



The role of electric cooking in providing sustainable school meals in low-income and lower-middle-income countries

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Approximately 418 million children are beneficiaries of school meal programmes globally. In general, supportive infrastructure is necessary for the successful delivery of school meals, but in many low-income and lower-middle-income countries (LLMICs), schools have poor access to essential facilities such as kitchens, electricity, and clean water. Moreover, schools in LLMICs often rely on charcoal or firewood for cooking with consequent negative health, social, economic, and environmental impacts that disproportionately affect women and children. The increasing availability of electricity and large energy efficient cooking appliances in LLMICs suggests that electric cooking could offer a potential solution. However, although the impacts of providing electricity to schools on educational outcomes have been explored, and the scope for electric cooking transitions at household level is increasingly studied, evidence on the role of electricity in providing sustainable school meals remains scarce, particularly in LLMICs. Most existing studies on school meals focus on the health and nutritional values of school meals and do not consider the energy used in their preparation or associated impacts. To address this gap, this Personal View explores the contribution of electric cooking to providing sustainable school meals. Recent case studies from Kenya, Lesotho, Nepal, and Guinea that introduced electric cooking as an alternative to traditional cooking fuels have shown how electric cooking can contribute to providing sustainable schools meals in LLMICs. This Personal View highlights multiple sustainable benefits from shifting to electric cooking, which include environmental, economic, and health benefits, and time saving, with potential gender benefits intersecting these domains. Sharing lessons learned from each study could improve the delivery and effectiveness of these interventions for other schools, and understanding the range of contexts and challenges could help towards programme design for wider scaling of sustainable school meal provision.

Introduction

The sustainable delivery of school meal programmes in low-income and lower-middle-income countries (LLMICs) faces stark challenges. According to the 2021 Global Survey of School Meal Programs, in low-income countries, 5–9% of all or most schools have access to electricity, piped water, dedicated eating spaces, and flush toilets, 23% have access to clean water, and 41% have kitchens.^{1–4} In over 88% of low-income countries, schools rely on biomass stoves for meal preparation, with 45% of schools in these countries reporting that the burden of providing cooking fuels is on children and their families.^{2,4,5}

Biomass stoves are inefficient and emit substantial air pollutants, which have detrimental health, economic, and environmental impacts.⁶ At the school level, little data are available on these impacts, which has reduced attention to the issues related to biomass stoves in schools and led to few investments addressing clean cooking.⁵ Studies that have focused on this area have underlined the magnitude of issues caused by biomass cooking in schools. According to Energy Sector Management Programme (ESMAP) estimates, schools in sub-Saharan Africa use approximately 8 million tonnes of firewood annually (assuming 50% of schools use traditional stoves and 50% use improved cookstoves).⁵ The cost of emissions of this firewood consumption were calculated to be between 12 million and 14 million tonnes CO₂ equivalent per year, which equates in monetary terms to between US\$575 million and \$668 million annually.⁵

Alternatives to biomass dependencies are urgently needed and recent evidence has highlighted electric cooking (also known as eCooking) as a potential solution. There has been a rapid increase in electricity availability (often renewably generated) in many LLMICs countries and a growing availability of large energy efficient cooking appliances, such as electric pressure cookers (EPCs) and induction stoves, which can cater to cooking at the scale required by schools.

Adopting energy efficient eCooking solutions offers multiple benefits over biomass cooking, as these solutions can reduce fuel costs, cooking time, and health impacts from air pollution.⁷ eCooking solutions can also help mitigate environmental issues (eg, deforestation), offer time savings (eg, no longer need to gather firewood), and alleviate gender-based burdens (eg, predominantly women cooks).^{8,9} Furthermore, many programmes rely on unpaid labour from students' parents for food preparation and serving, and electric solutions can substantially reduce this burden.^{3,4,10}

Modern eCooking technologies can also offer cost-effective and sustainable cooking solutions for schools on microgrids, including when combined with renewable energy sources such as solar photovoltaic cells.⁷ For grid-connected schools, research shows that promoting eCooking adoption can increase profitability for utilities, which is particularly important in parts of sub-Saharan Africa where there is surplus electricity generation and household consumption is low.¹¹

