricity sources such as individual solar panels. The typically smaller-sized plug-and-play solar kits with customized appliances such as radios and TV are named as an electricity source by 62 percent of households in kebeles with no EEP grid connection. Car batteries and individual generator sets have rarely been mentioned throughout all kebeles.

Table 2: Electricity sources among households (by level of community electrification)

Source of electricity	Share of households in percent			
	kebeles with advanced EEP grid coverage	kebeles with minor EEP grid coverage	kebeles with no EEP grid	total sample
Direct EEP grid connection	56	9	0	14
Grid connection via neighbour	30	11	0	11
Car battery	0.8	0	0	0.1
Individual generator set	0	0.5	0.4	0.4
Individual solar panel	4	40	42	35
Solar kit	11	43	62	44

Note: Shares in the individual columns add up to over 100 percent because a few households own multiple sources of electricity.

Current productive use of electric energy

Non-agricultural productive use of electric energy

This section depicts the current status of the non-agricultural use of electricity in the study areas. Table 3 presents the kebele representatives' estimated numbers of enterprises per kebele for some of the main non-agricultural enterprise types. Distinguishing kebeles by their connection to the EEP grid, the table shows that the average number of bars/restaurants, passenger and freight transportations in our study areas are higher in kebeles with grid connection as compared to those without connection to the grid. While such correlations do not necessarily imply a causal association between enterprise creation and electricity access, further analyses show that the number of enterprises does not correlate with population size. Despite the notable size of the kebeles, wood-works and welders/garages as main enterprise types in the manufacturing category are relatively rare in both categories of kebeles. Barbers are another enterprise type more commonly encountered in the visited kebeles.

Table 3: Non-agricultural enterprises and their grid connection status

		Average number of enterprises per kebele		Grid connection rate (electrified kebeles only)
		Electrified kebeles	Non-electrified kebeles	%
Trade	shops selling drinks	N/A	N/A	92
	small kiosks	N/A	N/A	37
	consumer goods shops	N/A	N/A	64
Service	bar/restaurant	7.2	4.4	Bars: 77 ; Restaurants: 93
	barbers	N/A	N/A	95
	battery-charging station	N/A	N/A	100
	passenger transportation	5.2	1.5	N/A
	freight transportation	3.2	2.3	N/A
Manufacturing	wood-work	0.0	0.2	100
	welders/ garage	0.1	0.0	100
Number of observations		**23 kebeles**	**13 kebeles**	**149 enterprises**

Note: N/A means that information is not available.

The last column of Table 3 provides additional information from interviews with local non-agricultural enterprises. The grid connection rate of main enterprise types in electrified kebeles ranges between 37 percent among small kiosks and 100 percent among battery-charging stations, wood-works and welders. Generally, trade businesses have the lowest level of grid connection, whereas the connection rates of service providers and manufacturers are higher. The higher EEP grid coverage in Oromia is also reflected in the connection rate of non-agricultural enterprises. While 90 percent of the sampled enterprises in Oromia are grid-connected, only about 70 percent of the enterprises sampled east of Lake Tana are found to have access to the EEP grid.

Looking at individual enterprise types, the connection rate of shops selling drinks is found to be higher than that of other trade enterprises like small kiosks or mixed consumer goods shops. This is due to the need for refrigerators in order to cool beverages to respond to the customers' demand for cold soft drinks, beer or water. Other trade services not listed in the table include three clothes shops, two phone shops, two grain retailers and one unspecified trade business. In the category of service providers, battery-charging stations only exist in electrified kebeles and all four of them are connected to the EEP grid. Barber shops were more often interviewed in electrified kebeles (20 out of 22 barber shops are located in electrified kebeles) where 95 percent of them have a connection to the EEP grid. The same holds true for restaurants, as 14 out of 16 restaurants in the sample are located in electrified kebeles. This may have to do with the fact that these business types are more likely to settle in agglomerations that are more likely to be reached directly by the EEP grid. This is less strongly the case for bars, which are the most common enterprise type in the sample (see Appendix Table A.1). They are more equally distributed between electrified (24) and non-electrified kebeles (30) in the sample, and have a lower grid connection rate in electrified kebeles than other service providing businesses. The category of other services consists of three pharmacies/dispensaries, one photo studio, one laundry service, one bath service and one secretarial service company. Small-scale manufacturing enterprises are concentrated in electrified kebeles and generally seem to have a high grid connection rate. The group of other manufacturing enterprises consists of two tailors, two maintenance shops and a tire repair service of which only one tailor is not connected to the EEP grid.

