

Time-use among men and women in Zambia: A comparison of grid, off-grid, and unconnected households.

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Abstract

Access to electricity is essential to improving quality of life. The goal of this study is to understand how different types of electricity access affect time use between men and women and identify the everyday activities where electricity may have the greatest impact on women's quality of life. Using the World Bank's Multi-Tier Framework (MTF) dataset for Zambia, we apply a Tobit model to examine how male and female household members allocate their time among different activities and the impact of different types of electric connections on those allocations. Our results show that compared to households without electricity, off-grid connections significantly increase women's time in paid work, more so than grid connections, while grid connections significantly increase the time both men and women spend listening to the radio and watching television. These activities have been shown to be key to empowering women through exposure to women in emancipated roles, decreased fertility rates, lower acceptance of intimate partner violence, and increased share of divorce and separation. Off-grid connected households showed no difference in television or radio time and increased time in energy-related activities for both men and women compared to households without electricity. These results suggest that efforts to expand grid-connected and off-grid electricity may have different effects on women's quality of life.

1. Introduction

Increasing electricity access is one of the United Nations' 17 Sustainable Development Goals (SDG). Increased access to electricity has been shown to improve productivity (Azimoh et al., 2015; Rath & Vermaak, 2018), increase income (Dasso & Fernandez, 2015; Dinkelman, 2011;

Khandker et al., 2013; Mondal & Klein, 2011), and create better opportunities for new and existing businesses (Ahlborg & Sjöstedt, 2015; Azimoh et al., 2015; Bastakoti, 2006; Mondal & Klein, 2011). It has also been shown to lengthen study times for children (Aguirre, 2017; Azimoh et al., 2015; Lenz et al., 2017; Mishra & Behera, 2016), improve health and sanitation conditions for women (Mishra & Behera, 2016), improve communication via cell phone adoption (Ahlborg & Sjöstedt, 2015), and improve access to information (Azimoh et al., 2015). Despite the known benefits of electricity, access remains low in much of the Global South. In Zambia, the focus of this study, only 42 percent of residents have access to electricity, with a large disparity between rural (11 percent have access) and urban (76 percent) residents (Luzi et al., 2019). Zambia also experiences high gender inequality, ranking 138th out of 191 countries in 2021 on the Gender Inequality Index (GII) (UNDP, 2022).

To improve electrification rates, Zambia has in recent years deployed several large-scale grid extensions and promoted many mini and off-grid technologies, such as solar photovoltaic systems and mini-hydroelectric power ranging from 100 to 1000 kW (REA, 2021). The country's Rural Electrification Agency (REA) recently set a goal of increasing electrification in rural areas to 51 percent by the year 2030, arguing that such access contributes to better living standards (REA, 2021).

Any type of electric connection provides modest benefits (e.g., lighting); however, more significant benefits depend on the capacity and reliability of that electricity (Luzi et al., 2019). For instance, higher capacity electricity can power larger appliances such as refrigerators and coolers, which can also be used to store medication at health clinics. While being connected to a central grid typically provides such a connection, rural and remote households are often far from the grid increasing their cost of connection. In such cases, mini-grids and off-grid solutions have shown promise (Peters et al., 2019). However, off-grid solutions are not always as effective, as they may not provide enough energy for productive uses (Aklin et al., 2017).

Electricity access, both grid and off-grid, provides benefits that are often assumed to be equal for men and women; however, the benefits and costs of energy access are rarely disaggregated by gender (Clark, 2021), and energy access and gender equality (along with women's economic empowerment) are intrinsically linked (Orlando et al., 2018). Certainly, women benefit from having access to electricity; studies show improved health and indoor air quality from the use of better cookstoves (Köhlin et al., 2011), a decrease in effort and time spent cooking (Krishnapriya et al., 2021; Matinga et al., 2019), increased productivity and more employment opportunities (Dinkelman, 2011; Grogan & Sadanand, 2013; Peters & Sievert, 2016), as well as a substantial reduction in fertility rates (Grogan & Sadanand, 2013). Yet these benefits depend to a great extent on the type of activities that men and women engage in within the household, how the addition of different electrical appliances reduce time or effort, and whether these benefits can challenge or alter gender norms, the latter of which is essential to achieving women's empowerment.

The goal of this study is to examine how different types of electricity connections affect everyday activities in Zambia, specifically how men and women in households with and without electricity allocate their time among different activities. We use time-use statistics, which provide quantitative summaries of how time is allocated across a 24-hour window. Analyzing individuals' time use among different activities has been shown to provide valuable insight into individuals' lifestyles (Harvey & Pentland, 2002). We thus also examine how these connections and activities contribute to women's quality of life. We do this using energy access data for Zambia from the World Bank's Multi-Tier Framework (MTF) survey.