However, barriers to adopting eCooking in schools exist. The upfront cost of the transition to eCooking can

Lancet Planet Health 2025

Published Online
March 4, 2025
[https://doi.org/10.1016/S2542-5196\(25\)00004-X](https://doi.org/10.1016/S2542-5196(25)00004-X)

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be challenging in LLMICs. Costs involve investments in new eCooking devices, infrastructure (eg, solar photovoltaic systems, upgraded electricity connections, kitchen modifications, and equipment cost), and operation and maintenance expenses.⁷⁻⁹ However, the substantial contribution of high-quality, modern energy cooking to meeting the Sustainable Development Goals can enable access to results-based finance to assist in covering the costs of eCooking adoption.¹²⁻¹⁴ Measuring the potential contribution of eCooking to achieving the Sustainable Development Goals is key to attracting funding for such projects.^{12,13}

Evidence on transitions towards household eCooking identifies further, location-specific factors that affect the adoption of eCooking technologies, including affordability, reliability of supply, technical challenges related to grid stability with high eCooking loads, and sociocultural factors (ie, awareness, users preferences, and beliefs).⁷ Therefore, context-dependent

characteristics are crucial for making optimal recommendations for the adoption of eCooking in domestic or institutional settings, such as schools.⁷

Overall, despite eCooking transitions at a domestic level being an increasingly prominent area of inquiry, inadequate attention has been paid to the potential of eCooking in school settings. Although many studies have focused on delivering electricity to schools as a means to improve education, few have examined the role of electricity in enhancing the provision of sustainable school meals. This Personal View addresses these gaps by exploring the contribution of eCooking to providing sustainable school meals in several case studies from lower-middle-income countries.

Methods

This Personal View compares case studies to understand how eCooking contributes to sustainable school meals and the impact of eCooking across economic, health,

	Kakuma refugee camp, Kenya	EPCs, Lesotho	Energising Home-Grown School Feeding, Guinea	Green School Kitchen, Nepal
Pilot projects and interventions	Testing large EPCs in 3 primary schools in Kakuma refugee camp in Kalobeyei, with each school connected to a standalone solar photovoltaic system or solar mini-grid	Assessing institutional EPCs in 5 peri-urban primary schools as alternative to cooking with firewood, charcoal, kerosene, or gas to reduce health impacts, deforestation, and cooking costs	Integrating modern energy services into WFP school canteens in Kissidougou, Guinea, by installing solar photovoltaic systems and EPCs (2 per school each connected to a smart meter) and improved firewood stoves as a backup and refrigerators (2 per school)	Provides clean energy for school kitchens, installing grid-tied solar photovoltaic systems, induction stoves, and metallic improved cooking stoves as backup; surplus solar generation used for powering schools' other electric devices (eg, printers and fans), irrigating school kitchen garden, or selling to municipal grid; Green School Kitchen projects carried out at 11 other schools, reaching additional 2280 students but not included in this case study as 6 have different project design and 5 ongoing
Funders and collaborating organisations	SNV Netherlands Development Organisation, EnDev, Modern Energy Cooking Services	WFP Innovation Accelerator (INKA)	WFP, EnDev and GIZ, and Plan International; WFP and Modern Energy Cooking Services carrying out follow-up study for schools	WFP, the Government of Nepal through the Ministry of Education, Science, and Technology and the Alternative Energy Promotion Centre, local authorities, and international donors (Governments of Japan and Norway)
Data collection	Inception, baseline, transition, and evaluation surveys collect data on sources of firewood and water from kitchen staff members; enumerators trained school cooks to measure fuel and water consumption before and after use of EPCs; cooking diary study and controlled cooking test were conducted to compare the cost of preparing dishes using firewood and electricity	Baseline and evaluation surveys, cooking diaries, smart meters, interviews, and focus group discussions used to understand cooking practices, challenges of cooking large meal numbers, energy consumption, time spent on cooking, economic, and social impacts of using EPCs	Baseline and evaluation surveys and interviews with the school headteacher, parent association representatives, canteen management committees, and school cooks to collect data on cooking fuel, cooking technologies, cooking practices, energy use, and health problems related to cooking; controlled cooking tests carried out and cooking diaries used to compare situation before and after the installation of solar photovoltaic systems and use of EPCs	Key informant interviews with school cooks and school principals to collect data on school menus, cooking fuels, cooking technologies, cooking practices, energy use, and health problems related to cooking; smart meters installed in 3 of 6 schools to measure energy consumption of eCooking appliances and time of use, and fluctuations in frequency and voltage
Number of schools	3 schools	5 schools	2 schools	6 schools
Number of students per school	178 at Angelina Jolie Girls Primary Boarding School; 789 at Jebel Mara Primary Day; 3178 at Morning Primary Day	201 at Rainbow; 190 at St Bernadette; 1279 at Legele School; 180 at Victor Nthethe; 27 at Star-Classic Pre-Primary School	116 at Soullankolo; 180 at Finaya*	152 at Indrayeny Secondary School; 75 at Sree Ganesh Basic; 235 at Shree Singadha Secondary School; 198 at Shree Chaitepial Basic School; 469 at Shree Tolidewal Danda Secondary School; 194 at Shree Saraswati Secondary School
Rural or urban	Rural	Peri-urban	Rural	Rural
Baseline cooking fuel for school meals	Firewood	All schools used LPG apart from Legele, which used firewood	Firewood	Firewood apart from Indrayeny which used LPG
Electricity source before intervention	Off-grid	Grid connected	Off-grid	Grid connected