Table 4 reproduces Table 2 on the availability of on- and off-grid electricity sources among households, now for enterprises. Enterprises in kebeles with advanced EEP grid electrification are all connected to the grid – either directly or, as in the case of one enterprise, via a neighbour. In kebeles with minor EEP grid coverage only 50 percent of the sampled enterprises have a direct and 27 percent have an indirect connection to the grid. In line with the household-level findings, the use of solar panels is more common in kebeles with minor or no EEP grid coverage. Solar energy is almost exclusively used by trade and service enterprises with the exception of one manufacturing enterprise, namely a wood-worker. The use of generators is more prominent among enterprises as compared to private households, but still remains rare. Enterprises using generators consist of two barber shops, a shop selling drinks, a bar, a restaurant, a battery-charging station, a secretarial service and a welder/garage. In the sample of non-agricultural enterprises, 62 percent thus use on-grid electricity sources, while 40 percent revert to off-grid electricity sources and 11 percent operate without the use of electricity.

Table 4: Electricity sources among non-agricultural enterprises (by level of community electrification and enterprise type)

	Share of enterprises in percent					
	Advanced EEP grid coverage	Minor EEP grid coverage	No EEP grid	Trade	Service	Manu-facturing
Direct EEP grid connection	97	50	0	49	39	83
Grid connection via neighbour	3	27	0	8	25	8
Individual generator set	6	5	0	1	6	8
Individual solar panel	10	10	13	20	5	0
Solar kit	6	15	67	32	24	0
Number of observations	**31**	**118**	**45**	**79**	**103**	**12**

Note: Shares in the individual columns add up to over 100 percent because a few enterprises own multiple sources of electricity.

The main purpose of electricity among non-agricultural enterprises is electric light. Having light allows enterprises to operate at night and therefore potentially facilitates the operations of almost any kind of business. The share of enterprises using electric light exceeds 85 percent for all three sectors, even reaching 100 percent for the manufacturing sector. The use of TVs and fridges, and to a lesser extent of radios/ audio systems, is more common in kebeles with advanced EEP grid connection and only rarely used in kebeles with no EEP grid connection.

Other electrical appliances and machinery are named as a purpose of electricity use by 30 percent of all sampled enterprises. Their use is relatively high in kebeles connected to the EEP grid, but rare in non-electrified kebeles. All three enterprise sectors make use of electrical appliances, but they are most frequently used by the manufacturing sector (82%), followed by the service sector (33%) and the trade sector (21%). Appliances used at low levels (below 10 %) across the three sectors are fans, inverters, laptops/computers and office equipment like scanners, printers and photocopiers. Enterprises in the service sector most frequently mentioned hair clippers as other electrical appliances. Two more specialized service enterprises use a washing machine and laboratory examination equipment, respectively. Manufacturing enterprises most frequently use electric tools, such as cutters, grinder and compressors.

Table 5: Purpose of electricity use of non-agricultural enterprises using any electricity source (by level of community electrification and enterprise type)

	Share of enterprises in percent					
	Advanced EEP grid coverage	Minor EEP grid coverage	No EEP grid	Trade	Service	Manu-facturing
Electric light	100	92	57	86	85	100
TV	52	26	3	25	26	27
Fridge	35	20	0	15	22	9
Radio/ audio system	16	11	0	7	12	9
Other electrical appliances & machinery	42	36	6	21	33	82
Number of observations	**31**	**107**	**35**	**71**	**91**	**11**

Agricultural use of electric energy

Main, and basically sole, agricultural businesses in the sampled kebeles are mills, as indicated by community representatives (Table 6). The availability of electricity seems quite effective in triggering the move from diesel-run grain mills to electric grain mills: with 84 percent, electricity-run grain mills are much more common than diesel-run grain mills in electrified kebeles. All other, non-connected mills are run off-grid with diesel, since other off-grid electricity sources are either not powerful enough or, as in the case of standalone solar-powered mills, have not yet made inroads to the study area. None of the interviewed representatives reported vegetable oil extractors to be present in their kebele. Other agricultural businesses encountered during the enterprise survey include two bakeries, both of which are located in electrified kebeles with one having access to electricity from the

EEP grid and the other not. Furthermore, three other processing businesses were interviewed; two of them in electrified kebeles and one in a non-electrified kebele, the latter without any electricity source.

Table 6: Agricultural businesses and their electricity access

	Average number of enterprises per kebele		Grid connection rate (electrified kebeles only) %	Share of non-connected enterprises with off-grid electricity source %
	Electrified kebeles	Non-electrified kebeles		
Diesel-run grain mill	0.8	1.9	84	100
Electricity-run grain mill	2.3	0.0		
Vegetable oil extractor	0.0	0.0	N/A	N/A
Bakery	N/A	N/A	50	0
Other processing enterprise	N/A	N/A	50	100
Number of observations	**23 kebeles**	**13 kebeles**	**36 enterprises**	**21 enterprises**

Note: N/A means that information is not available.