The remainder of this paper is organized as follows: In the next section, we describe five types of daily activities, and the role electricity plays in each, before discussing specific time use studies focused on electricity access. In Section 2 we describe our methods and how we analyze our data; Section 3 presents our results. Section 4 we discuss their implications followed by conclusions in Section 5.

1.1. Household activities and role of electricity

We separate the daily activities of men and women into five categories and highlight studies that note any impact of electricity access in those categories. These categories include cooking, energy-related activities, care work for children and other members of the household, paid work inside and outside the home, and finally, entertainment-related activities such as watching television and/or listening to the radio.

Cooking activity in the MTF survey includes preparing food, tea, or boiling water. Indoor air pollution caused by the use of biomass, coal, or kerosene to cook generates significant negative health impacts, which predominantly impact women. Better technologies may reduce pollution and result in better health for women (Köhlin et al, 2011); however, switching to electric technologies is often not feasible due to financial (Gill-Wiehl et al., 2021) and cultural constraints (Winther, 2007).

Energy-related activities include activities such as chopping or making pellets for preparing fuel or energy source such as firewood and charcoal. Time spent in these activities can limit the extent to which women can seek employment opportunities outside the home (Apps, 2003). Studies show that the time spent in gathering and using these fuels declines when a household gets an electric connection (Pereira et al., 2011), and these connections can improve the work-leisure balance for women (Barnes & Sen, 2004).

Care work includes activities such as caring, attending, or playing with and for younger children, and helping children with schoolwork. These activities are often done by women in both developed and developing countries, and despite the considerable contribution these activities make to family well-being, the work is typically unpaid (OECD, 2011). When households gain access to modern energy services, care work such as helping children with homework may occur at different times of day due to the presence of lighting and improved sleep (Standal & Winther, 2016). Children benefit by being able to study for longer hours (Dutta et al., 2017). Conversely,

when electricity access is unreliable, women often must resort to using traditional fuels such as coal, animal dung, and firewood (Kim & Standal, 2019), limiting their ability to participate in care work.

The next category of time use includes paid work inside and outside the home. Compared to men, women report spending at least twice as much time in unpaid work and share a higher work burden when considering both unpaid and paid work (Seymour et al., 2017). Access to electricity has shown to increase women's participation in paid work (Grogan, 2018), with women benefitting more from greater productivity and greater increases in earnings than men (Rathi & Vermaak, 2018). Energy-related work and care work are related, since women often face trade-offs between domestic chores and working outside the home (Costa et al., 2009).

The final category, entertainment activities, includes time spent watching television or listening to the radio. Households are noted to purchase television and lighting appliances once connected to the grid (Köhlin et al., 2011). Where women have exposure to information via television, significant impacts have been noted in fertility reduction (Grimm et al., 2015; La Ferrara et al., 2012), a lower acceptance of intimate partner violence (Sievert, 2015), and reported increases in autonomy (Jensen & Oster, 2009). The presence of televisions has been noted to create a qualitative shift in social power through the availability of information, and the use of mobile phones allows women to stay connected to the extended family (Standal & Winther, 2016).

Understanding how the type of electric connection affects unpaid domestic work and care-related activities like childrearing is crucial to determining if Zambia can not only achieve its electrification goals, but also improve women's quality of life.

1.2. Time Use Studies

Time allocation is impacted by numerous factors including the age and gender of household members, their access to water, fuel, and infrastructure, as well as individuals' proximity to community centers such as schools, health care centers, financial institutions, and markets. We can observe how time use is gendered by analyzing the total amount of time and the type of work in which men and women engage. Rubiano-Matulevich & Viollaz (2019) find that in both developed and developing countries, women spend more time in unpaid work and fewer hours in the market compared to men, regardless of their age or marital status. Picchioni et al (2020) find significant gender differences in time use in Nepal and India, at least among the rural communities. The presence of adult men and large numbers of children within a household are associated with an increase in leisure time for both women and men; however, that leisure time decreases for women only when the elderly is present. Thus, factors such as age, gender roles, and access to resources affect how time within the household is allocated among different activities and can either constrain or increase time available for paid employment outside the home.

Some studies have combined time use and electricity and have even incorporated gender attributes. For example, Picchioni et al., (2020) use energy expenditure and time use to focus on nutrition and well-being outcomes of men and women. Scheurlen (2015) highlights time use impacts from the reduced availability of fuel resources. Similarly, Johnson et al. (2019) focus on the gendered impacts of electricity access at the household level, specifically from a solar mini-grid in Zambia, using a case study. Quantitative studies have focused on specific impacts like economic outcomes (Azimoh et al., 2015; Mishra & Behera, 2016) and outcomes for children (Aguirre, 2017; Barman et al., 2017; Furukawa, 2014); however, they often do not disaggregate by gender (Bensch et al., 2011; Bernard, 2012).