(Table 1 continues on next page)

	Kakuma refugee camp, Kenya	EPCs, Lesotho	Energising Home-Grown School Feeding, Guinea	Green School Kitchen, Nepal
(Continued from previous page)				
Electricity source after intervention	All off-grid systems, either standalone solar photovoltaic system or solar mini-grid	Grid connected	Stand-alone photovoltaic capacity 3.5 KWp and 21.6 KWh of storage (LiFePO4)	Grid tied hybrid solar photovoltaic system and battery storage
Number of EPCs per school	2 EPCs per school	2 EPCs per school apart from Legele, which had 4 EPCs	2 EPCs per school	One induction stove per school apart from Indrayeny and Ganesh schools with two each; EPCs not used at these schools
Size of electric cooking vessels	21 L and 40 L EPCs	40 L EPCs	19 L EPCs	30 L and 40 L induction base pots, and a 22 L induction base stove top pressure cooker
Meals served per day	1 lunch and dinner meal at Angelina Jolie Girls Primary School; 1 lunch meal for staff members at Jebel Mara Primary School; 1 lunch meal for staff members at Morning Star Primary School	1 lunch meal at Legele; 1 breakfast, 1 lunch, and 1 dinner meal at Victor Nthethe; 1 breakfast and 1 lunch meal at Rainbow, St Bernadette, and Star-Classic Primary School	1 lunch meal at Soulankolo Primary School	1 lunch meal at all schools
Total number of days data were recorded at baseline	12	49	13	N/A
Total number of days data were recorded after transition	12	234	9	30 days of smart meter data at Shree Chaitepipal Basic School, Shree Singadha Secondary School, and Shree Tolidawal Danda Secondary School
Further information on case studies is available in the appendix (pp 2–21). EPC=electric pressure cooker. WFP=World Food Programme. LPG=liquefied petroleum gas. *Results presented for the Guinea case study are based on the Soulankolo Primary School data only and the Finaya Primary School was excluded because the EPC testing was unsuccessful.				
Table 1: Description, baseline situation, interventions, and methods of data collection of case studies from Kenya, Lesotho, Guinea, and Nepal				

environment, and gender domains. It also explores the contextual characteristics that influence the success of an intervention and how to tailor context-based interventions to achieve an intended outcome.

A comparative case studies approach is suitable when undertaking of an experimental design is not feasible, or when there is a need to understand and explain how contextual factors influence the success of programmes, interventions, or policy initiatives.¹⁵ Analysing multiple case studies can also produce more robust results.¹⁶ Comparative case studies involve proposing, analysing, and synthesising similarities, differences, and patterns across cases that share common goals.¹⁵

Four case studies of schools in Kenya, Lesotho, Nepal, and Guinea were chosen to explore the potential role of eCooking in providing sustainable school meals (table 1). These studies were taken from projects by the World Food Programme (WFP), SNV Netherlands Development Organisation (SNV), Energising Development (EnDev), Sustainable Energy for All, and Modern Energy Cooking Services (MECS), which are central to testing the use of eCooking in school meal programmes in LLMICs.