Transformation and processing of agricultural products as key agricultural productive use of electricity also plays an important role at household level. In the representative sample of agricultural households, 79 percent stated to process at least some of their agricultural products before consuming or selling them in ways described in Table 7, which only exclude the different forms of cooking. Processing is not more common in electrified than in non-electrified kebeles. This has to do with the fact that much processing is done with motorized appliances and mostly outside of the home. 82 percent of processing households use motorized or electric appliances and 74 percent transform agricultural products manually, while only one percent use animal labour (e.g. for threshing). Table 7 also indicates that processing households in electrified kebeles rely less on alternative means of transformation other than electricity. Here, electric appliances might replace several work steps in the process, while in non-electrified kebeles the electricity from off-grid sources might be insufficient or less available. This obviously depends as well on the output of the transformation process: main outputs are flour and deshelled or dehulled grains with 81 and 73 percent of processing households reporting to produce them, respectively. 36 percent of the processing households sells or consumes hulled products, while 27 percent produce beverages. Only few households report to produce oil from agricultural products.

Table 7: Domestic processing of agricultural products (by community electrification)

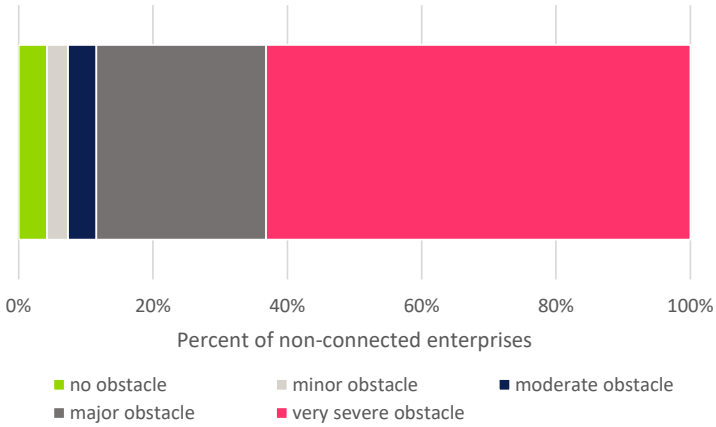
	Electrified kebeles %	Non-electrified kebeles %	Total sample %
Share of processing households	74	88	**79**
Number of households	**371**	**199**	**570**
Means of transformation (among processing households)			
motorized or electric appliance	82	83	**82**
manually	74	75	**74**
animal labour	0.4	3	**1**
Output (among processing households)			
flour	82	80	**81**
deshelled grain	71	77	**73**
hulled product	35	38	**36**
beverage	23	34	**27**
oil	0.4	0	**0.2**
Number of processing households	**273**	**176**	**449**

There are only minor differences in outputs between electrified and non-electrified kebeles. Main processing inputs are maize, teff, wheat, millet and chickpeas (see Table A.2). Between 61 to 79 percent of farmers that

produce these crops also process them. Table A.2 further suggests that none of the crops that are transformed are considered a traditional cash crop, but can be classified as food crops. About half the processing households (53 percent) state that they have sold transformed goods in the past 12 months, whereas the remaining 47 percent process agricultural products merely for household consumption.

Both agricultural and non-agricultural enterprises without grid connection further indicated that the lack of electricity poses severe obstacles to their business operations (Figure 5). For 63 percent of respondents, the lack of electricity is even a very severe obstacle and only 11 percent of the sample consider the lack of electricity as no obstacle, a minor obstacle or a moderate obstacle.

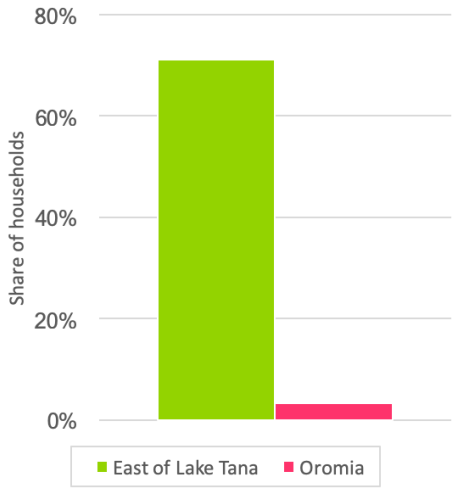
Figure 5: Lack of electricity as an obstacle to business operation in the perception of non-connected enterprises



Agricultural use of electricity in irrigation

The present study covered two areas with very distinct irrigation patterns. While 71 percent of all agricultural households from east of Lake Tana engage in irrigation, the equivalent is only 3 percent in the Oromia region (Figure 6). We define irrigating households as households who were irrigating at least part of their fields in the agricultural season, called belg season in Ethiopia, which roughly covers the period from January to May.

Figure 6: Households in representative sample engaging in irrigation (by study area)



The availability and accessibility of water is an essential component to engage in irrigation. As can be taken from Table 8, the most common source of water is surface water, which is more readily available east of Lake Tana compared to the Oromia sub-sample, mainly coming from rivers or streams or alternatively from canals, lakes or ponds. Dams are not in use in either of the study areas. In the Oromia region, ground water is instead more common (27 compared to 14 percent in the east of Lake Tana region), and here boreholes are required. Rain water and piped water as alternatives to surface or ground water sources are rarely used and can only be found among households in Oromia region.