Here we analyze the impact of different types of electricity access on the time spent in different household activities and disaggregate those activities by gender. Our goal is to compare the time use of women and men in households with electricity (both off-grid and grid connection) and without and explain associations between gendered time use and electricity access. We also aim to identify everyday activities in which an electric connection can deliver the largest quality-of-life impacts for women.

2. Methods

2.1. Dataset and Study Context

Here we use Multi-Tier Framework (MTF) survey data for Zambia provided by the World Bank (ESMAP, 2018)—the most recent deployment of that survey. This global baseline survey, conducted in 2017-2018, contains information on household access to electricity, clean cooking solutions, as well as alternative sources such as solar devices for 3,738 households in rural and urban Zambia. The dataset also contains demographic information, household electricity connection status, whether the household is connected to the grid, and the type of electrical appliances owned and desired.

2.2. Time Use Categories

One section of the survey includes responses to how men and women household members allocate their time among different activities (see Table 1). These quantitative summaries include information on the type of activity and the time spent on each by each respondent within the household. For our analysis, we combined activities similar to the categories described above: Energy Time, Cook Time, Care Time, Paid Work Time, and TV-Radio Time. These categories are also noted to take up the largest proportion of time in a 24-hour window. Table 2 lists the average number of minutes spent each day by i) Women aged 15 years and older, and ii) Men aged 15 years and older in each category.

Category in this study	Activities in survey
Cook Time	Cooking (Food, tea, boiling water)
Energy Time	Preparing fuel/energy source (chopping, making pellets)
Care Time	Caring, attending, or playing with and for younger children

	Helping children with schoolwork
Paid Work Time	Working outside of the house (for pay and/or self-employed) Income-generating activities inside the house
Entertainment Time	Watching TV or listening to the radio for news and information, or entertainment

Table 1: Categories of activities

Within the MTF survey, the household characteristics were available at the individual level, but time-use data was provided as a total time for each gender group within a household. As a result, we calculated the time spent per category per adult in a household by dividing the total time spent per gender group by the number of individuals (aged fifteen or older) within that group. For example, if the aggregate time spent in care work for one household that included three women was 180 minutes, we divided the aggregate by three (i.e., $180/3 = 60$ minutes).

CATEGORY	No Connection		Off-Grid		Grid	
	Men	Women	Men	Women	Men	Women
Cooking	16.5 (30.4)	47.6 (52.9)	16.6 (29.5)	57.7 (60.5)	16.2 (26.6)	57.8 (67.2)
Energy-related	6.5 (19.1)	11.4 (25.4)	12.1 (33.7)	17.4 (41.7)	4.9 (19.8)	7.9 (20.4)
Care Work	23.9 (56.4)	52.7 (107.0)	38.4 (75.7)	60.3 (110.3)	41.7 (80.7)	80.0 (136.6)
Paid Work	156.6 (214.5)	79.5 (160.7)	136.9 (186.1)	101.8 (145.3)	159.9 (233.3)	101.4 (180.1)
Entertainment	26.9 (64.0)	33.1 (82.1)	34.5 (85.8)	35.6 (91.8)	117.9 (147.7)	137.7 (177.8)

Table 2: Average time (Standard Deviation) spent in each category

We categorized each household's electric connection as either "No connection" (i.e., the household has no access to electricity), "Off-Grid" (i.e., the household relies on a generator, solar lantern, solar lighting product, Solar Home System, rechargeable battery, or Dry-cell battery), or "Grid Connection" (i.e., the household is connected to the grid) Table 3 identifies the number of households with each type of connection.

Connection Type	Frequency
No connection	1513 (43%)
Off-Grid	780 (22%)
Grid	1222 (35%)
Total	3515

Table 3: Number of households by electric connection type

2.2. Data Analysis

We first calculated the time spent by men and women in each category across households with different types of electricity access. We next use a Tobit model to regress the time spent in each category of activity on the status of electric connection and other household and household-head characteristics. The descriptive statistics of the key variables are provided in Table 4. The Tobit model (Tobin, 1958) is a censored regression model where the dependent variable is bound above or below, or both, by a certain value. In this case, the lower bound on time is 0 minutes and the upper bound is 1440 minutes (the maximum time that can be theoretically allotted to an activity, i.e., 24x60). This model is used in studying time-use data in which there is a large proportion of observations with 0, leading to a right-skewed distribution and for which OLS estimators tend to be biased and inconsistent. By using a Tobit model, the zeros observed in the dataset are treated as if the respondent did not participate in that activity. The model uses the maximum likelihood technique to estimate the linear relationship between the time spent in each activity and explanatory variables such as household income¹, the electric connection status of the household, marital status² of the head of the household, the household type (single or multiple households), locality of the household (Rural/Urban), and the number of children in the household.