Multiple methods of data collection were used in the four case studies, such as baseline and evaluation surveys, interviews, focus group discussions, and bespoke methods (controlled cooking tests¹⁷ and cooking diaries¹⁸ [often paired with smart meters; appendix p 1]). In Lesotho, Nepal, and Guinea, primary data were collected by country-based teams from WFP. In Kenya, primary data for the Kakuma case study were collected by SNV and Gamos East Africa. Each organisation has its

own ethical guidance for collecting primary data. We calculated the average savings in fuel consumption, fuel costs, cooking time, and water consumption in each case study to assess the potential benefits of eCooking compared with baseline fuels.

Results

The case studies are detailed in the appendix (pp 2–21). The following sections expand on the key features of each study to outline the contextual factors and contributions of eCooking to school meal provisions across different sustainability domains.

Kakuma and Kalobeyei, Kenya

The Kalobeyei integrated settlement and Kakuma refugee camp are located in Turkana County, which is considered an arid region. There are approximately 38 schools (21 primary schools and 17 pre-primary, nursery, and secondary schools) in Kakuma and six primary schools in Kalobeyei that mainly use firewood, which is supplied in bulk by the UN Refugee Agency. Following a pilot study of eCooking in Kakuma households,¹⁹ SNV (supported by EnDev and MECS) tested the use of large EPCs in three schools in Kalobeyei (table 1).

A cooking diary study and controlled cooking tests were conducted, which compared the cost of preparing dishes with firewood versus electricity as a fuel source. The findings indicated that there were substantial cost savings when electricity was used for cooking (appendix p 2). For example, beans and githeri (common school meal dishes in Kenya) were at least 50% less expensive to

See Online for appendix



Figure 1: Adding new circuit breakers and electric sockets in the school kitchens

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prepare with an EPC versus with an improved institutional stove. This finding highlights the potential for long-term cost savings for schools from switching to eCooking.

School cooks reported that cooking with EPCs provided a cleaner cooking environment when compared with firewood, as EPCs did not produce smoke or soot, which meant that pots were easier to clean and there was less eye irritation. EPCs also produced less heat than firewood, allowed for faster cooking, and enabled multitasking (appendix p 3). This efficiency particularly benefited teachers, who used EPCs to prepare their own meals. Additionally, water consumption per meal per kilogramme of food was measured to compare water consumption when an improved institutional firewood stove, a 40 L EPC, and a 21 L EPC were used. The average water consumption savings due to shifting from firewood to EPCs was 24–61% across all schools (appendix p 4).

The type of dishes and the number of students were determining factors for the use of EPCs. In the Angelina Jolie Boarding School, cooks were able to cook most dishes (eg, beans, yellow split peas, meat, and vegetables) after switching to EPCs. However, cooks were unable to prepare other school meal dishes (eg, ugali and porridge) due to the size limitation of EPCs. Staff meals were all cooked with EPCs. As Jabel Mara and Morning Star Primary schools had many students, they could not use EPCs to prepare all the school meals. Therefore, these schools used EPCs to cook only the staff meals. Lastly, the use of EPCs was constrained by the battery storage capacity of the solar photovoltaic system.

The Kenya case study highlights the opportunities that shifting to eCooking could bring to schools. A key factor that would accelerate the transition to eCooking is the development of suitable eCooking appliances that can facilitate preparing and cooking meals for a large number of students. Improvement of the infrastructure of each school's electricity supply is imperative to ensure stability during cooking.