Table 8: Water sources used by irrigating farmers (by study area)

	East of Lake Tana %	Oromia %	Total sample %
Surface water	86	69	**82**
river/stream	87	62	**82**
canal	8	27	**11**
lake/ pond	11	30	**15**
dam	0	0	**0**
Ground water	14	27	**17**
drilled well	11	11	**11**

hand-dug well	75	8	50
borehole	13	81	39
Rain water	0	5	2
Piped water	0	1	1
Other	0	4	1
Number of observations	434	135	569

Note: Shares may add up to over 100 percent because some farmers rely on multiple water sources for irrigation.

The transportation of water from the source to the field to be irrigated provides scope for the use of electricity. Only very few irrigating households in the sample use grid-electricity motorized water pumps and none of the farmers in the FGDs utilize grid electricity for irrigation. Only one district official reported that there is a large commercial farm using grid-electricity to irrigate 75 hectares of land. Instead, the most common practices of irrigation are river diversion using gravity and the use of diesel pumps (Table 9). Ten percent of all irrigating households water their fields manually using a bucket, hose or watering can. Which method is used to access water largely depends on the location of irrigated fields since the availability of water, the distance to the water source, the distance to an electricity grid access point, and the given topographical circumstances of the farm heavily influences its choice. The exploitation of gravity is susceptible to shortcomings from low water levels in streams or rivers, especially during the dry season. The FDGs actually revealed that not only switching costs from diesel to grid-electricity motorized pumps hindered farmers to adopt electricity for irrigation, but primarily the unavailability of grid electricity at their fields. Agricultural fields in the survey areas use to be located away from the agglomerations with farmers' houses in areas not covered by the electricity grid. Diesel pumps have the additional advantage of a higher portability. Nevertheless, farmers seem to be open to switch to grid-electricity motorized pumps given the high per unit cost of diesel in addition to challenges in accessing fuel in nearby markets.

Table 10 shows that the ownership of the utilized pumps largely differs in the two study areas. In the East of Lake Tana sub-sample, a majority of 62 percent of households own diesel pumps whereas 30 percent rent the pumps they use. One reason for this difference is that farmers in the East of Lake Tana region have a higher individual demand for water pumping as they irrigate more plots with larger average plot sizes. From the FGDs it furthermore becomes clear that households in this study area preferred owning the pumps as they had experienced complications related to pump renting in the past. In Oromia region, only 29 percent of diesel pump users also own them; 44 percent of households rent the pumps from private firms while 26 percent are borrowed from farmer associations. According to qualitative data from the FDGs, some farmers were supported by local governments in Oromia region to acquire diesel-motorized pumps on credit. Other ways to have access to diesel pumps include borrowing the pump from friends or family, sharing the ownership with other individuals and being provided a pump by the land owner. Farmers often complained during the FGDs that credits tailored to the investment in productive agricultural machinery is often not available or too small in size.

Table 9: Methods to obtain water for irrigation

	Total sample %
Diesel motorized water pump	77
Mechanical pump	0.4
Tractor motorized pump	0.4
Solar motorized pump	0.4
Grid-electricity motorized pump	0.2
Gravity	66
Bucket/hose/watering can	10
Number of observations	570

Table 10: Ownership of diesel motorized pumps used by irrigating households

	East of Lake Tana %	Oromia %
Owned by this household	62	29
Rented	30	44
Owned by farmer association	4	26
Other	4	1
Number of observations	363	85

Note: Shares on the methods to obtain water add up to over 100 percent because some farmers rely on multiple methods.

Lastly, irrigating households were asked whether the lack of water and electricity poses a problem for irrigation. The results in Figure 7 suggest that the lack of electricity is more frequently viewed as an obstacle to irrigation as

compared to the lack of water. Half of the irrigating households do not perceive the lack of water as a problem for irrigation, 29 percent see it as a minor problem while only 21 percent view it as a severe problem. The answers were more ambiguous for the lack of electricity; whereas 46 percent of irrigating households state that the lack of electricity is a severe problem, 54 percent view it as a minor problem or no problem at all. While these figures reflect obstacles for irrigation among irrigating farmers that have some kind of access to water, they do not capture the perception of households for which the lack of water might be a restricting factor to engage in irrigation in the first place. The lack of water seems to be more often perceived as problem by irrigating farmers from east of Lake Tana as compared to those in Oromia, whereas the lack of electricity more often perceived as a severe problem in the Oromia region (see Figure A.1 in the Appendix). Looking at differences between on-grid, off-grid and no energy users, it is found that 80 percent of on-grid electricity users and 78 percent of off-grid users see a problem in the lack of electricity for irrigation. Interestingly, only 61 percent of irrigating households that do not use any electricity see it as a problematic factor for the engagement in irrigation (see again the figure in the Appendix). This may be explained by the greater salience of lack of electricity at the households' fields in already electrified communities, where households benefit from electricity in their homes.