Variables	Mean
Rural/Urban (0 Rural, 1-Urban)	0.5
Number of Children	1.4
Number of Adults	2.5
Type of Electric Access (0- No connection, 1- Off-Grid, 2-Grid Connection)	0.9
Ownership of electric stove (0-No, 1-Yes)	0.13
Housing Type (1- Single households, 2- Multiple households,)	1.1
Household Median Income ¹ (Zambian Kwacha)	2,090

¹ The median income for each category was calculated and multiple incomes within a household were combined to obtain the median household income

² Marital status for the household head was re-classified as Married (0) if their marital status was either monogamously/polygamously married or cohabitation with a single partner, and Single (1) if their marital status was never married, divorced, or separated.

Marital status of household head ² (0-Single (Never married, divorced, or separated), 1-Married (Monogamous, polygamous, cohabitation with a single partner)	0.3
Gender (0- Male, 1-Female)	0.2
Education level (1- None, 2- Primary, 3- Jr. Secondary, 4- Sr. Secondary, 5- Trade School, 6-College, 7-University)	3.1
Age	41.1

Table 4: Descriptive statistics of key variables

In the *Cook Time* model, we regress the time spent cooking on the explanatory variables mentioned above, and we include a dummy variable representing whether the household uses an electric stove for cooking or not. In the *Energy Time* model, the dependent variable is the time spent in energy-related activities and the independent variables are the same as the time spent in cooking. In the *Care Time* model, we regress the time spent in care activities on the same independent variables as the earlier models excluding the use of the electric stove. In the *Paid Work Time* model, we regress the time spent in paid work, both inside and outside the home on the same independent variables as above, excluding the use of electric stove and median household income. The former variable was excluded since no direct connection between the use of electric stoves and paid work has been identified and the latter was excluded to avoid reverse causality as an increase in paid work time contributes to an increase in income. In the final *TV/Radio Time* model, we regress the time that men and women spend listening to radio or watching television for news and entertainment, excluding electric stove use.

3. Results

The average time spent by each gender among different activities in a 24-hour window is provided in Figure 1. With every type of electric connection, women on average spend at least three times as long as men in cooking activities. In energy-related activities, women always spend more time than men, and spend nearly twice as much time as men when there is no electricity and when the household has a grid connection. In care work, across all 3 connection types, women spend more time than men, with the greatest difference between gendered time use in households without electricity. In paid work, the reverse is true. Across connection types, men spend more time than women, and the difference between genders is highest in households without electricity. In entertainment time, both men and women spend nearly the same time across connection types, with women spending slightly more time than men on average.

The results of the Tobit regression are provided in Table 5. We discuss them by activity type and for both men and women. To understand how the connection type and other dependent variables change the time spent in each activity, we provide the marginal results from the model in Table 6. Since the Tobit model uses censored data, i.e., data that ranges between 0 and 1440 minutes (24 hours * 60 minutes), we use the marginal effects explain the effect of each independent variable while holding all other variables constant.

243 *a. Cook Time*

244 In all households regardless of electric connection type, the household head being married
245 increases the time spent in cooking for men and women by 21.2 minutes ($s.e = 1.9$) and 4.2
246 minutes ($s.e = 1.0$) respectively. As the number of children increase in the household, the time
247 spent in cooking decreases for men by 3.4 minutes ($s.e = 0.4$) and increases by 8.5 minutes ($s.e$
248 $= 3.2$) for women. Compared to a single-family household, women in multi-family household
249 spend 11.0 minutes ($s.e = 3.5$) more in cooking. The results are not statistically significant for
250 men. Median household (log transformed) income is not statistically significant for either gender.