EPCs, Lesotho

In 2025, approximately 12% of 1508 primary schools and 65 secondary schools in Lesotho had access to electricity, with plans to deliver electricity to 204 additional schools under the Lesotho Renewable Energy and Energy Access

Project 2020–27 through the distribution of mini-grids.^{20,21} Most schools rely on fuels that produce high amounts of pollution for cooking school meals.²² In 2022, the WFP introduced large EPCs in five peri-urban primary schools to assess whether institutional EPCs could be a viable alternative to cooking with firewood or liquified petroleum gas (LPG) in non-pressurised pans to reduce health impacts, deforestation, and costs.²² Multiple methods were used to collect data (table 1). Kitchens were retrofitted by adding new circuit breakers and electric sockets, and electrical cables were updated (figure 1).²²

The reliability and quality of power supply is essential for eCooking, particularly during cooking times. In Lesotho, key cooking hours were between 0600 h and 1300 h. Figure 2 shows voltage and frequency at five schools in Lesotho across 1 week. The average voltage registered at all schools was around 220 V, with measurements varying between 167·5 V and 250 V over the week, which did not affect EPC performance. This finding aligned with a MECS study that explored the performance of an EPC at lower voltages than the voltage rating (240 V).²³ The MECS study found that a 1 kW EPC operated satisfactorily at half the power rating, despite a longer cooking time (around 10 min). Three schools (Leqeletse, Star Classic, and Victor Nthethe) experienced major power cuts (between 2 h and 5 h) in the week. During the power cut, schools reverted to their baseline fuels. Rainbow Pre-Primary School and St Bernadette Nursery School had a reliable power supply (ie, did not experience power cuts), and were able to cook exclusively with EPCs. However, in cases where schools might not have access to reliable power supplies, fuel stacking is an important consideration.

The daily energy used for cooking depends on the number of meals cooked per day, the number of dishes per meal, the cooking process per dish, and the amount of food cooked. Comparing the average daily costs of electricity consumed by EPCs versus the cost of LPG or firewood showed that cost savings range between 27% and 69% for schools that switched from LPG, and 85% for Leqeletse Primary School, which switched from firewood (appendix p 7). The introduction of EPCs in schools did not change the types of food (eg, papa and cabbage) that were served. The analysis of the energy cost for these two dishes shows statistically significant cost saving across all schools, particularly in Leqeletse Primary School, which switched from firewood to EPC. One meal of papa and cabbage for 1279 students costs \$17 in firewood, but costs \$1 when cooked with an EPC (appendix pp 8–9).

As the cost of energy per kWh is almost equal for all fuels in Lesotho (electricity costs \$0·133 per kWh, LPG costs \$0·158 per kWh, and firewood costs \$0·104 per kWh), cooking with an EPC saves energy because of its efficiency.²² The economic benefits of switching to EPCs are already evident, and could improve in the future due to the projected increase of LPG and