Potential use of electric energy in rural Ethiopia

About 40 percent of enterprises and 75 percent of representative households in the study sample remain without connection to the electricity grid. Given the current extension of the electricity grid, 83 percent of these enterprises and 95 percent of these household are either located in non-electrified kebeles or located more than 50 meters away from the next electricity grid pole and thus not sufficiently close to the existing grid (Figure 8). For them, acquiring a grid connection remains a problem of the availability of infrastructure, not of a lack of interest or individual affordability. This is especially an issue for households, who are more dispersed and are therefore more often located in communities that are touched by the electricity grid, but where low-voltage are still too far away to get connected. Out of the 13 non-electrified kebeles in our sample, only five community representatives reported to be aware of plans to connect their community to the EEP electricity grid.

Figure 8 also shows that among the few non-connected that are located in electrified kebeles and close enough to a grid pole, most businesses and all households are interested in acquiring a connection to the grid; only a handful of them perceive the grid connection as too expensive. Additional to the findings of this figure, it is found that 36 percent of enterprises and 42 percent of households interested to be connected have already applied for a grid connection with EEP.

Figure 7: Is the lack of water and electricity a problem for irrigation?

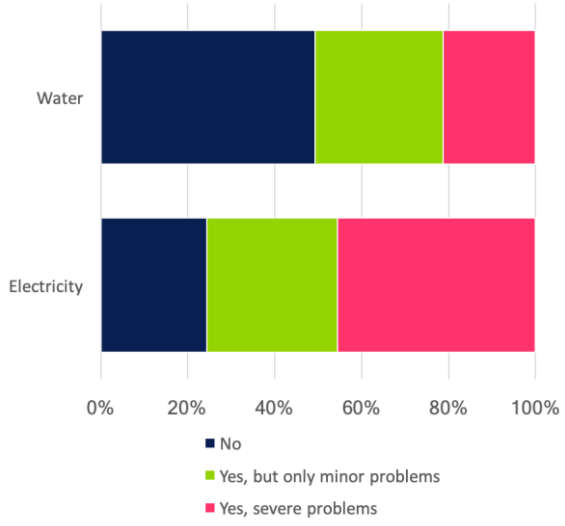
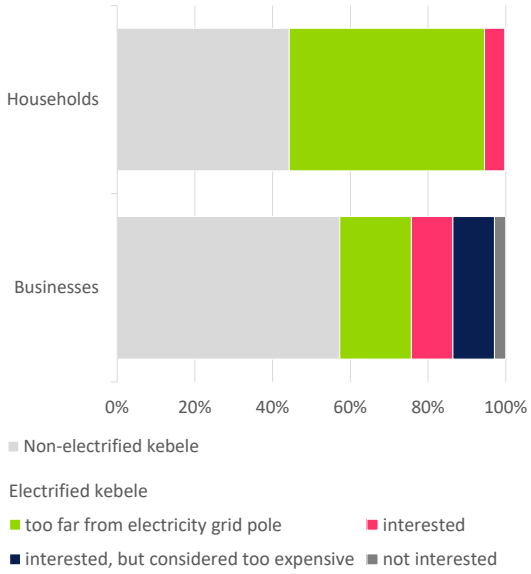


Figure 8: Availability and interest in grid connection among the non-connected



The descriptive statistics in Figure 5 above showed that a large share of 63 percent of all non-connected enterprises perceive the lack of electricity as a very severe obstacle to their business activities. There are two ways in which a connection to an electric energy grid could open up the potential for productive use of electricity in order foster economic growth. On the one hand, existing business activities could be improved or specialized

while, on the other hand, the connection to the EEP grid potentially also encourages the establishment of new businesses that are more energy-intensive. Four related impact channels can be identified through which micro-enterprises could benefit from grid electricity access, namely by saving cost from substitution of energy sources, by extending operations (e.g. operating hours after dark), by acquiring electric appliances and machinery to improve the productivity of business activities and lastly by taking advantage of potentially newly generated demand in the study area. This demand could either be demand within the communities induced by the availability of electricity and its effects on expenditures and productivity, or it could be additional demand from outside the community attracted by new, better or cheaper services.

General conditions for electricity usage in Ethiopia are fairly favourable: with US$0.007 per kWh, consumers enjoy one the lowest electricity price in the world (Global Petrol Prices 2021). Supply capacities are drastically expanded, from 4.2 GW in 2016 to a forecasted total installed generation capacity of 10.4 GW in 2022 (US&FCS and US DoS 2020).