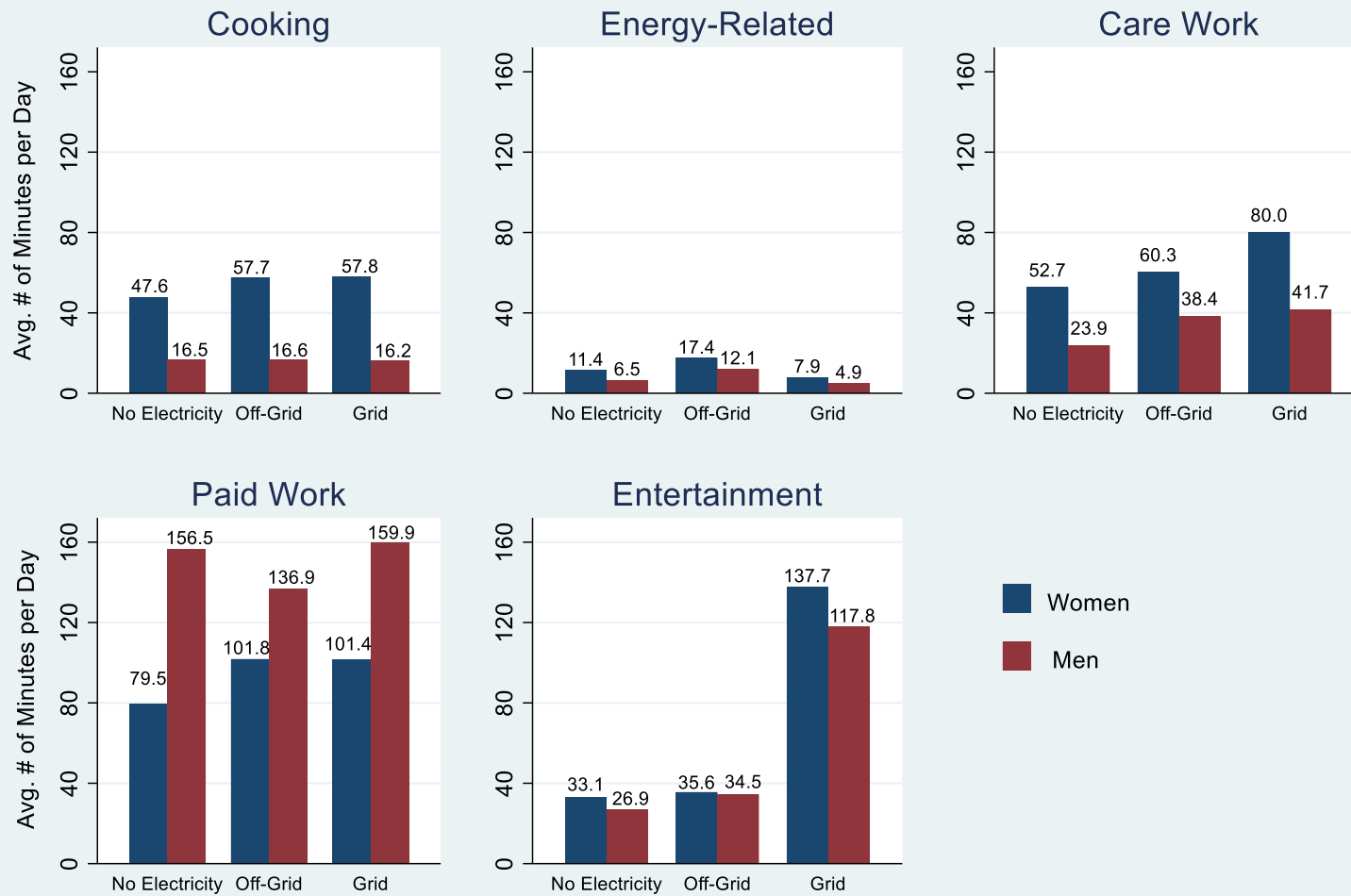
251 Compared to households without electricity, women in households with off-grid
252 connections and grid connections increase their time spent cooking by 17.2 and 8.0 minutes per
253 day, respectively. Time spent cooking by men did not change significantly ($p > 0.05$) with either
254 type of connection. When an electric stove is used in the household, time spent cooking is
255 reduced by 8.4 ($s.e = 0.7$) minutes for women but increased by 3.4 ($s.e = 0.4$) minutes for men.

256 *b. Energy Time*

257 Similar to the Cook Time model, in all households regardless of electric connection type,
258 household heads being married increases energy time by 3.4 minutes ($s.e = 0.8$) for men and 3.9
259 minutes ($s.e = 0.9$) for women. Having one more child in the family increases energy time for
260 women by 2.8 minutes ($s.e = 0.3$). The result is not statistically significant for men. Similar to the
261 cooking time model, the locality of the household is not statistically significant. Compared to
262 single family households, being in a multi-family household reduces energy time for men by 3.7
263 minutes ($s.e = 1.0$) but not for women. As the income variable increases, the time spent in energy
264 also increases for men by 1.3 minutes ($s.e = 0.4$) and for women by 1.2 minutes ($s.e = 0.4$).

265 Compared to households without electricity, both men and women in households with off-
266 grid electricity spend more time in energy-related activities. For men, energy activities are
267 increased by 8.1 minutes ($s.e = 1.6$) in off-grid households compared to 10 minutes ($s.e = 1.8$) for
268 women. Neither men nor women spend more or less time in energy-related activities in grid-
269 connected households. Ownership of an electric stove decreases the average energy time for both
270 men and women by 7.9 minutes ($s.e = 1.6$) and 6.9 minutes ($s.e = 1.3$) respectively.