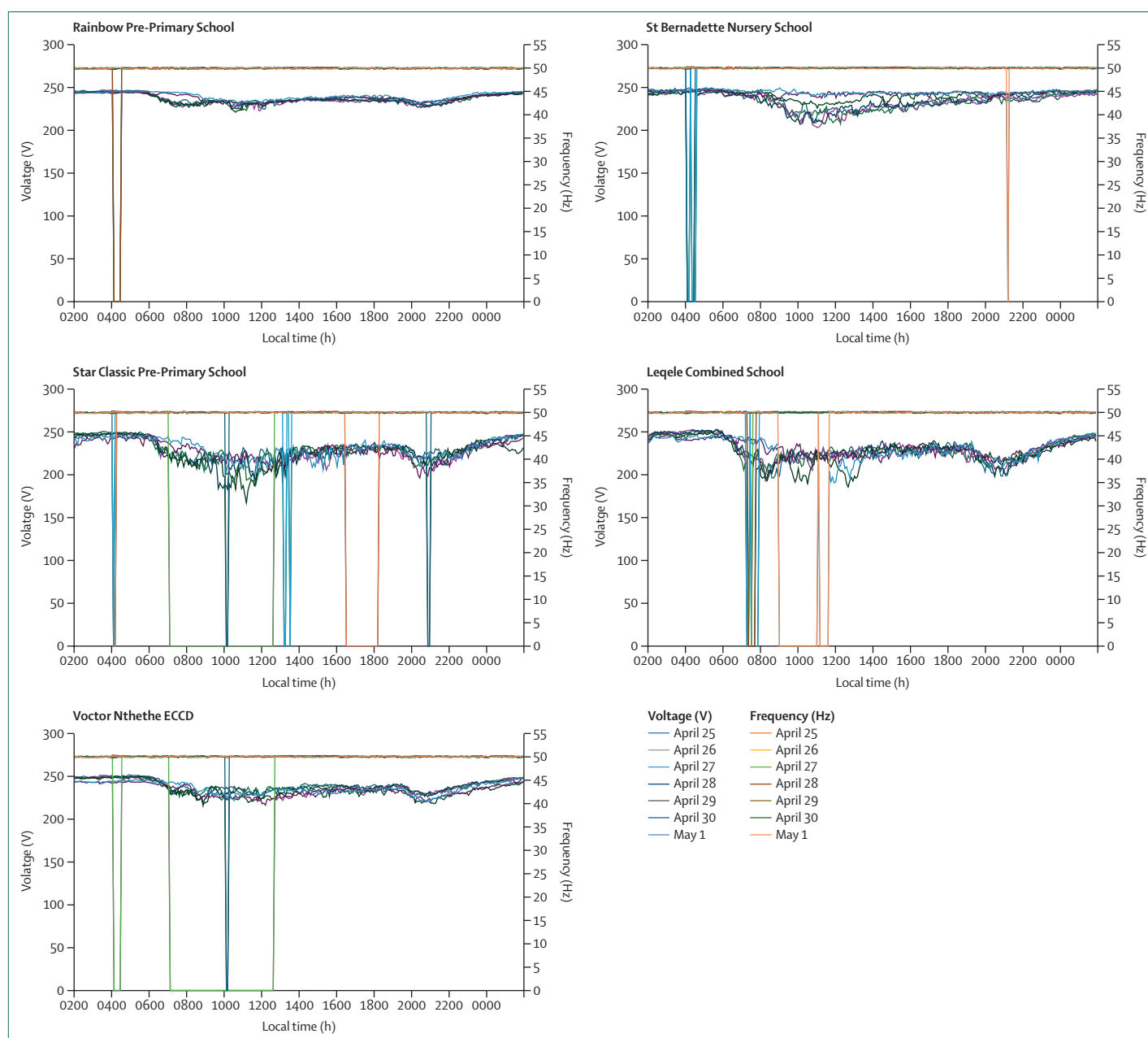


Figure 2: Voltage and frequency measured at different schools in Lesotho
Reproduced from Nsengiyaremye and Khalifa.²²

firewood prices, the production of larger EPCs, and improved cooking techniques.²²

EPCs save approximately 37% of cooking time when compared with LPG and firewood, which is a time saving of more than 1 h per day (appendix p 10).²² EPCs also allowed multitasking, given that some teachers might participate in cooking and preparing school meals. School cooks reported that washing EPCs requires less time and water than for other cooking appliances, and that EPCs reduce food waste.²²

The pilot project aligns with the expected increase of electricity availability in schools in Lesotho under the Lesotho Renewable Energy and Energy Access Project 2020–27, and the introduction of EPCs in schools is compatible with existing power generation infrastructure. EPCs were the most suitable option compared with other eCooking solutions as they can substantially reduce energy demand due to insulation, pressurisation, and automation.²⁴ As school cooking occurs between 0600 h and 1400 h, an off-peak period of



Figure 3: A traditional Nepali chulo firewood stove

This stone stove was used at Tolidewal Danda Secondary School for cooking all school meals before the Green School Kitchens interventions. Copyright: World Food Programme and Nepal engineering team.

power demand, utilities, or mini-grids could meet increased demand alongside existing infrastructure.²² EPCs are also compatible with school menus.²²

Energising Home-Grown School Feeding, Guinea

The Energising Home-Grown School Feeding project is an innovative approach to integrate modern energy services into WFP school canteens in Guinea. WFP, EnDev and GIZ, and Plan International provided solar photovoltaic systems, introduced EPCs, backup improved firewood stoves, and refrigerators in two schools in Kissidougou.²⁵ Both schools selected for the study (Finaya and Soulankolo Primary Schools) are in rural, off-grid areas. The project aimed to reduce the environmental and health impacts caused by cooking with firewood, and improve food preservation conditions. Multiple methods were used to collect data (table 1).