Non-agricultural sector

Enterprises interested in acquiring a connection to the EEP electricity grid were asked in open-ended questions whether they would consider changes in their business activities and how they would change them if they were connected to the grid. The data shows that a large share of 83 percent of non-agricultural enterprises without grid electricity access would consider changes in their business activities if they were connected to the EEP grid. The changes they would consider fall into two broad categories, namely improving current activities and exploring new business activities. Many enterprises (66 percent) consider acquiring a fridge and selling soft drinks or alcoholic beverages. Other operations mentioned by at least 5 percent of these enterprises are baking and mobile-phone battery charging, each by about 6 percent. Similarly, about 6 percent explicitly mentioned that being connected to the electricity grid would allow them to work at night. In terms of enterprise type, 65 percent of these electricity usage ideas fall into the trade category, 29 percent into the service category, and another 6 percent into the manufacturing category. The consideration to engage in manufacturing activities include activities like milling, wood work, tailoring and mobile maintenance.

In line with these expectations, an impact report of electrification in rural Tanzania found a positive and statistically significant impact on the number of saw mills and welders in treatment villages two years after their electrification (Bensch et. al, 2019). These results suggest that especially new businesses activities with high energy demand could be created as a result of electrification. The interviews conducted alongside the quantitative analysis further suggested that entrepreneurs shifted their operating hours towards the night as a consequence to the availability of electric light, reporting that they could engage in other productive activities during the day and that they were able to attract additional customers at night. Nevertheless, the report also concludes that a general lack of customers (e.g. from outside the village) and financial constraints of entrepreneurs to buy more expensive electric appliances may restrict the growth of small rural enterprises to a certain extent.

Agricultural sector

Agricultural enterprises as well as farming households can benefit from grid electricity access by modernizing their existing processing operations, which often currently rely on manual power or fossil fuels, and by further adding value to their agricultural produce. Grain milling, which are already the most common type of processing among agricultural enterprises as well as farming households, can generate both of these benefits of grid electricity. The descriptive statistics in previous sections of this report have shown that the average number of electricity-run grain mills is clearly higher than the number of diesel-run grain mills in electrified kebeles. Accordingly, the majority of 12 out of 14 sampled grain mills in non-electrified kebeles would consider acquiring an electric mill if they were connected to the grid. Financial constraints to purchase electric equipment represents a barrier to modernization once a grid connection has taken place. Furthermore, the absence of product descriptions in local language might prevent the purchase of efficient electric appliances (Eludoyin et al., 2021).

Besides flour, farming households also commonly engage in the deshelling of grains, implying that currently processing activities are mainly focused on primary processing. Even if a large share of 79 percent of households claims to transform products, only slightly more than half of those processing household are found to market these transformed goods. The other half solely transforms outputs for their own consumption. These findings suggest that processing other than grain milling is not widely done and that there is scope to capture additional value on the market. Officials from two districts located east of Lake Tana report to have observed that people in their communities have started using processing machines for de-husking and polishing rice as a result of electrification. Santana et al. (2021) further show that electrification in rural Ethiopia brings about medium- and long-term scope to engage in other forms of grain processing, such as mechanical threshing, cleaning, hulling and

drying of maize, wheat, teff and barley. These findings suggest that the primary processing activities could be diversified and expanded when electrification takes place.

Borgstein et. al. (2020), another report by the Rocky Mountain Institute (RMI), proposes that agricultural actors could also engage in secondary processing for commercial purposes. The report illustrates this concept with the example of wheat processing, where the processing into flour is referred to as primary processing, while the production of flour into bread is considered the secondary processing. They show that the scale-up of bread baking from domestic consumption to commercial purposes can allow farming households to capture an additional value of US$0.57 per kg of flour. In our study area only two bakeries were sampled from the total of 244 interviewed enterprises, suggesting that bread baking was not commonly commercialized to the date of the data collection. However, four non-electrified non-agricultural enterprises mentioned during the interviews that they would like to engage in bread/injera baking if they were connected to the EEP grid, implying that electrification could potentially promote the engagement in this type of secondary processing. Even if local rural communities produce teff that is used in the production of injera, farming households often sell this more expensive grain and consume less pricey alternatives such as maize. This means that local demand for injera could currently be low and the scope for the expansion of injera baking might be limited (Santana et al., 2021). Other productive use of electricity in rural Ethiopia could arise from cooling facilities for milk, butter making, beer brewing and coffee washing (Borgstein et. al, 2020; Santana et al., 2021).

Another way to make productive use of electrification in the agricultural sector could be an upscaling of irrigation. It was found that there is large scope to spread the use of irrigation among farming households as only 34 percent of the households in the representative sample engage in irrigation. The practice of irrigation could improve crop yields, increase the number of harvest seasons within a year and allow the production of high-value crops such as vegetables like head cabbage, tomatoes, red pepper, onions and garlic as well as fruits like avocados, bananas and mangoes (Borgstein et al., 2020). The observations of officials from all six districts confirmed the expectations regarding the possibility to have multiple harvest seasons per year, reporting that irrigating farmers can benefit from up to three harvesting seasons, whereas rainfed farming often restricted the number of harvests to one per year.