Time Spent in Household Activities by Connection Type and Gender



Data: MTF Survey 2017-2018 (Zambia), ESMAP, World Bank

Figure 1: Time spent among different activities disaggregated by gender

VARIABLES	Cooking (n=2,635)		Energy-related (n=2,635)		Care Work (n=2,635)		Paid Work (n=3,515)		Entertainment (n=2,635)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Connection Type										
Off-Grid	2.8 (4.0)	25.2*** (4.8)	27.9*** (5.0)	23.9*** (4.0)	46.3*** (11.6)	26.4* (15.0)	5.1 (18.4)	100.5*** (16.2)	21.2 (18.6)	2.4 (21.8)
Grid	-3.9 (3.5)	12.2*** (4.4)	7.1* (4.2)	2.4 (3.0)	34.7*** (10.7)	42.4*** (15.2)	35.4* (20.8)	40.4** (19.2)	214.7*** (14.9)	251.4*** (19.3)
Has Electric Stove?(0-No/1-Yes)	7.6** (3.2)	-12.7*** (4.9)	-31.1*** (5.3)	-19.0*** (3.7)	-31.3*** (11.3)	-42.1*** (16.3)	<i>Not Included</i>		<i>Not Included</i>	
Marital status of Head (0-Single/1- Married)	8.8*** (2.1)	32.0*** (2.9)	13.5*** (3.0)	10.8*** (2.3)	77.3*** (7.9)	112.9*** (10.7)	229.3*** (15.3)	60.5*** (13.8)	56.9*** (10.7)	95.6*** (13.1)
Total # of Children	-7.2*** (1.0)	12.8*** (1.0)	0.2 (0.9)	7.8*** (0.8)	27.0*** (2.4)	55.3*** (3.6)	9.7** (4.4)	32.3*** (3.8)	0.8 (3.5)	21.0*** (3.9)
Urban/Rural										
Urban	-3.6 (2.9)	2.3 (3.6)	-2.1 (3.3)	-0.9 (2.8)	16.6* (9.0)	31.2** (13.0)	-11.3 (19.0)	12.2 (17.2)	-16.5 (13.3)	-21.9 (16.7)
House Type										
Multi Household	-2.6 (3.8)	15.9*** (4.9)	-16.9*** (5.0)	-0.9 (3.1)	23.0** (9.8)	66.3*** (15.5)	1.9 (23.9)	12.2 (22.5)	20.9 (14.2)	63.2*** (17.7)
Log (Median HH Income)	2.3* (1.2)	-0.4 (1.6)	5.1*** (1.4)	3.3*** (1.2)	21.2*** (4.1)	20.5*** (5.5)	<i>Not Included</i>		50.1*** (5.3)	50.1*** (6.2)
Constant	-12.8 (8.9)	-8.7 (11.9)	-83.8*** (11.5)	-61.1*** (9.7)	-348.3*** (36.0)	-411.3*** (42.5)	-168.9*** (17.3)	-238.9*** (16.4)	-560.1*** (42.8)	-662.6*** (49.0)

Table 5: Regression results from the Tobit model . Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

Variable	Cook Time (n=2,635)		Energy-related (n=2,635)		Care Work (n=2,635)		Paid Work (n=3,515)		Entertainment (n=2,635)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Connection Type										
Off-Grid	1.4 (2.0)	17.2*** (3.4)	8.1*** (1.6)	10.0*** (1.8)	14.2*** (3.8)	9.5 (5.5)	2.4 (8.5)	38.6*** (6.4)	5.4 (4.9)	0.5 (4.8)
Grid	-1.8 (1.6)	8.0** (2.9)	1.7 (1.0)	0.8 (1.0)	10.2** (3.2)	15.8** (5.7)	16.9 (10.0)	14.2* (6.8)	88.2*** (6.2)	96.0*** (7.4)
Has Electric Stove?(0-No/1-Yes)	3.6* (1.5)	-8.4** (3.2)	-7.9*** (1.3)	-6.9*** (1.3)	-9.5** (3.4)	-15.6* (6.1)	<i>Not Included</i>		<i>Not Included</i>	
Marital Status of Head (0-Single/1- Married)	4.2*** (1.0)	21.2*** (1.9)	3.4*** (0.8)	3.9*** (0.9)	23.5*** (2.4)	42.0*** (4.0)	108.8*** (7.4)	22.4*** (5.2)	21.7*** (4.1)	33.6*** (4.6)
Total # of Children	-3.4*** (0.4)	8.5*** (0.7)	0 (0.2)	2.8*** (0.3)	8.2*** (0.7)	20.5*** (1.3)	4.6* (2.1)	12.0*** (1.4)	0.3 (1.3)	7.4*** (1.4)
Urban/Rural										
Urban	-1.7 (1.4)	1.5 (2.4)	-0.5 (0.8)	-0.3 (1.0)	5.0 (2.7)	11.5* (4.8)	-5.4 (9.0)	4.5 (6.4)	-6.3 (5.1)	-7.7 (5.9)
House Type										
Multi Household	-1.2 (1.7)	11.0** (3.5)	-3.7*** (1.0)	-0.3 (1.1)	7.4* (3.3)	27.1*** (6.9)	0.9 (11.4)	4.6 (8.5)	8.2 (5.7)	24.0*** (7.2)
Log (Median HH Income)	1.1 (0.6)	-0.3 (1.0)	1.3*** (0.4)	1.2** (0.4)	6.4*** (1.3)	7.6*** (2.0)	<i>Not Included</i>		19.1*** (2.0)	17.6*** (2.2)