The water scarcity during dry seasons might represent one of the largest obstacles to the take-up of irrigation. Regional differences among the kebeles surfaced during the FGDs. Whereas three farmer groups in Oromia do not perceive the lack of water as a problem at all, the fourth kebele in Oromia has implemented a water committee to efficiently manage water resources in the dry season. All four farmer groups interviewed in the east of Lake Tana area further highlight the problem of water scarcity. The farmer group in one kebele reports that upstream farmers overuse the water from the river during dry season, while a group from another kebele claims that farming households do not respect the minimum distance between wells required to ensure the availability of water. In a third kebele, farmers argue that an irrigation project, the Ereb river project in Abua ena Kokit, disturbs their irrigation practice. Several district officials further report that irrigation schemes (e.g. building canals or constructing ponds to collect rain water) have been undertaken in the past. However, some representatives point out that irrigation systems are often old and require maintenance, but that the communities' budgets do not allow for renovation.

Some district officials state that NGOs and other organizations came to villages to demonstrate the use of solar motorized water pumps and collected survey data, but either the take-up was limited or the organizations did not return to provide farmer with access to this technology. Generally, the use of solar power for irrigation is not yet widely spread nor widely known among irrigating farmers. Farming households therefore seem to widely rely on diesel motorized pumps. In few cases, pumps were reported to be provided by NGOs, subsidized or offered on credit by local and regional governments. The lack of access to fuel on local markets as well as high per unit fuel cost impede the optimal use of diesel pumps for irrigation. Many farming households do not own the equipment themselves resulting in additional rental fees. District representatives claim that there is a lack of supply of motorized water pumps in local communities and that prices fluctuate strongly if there are retailers present in the market.

The general impressions gleaned from our field survey work activities, including more explicit statements made during the FGDs, confirmed some stylized facts about the local agricultural marketing conditions, in that access to input and output markets is limited through the lack of transportation infrastructure. On the one hand, the complete absence of local input suppliers or their monopolistic position does not allow farmers to acquire the inputs they need to improve their production at an affordable price. On the other hand, farming households only have limited access to output markets and might not be able to capture adequate prices for their products. Especially brokers, that act as intermediaries between producers and buyers, seem to interfere in local markets, offering low quality inputs at high prices and offering low prices for agricultural produce. To improve market

access of farming households and thus enable them to invest in irrigation equipment, the government needs to ensure that road infrastructure is available and reliable in remote kebeles as the access to markets needs to be guaranteed all through the year, especially during the rainy season. The investment into modern irrigation systems is further discouraged by financial constraints and the uncertainty about water supply as well as land ownership. In the FGDs, it was found that the access to credit institutions largely differs between kebeles and that a large share of farming communities needs to self-finance their irrigation activities. Those farmers that had access to financial services suggested that the loans were not tailored to their needs as the loan size is usually insufficient, the interest rates are high, the waiting periods for loans are long and the repayment requirements are not in line with farm schedules.

In theory, the household electrification could allow farming households to use the electric energy for water pumps, thereby decreasing their per unit energy cost and increasing their profit margin. District officials however remark that even if farming households are connected to the EEP grid, the grid does not reach the fields that are to be irrigated. For that reason, they claim that the electricity grid is not designed to use it for irrigation and that there is no coordination between the agricultural sector and the electricity authority. The extension of the EEP electricity grid in residential areas of rural Ethiopia will thus not necessarily allow for the productive use of electric energy on agricultural fields. The planning of the electricity grid therefore needs to take into consideration the electrification of areas outside the villages to give farmers the opportunity to make productive use of their electrification by using modern technology for irrigation.

Conclusion

Almost all non-connected enterprises in our rural Ethiopian sample consider the lack of electricity as a severe or very severe obstacle to their business operations. Electrification has the potential to foster economic growth through cost reduction from the replacement of diesel-run appliances, by improving the productivity of existing production and by exploring new business opportunities. In the non-agricultural sector, the connection to the EEP grid could allow enterprises to extend existing business activities and to establish new businesses that are more energy-intensive, such as charging batteries, offering barber services and several manufacturing activities. Irrigation can increase the productivity of agricultural production and agricultural processors can modernize their operations by replacing manual and diesel-fuelled machines by electric appliances. These potentials are particularly pronounced in Ethiopia where electricity prices are low and expanding supply capacities that lead to higher levels of grid reliability.

This report shows that despite the presence of solar power in enterprises where grid connection is low or unavailable, grid connections seem to be critical to ensure introduction of higher-power appliances. At the same time, the key agricultural service, milling, is similarly available in electrified and non-electrified communities thanks to off-grid diesel mills and households relying on manual milling. There seems to be a high willingness among sampled grain millers to replace diesel generators by grid electricity with lower per-unit costs, and also non-agricultural businesses would consider changing to electric appliances once connected to the EEP grid, most of them seeing opportunities in selling cold beverages. According to farmers in the study regions, water scarcity currently seems to the larger obstacle to irrigation in comparison to the lack of electricity, along with high per unit fuel cost of diesel motorized water pumping. Even if 22 percent of farming households in the representative sample have access to the EEP electricity grid, it was found that on-grid electric energy is not used for water pumping in the study area. The main reason for this absence of grid-electricity motorized pumps is that the electrification of communities is mostly concentrated in residential areas and does not reach areas where agricultural fields are located. The high portability of diesel pumps makes these pumps the technology of choice among farmers in our sample regions and beyond.