280 **Table 6:** Marginal effects from the Tobit model. Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

c. *Care Time*

In all households regardless of electric connection type, the household head being married increases the time spent in care activities by 23.5 minutes ($s.e=2.4$) for men and 42 minutes ($s.e=4.0$) for women. An increase in the income variable increases time in care work for both men and women by 6.4 minutes ($s.e=1.3$) and 7.6 minutes ($s.e=2.0$) respectively.

Compared to households without electricity, the presence of an electric connection increases the time spent in care activities for both men and women. The increase in time for men in households with an off-grid connection is 14.2 minutes ($s.e = 3.8$), but is not statistically significant for women ($p > 0.05$). Care time for both groups increases in grid connected households by 10.2 minutes ($s.e=3.2$) for men and 15.8 minutes ($s.e=5.7$) for women. Owning an electric stove decreases the time for both men and women by 9.5 minutes ($s.e=3.4$) and 15.6 minutes ($s.e= 6.1$) respectively.

d. *Paid Work Time*

In all households regardless of electric connection type, the household head being married increases the paid time for men by 108.8 minutes ($s.e=7.4$) and for women by 22.4 minutes ($s.e=5.2$). With an additional child in the household, men spend 4.6 minutes ($s.e=2.1$) more and women spend 12 minutes ($s.e=1.4$) more in paid work. Neither the urban location or being in a multi-family household are predictors of time spent in paid work.

Compared to households without electricity, women in households with off-grid and grid connections spend 38.6 minutes ($s.e=6.4$) and 14.2 minutes more in paid work, ($s.e=6.8$) respectively. There is no statistically significant change for men in paid time.

e. *TV Radio Time*

Similar to the paid work model, regardless of the electric connection type, the household head being married increases the time in entertainment by 21.7 minutes ($s.e=4.1$) for men and by 33.6 minutes ($s.e=4.6$) for women. An additional child in the household increases a women's time in entertainment activities by 7.4 minutes ($s.e= 1.4$) but is not significant for men. Median household income is also statistically significant for both men and women. A unit increase in income increases the time spent in entertainment activities by 19.1 minutes ($s.e=2.0$) for men and 17.6 minutes ($s.e=2.2$) for women. Being in a multifamily household is statistically significant for women only and increases their time by 24 minutes ($s.e=7.2$). Location of the household is not statistically significant for either gender.

Compared to households without electricity, both men and women in grid connected households experience a significant and sizable increase in time spent watching television and listening to the radio: 88.2 minutes ($s.e=6.2$) for men and 96 minutes ($s.e=7.4$) for women. An off-grid connection did not increase TV/Radio time significantly for either men or women.

4. Discussion

In this study, we compared how men and women in grid and off-grid-connected households in Zambia spend their time in a day compared to those without electricity. Our results show the type of connection matters. Both off-grid connections and grid connections increase the time women spend cooking, though owning an electric stove, which often necessitates a grid-connection, leads to less time cooking for women. Grid connections have no effect on time spent in energy activities, but off-grid connections increase that time. In care work, both grid and off-grid connections increase men's time in these activities, whereas only grid connections increase women's time in care work. Both off-grid and grid connections increase the time in paid work for women. Finally, having a grid connection increases the time both men and women spend listening to radio or watching television, both of which been shown to empower women (Heywood, 2021; Jensen & Oster, 2009). Off-grid connections led to no such increase.

Electricity did not impact men's cooking time, which may be because they rarely cook. Across households, 85 percent of women reported cooking every day compared to only 22 percent of men. However, when a household owns an electric stove, the cooking time increased for men, yet decreased for women. This suggests that owning an electric appliance may encourage more men to assist in cooking; doing so may be easier than using traditional methods (Krishnapriya et al., 2021).

Having an off-grid electric connection increased the time in energy-related activities for both men and women. This counterintuitive result is consistent with the literature on fuel use in Zambia. Mulenga et al. (2019) examined cooking fuel choice in urban households to understand the effect of electricity access, finding that in both households with and without electricity, charcoal remained the most prevalent cooking fuel. Households that use charcoal or other fuels to cook may simply continue to rely on them. It is also important to note that the off-grid systems in our sample consist primarily of batteries and generators; only a few households had solar home systems. The low capacity of the former may simply not allow for the replacement of traditional stoves and fuels. There may be another explanation. In a concurrent study, we found that households prefer using traditional stoves to cook certain types of food like beans (legumes), which require more time to cook. An electricity connection may be ineffectual to households that prefer using these traditional practices and norms (Hooper et al., 2018; Winther, 2007). Regardless of the type of electric connection, women spend more time than do men in energy activities and that time increased as the size of the household increased.

Our results show that while an off-grid connection increases men's time in care work—perhaps because women are more engaged in work outside the home (see below), having a grid connection increases the time for both men and women, and for women more so than men. Larger households led to increased care time, suggesting that electricity connections in large households may have an outsized impact on women's quality of life in those particular homes. Standal & Winther (2016) showed that an electric connection increases the amount of time

women spend helping children with their homework. The extent to which this is an improvement in women's quality of life (or not) likely depends on the individual.

Electricity access is strongly associated with time spent in paid work for women, and their paid work increased more with an off-grid connection than it did with a grid connection. This result indicates two things: first, the marginal value of having any type of electric connection is high for women, both in increasing paid work, and likely allowing for additional income to be generated for the family. And second, a grid-connected household may increase women's activities inside the home (i.e., care work), restricting the amount of time available for paid work outside of it. It is important to understand the trade-offs that women make to engage in paid work whether inside or outside the home. Certainly, paid employment impacts household income, and thus consumption, yet the time spent doing household chores, participating in leisure and self-care activities, and doing unpaid work also contribute to an individual's well-being. Women engaging in paid work, thus, could be taking on more work by also doing household chores (Antonopoulos, 2008; Medeiros et al., 2010). Additionally, the disproportionate time spent in unpaid care is known to either contribute to or exacerbate gender gaps in labor markets (Ferrant et al., 2014).

Perhaps our most remarkable result is the significant increase in time spent watching television or radio in households connected to a grid. This is particularly important and impactful for women since watching television exposes them to valuable information about contraception and domestic violence. In seeing other women in emancipated roles, watching television can decrease fertility rates (La Ferrara et al., 2012; Fujii & Shonchoy, 2020; Grimm et al., 2015), lead to lower acceptance of intimate partner violence (Sievert, 2015) and increase the share of divorce and separation (Chong & Ferrara, 2009). Providing grid-connected electricity may be the single greatest contributor to reduced gender inequality simply via increased access to radio and television programs. At the same time, tv and radio time did not increase here for men or women with an off-grid connection. Off-grid systems have been noted to benefit women through the use of mobile phones and home business opportunities (Hossain & Samad, 2021). However, when these systems lack capacity and reliability, they may be less empowering, especially when we consider they also increase women's time spent preparing and collecting fuels. The extent to which mobile phones, television and radio alter women's quality of life differently requires additional work.

5. Conclusion

Our study shows that that electricity access impacts households and particularly women in two ways: first, by saving time through the use of appliances that may reduce drudgery and invite men into the kitchen. Time saved here can be spent in other activities such as care work or paid work, though how that time gets reallocated depends on intra-household bargaining, gender relations, and norms (Apps, 2003). For example, women might enjoy cooking or prefer spending more time with their children and family, or might prefer to use that additional time to seek paid opportunities outside the home, engage in a home business or in self-care including time spent in

entertainment activities. If electricity leads to women spending extra time in those activities, then it improves their quality of life and can be viewed as a benefit. However, should gender roles, norms, and power relations within the house lead to more work and drudgery, such as time spent collecting fuel, then electricity's positive impacts are reduced.

Second, grid connections led to a significant increase in television and radio time, for both men and women. These forms of media have been shown to benefit women in particular by increasing their awareness of issues that reduce their quality of life such as domestic violence and the lack of contraception. From this perspective, grid connections can be considered an essential service to improve quality of life for women. Those advocating for UN SDG 7, i.e., universal access to energy, must be careful to distinguish between off-grid and grid access if women's empowerment is a goal.

Finally, our study did have two limitations that are shared among most time-use surveys in general (Apps, 2003; Seymour et al., 2017). The first is our inability to shed light on how individuals actively reallocate their time among different activities. Doing so requires a comprehensive approach that models intra-household dynamics within and across groups (Pachauri & Rao, 2013). Even though an electric connection in the household may save time for men or women, our model does not explain how that newly saved time is reallocated toward other activities. Additionally, children's contributions to household labor, especially in cooking, energy-related activities, and care work (for younger siblings) affect how adults spend their time. These characteristics are difficult to account for using surveys and often require qualitative work to adequately capture. Nevertheless, our study demonstrates that distinguishing the impacts of grid and off-grid connections to household time use is a crucial step in encouraging women's empowerment and achieving gender equality.

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