Existing research supports the overall picture emerging from this study of mixed evidence on the opportunities of productive use from grid electrification in rural areas, especially in the agricultural sector. Electricity access is an important barrier to rural development to be addressed by policy, but governments need to consider two important constraints: first, rural grid coverage would need to be expanded considerably in order to increase the use of electric energy for irrigation, which is often seen as one important additional agricultural productive use. Decentralized solutions such as solar-powered pumps may often prove to be a more cost-effective and flexible solution and the relative cost-efficiency of grid expansion vis-à-vis off-grid options for irrigation need to be studied further. Here, the daily and seasonal electric load shapes of irrigation must also be considered. Second, rural development typically faces a myriad of barriers that call for more integrated rural development strategies, which also address the lack of access to input and output markets, the improvement of farming practices and households lack access to financial services to invest into expensive inputs.

Appendix

Table A.1: Type of interviewed businesses

	East of Lake Tana	Oromia	Total Sample
Trade business			
shop selling drinks (and more)	2 (+6)	15 (+3)	**17 (+9)**
small kiosk (and more)	16 (+4)	10	**26 (+4)**
mixed consumer goods shop	5	10	**15**
other trade business (incl. 3 clothes shops, 2 phone shops, 2 grain retailers & 1 unspecified trade business)	0	8	**8**
Service			
bar (and more)	46 (+3)	5	**51 (+3)**
restaurant (and more)	2 (+5)	6 (+3)	**8 (+8)**
barber (and more)	12 (+1)	9	**21 (+1)**
battery charging (and more)	0 (+1)	1 (+2)	**1 (+3)**
bakery	1	1	**2**
other services (incl. 3 pharmacies/dispensaries, 1 photo studio, 1 secretarial service, 1 laundry service, 1 bath service)	1	6	**7**
Manufacturing			
carpentry	0	3	**3**
welding/ garage	2	2	**4**
mill	35	10	**45**
processing (and more)	1 (+2)	0	**1 (+2)**
other manufacturing (incl. 2 tailors, 2 repair/maintenance and 1 tire repair)	1	4	**5**
Number of observations	**146**	**98**	**244**

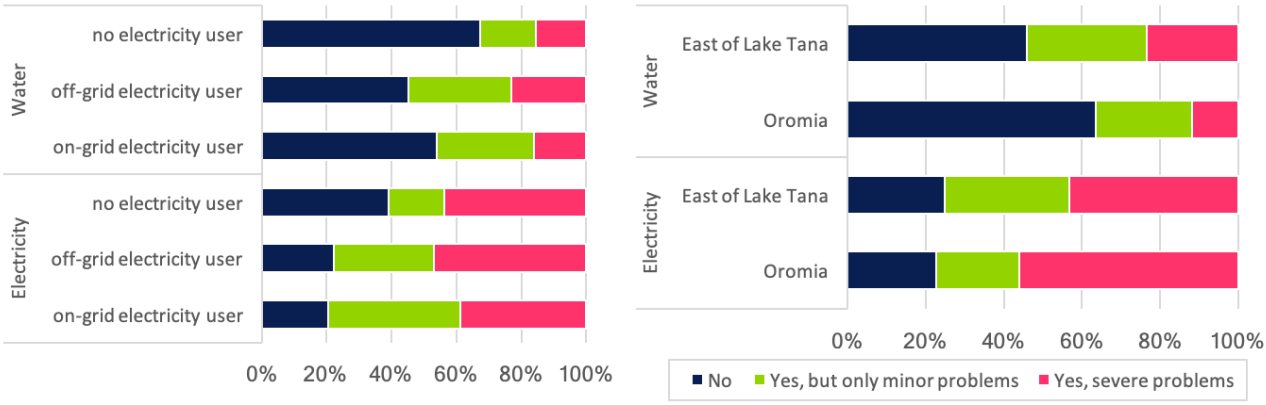
Note: Enterprises engaged in more than one activity are categorized based on the enterprise activity that requires the higher skill level. These enterprises are represented by the numbers in brackets in the table.

Table A.2: Basic agricultural input to processing

Crop	Share of processors stating to transform this crop %	Share of processors among households growing this crop %
maize	59	69
teff	41	61
wheat	30	62
millet	18	79
chickpeas	15	77
barley	14	63
fababean	11	43
sorghum	10	63
oats	8	65
grasspea	8	50

Note: The table displays crops that were mentioned as processing input by at least 5% of households. The third column was calculated by dividing the number of households stating to transform a certain crop by the number of all households producing the same crop in the past year (current belg and/or last meher season).

Figure A.1: Perception of problems resulting from the lack of water and electricity (by electricity user type and study area)



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