At Soulankolo Primary School, the average voltage registered was around 221.3 V, with measurements varying between 219.5 V and 222.4 V over the data collection period (appendix p 12). This variation did not have an impact on the use of EPCs. As firewood is collected free of charge by students or women's groups from surrounding communities at Soulankolo Primary School, there was no cost for cooking with firewood, and cooking with an EPC was more expensive. However, replacing the three-stone stove with EPCs could save approximately 38 tonnes of non-renewable biomass over 25 years (the lifespan of the solar photovoltaic system), saving around 75 tonnes of carbon emissions. Replacing the improved cook stove with EPCs could save approximately 29 tonnes of non-renewable biomass and around 58 tonnes of carbon emissions (appendix p 13). The solar photovoltaic system was also used to provide electricity for refrigerators (two per school) and telephone charging. Financial benefits could be low in areas where firewood is collected for free, but this reduction has wider environmental, health, and gender impacts.

At Soulankolo Primary School, the average cooking time for EPCs was longer than firewood and improved cookstoves, as both EPCs were used to cook rice for approximately 1.5 h, after which a single EPC was used to cook the sauce for approximately 1 h. With wood-burning stoves, two 100 L pots were used to cook rice and sauce simultaneously (appendix p 14). Although more time was spent cooking with EPCs, an average of 45 min was saved that would have been spent on firewood collection. The average water savings from the transition from firewood to EPC were 24.15% (appendix p 14).

Finaya Primary School was excluded from testing the EPCs for several reasons. The number of school meals exceeded the capacity of EPCs (19 L per EPC), which led to using EPCs multiple times or using both the improved cookstoves (100 L per stove) and EPCs to cook and serve school meals on time. Women from the local community and parents volunteered to cook and prepare school meals as Soulankolo Primary School and Finaya Primary School did not employ cooks. Therefore, the improved cookstoves were preferred as their larger capacity allowed for faster cooking, which enabled the person cooking to conduct other productive activities, such as farm work. The study was repeated a week later at Finaya, but failed as the entire solar photovoltaic system shut down due to the lack of charge caused by severe weather conditions, which meant that improved cookstoves had to be used. The school was advised to consume any food that had been stored in the refrigerators, which also shut down. Fuel stacking (eg, use of LPG as an alternative) is important in the period of transition to eCooking to address these challenges, and to serve school meals on time.²²

Green School Kitchen (GSK), Nepal

In Nepal, many schools rely on biomass, LPG, kerosene, and petrol to meet their energy needs,²⁵ with over half of public schools not having access to electricity.²⁶ To address this deficit, the government of Nepal, WFP, and local authorities developed the GSK project. This initiative aims to provide integrated solutions for both electricity and clean cooking, installing grid-tied solar photovoltaic systems and induction stoves with backup metallic improved cooking stoves to optimise firewood use during low solar generation periods. The project seeks to reduce firewood consumption (figure 3), minimise deforestation, and replace LPG use where applicable. Surplus solar power is also used for other school needs or sold to the grid. This case study examined six completed GSK projects in schools where induction stoves and solar energy systems were implemented (appendix p 16). Multiple methods were used to collect data (table 1).

In all schools, the use of firewood and LPG decreased substantially, without changes to school menus (appendix p 17). At Indrayani Secondary School, where LPG was the primary cooking fuel, cooking shifted entirely to electricity within 5 months, resulting in no fuel stacking. The

two induction stoves were used for 2·5 h daily, with rice cooked in 25 L and 35 L pots on the 3·5 kW stove, and lentils or curry cooked with a 22 L induction base pressure cooker on the 2 kW stove. For the other five schools where firewood was the main fuel, firewood consumption fell by an average of 89·3% after GSK interventions, saving around 4·8 kg of firewood per student per month. Schools with both induction stoves and metallic-improved cooking stoves saw a higher reduction (90·8%) than Shree Saraswati Secondary School, which only received metallic-improved cooking stoves (83·3%). The firewood savings at Shree Saraswati were larger than typical reductions reported in the literature for similar stove upgrades (45–65%),²⁷ possibly due to the reliance on key informant interviews based on estimates rather than actual measurements. The baseline firewood consumption data at Tolidawal School also appeared to be lower than at other schools, which could indicate inconsistencies in data reporting (appendix p 18).²² Despite these discrepancies, the substantial reductions in firewood and LPG use across all schools that received induction stoves suggest that respondents appreciated the range of benefits from eCooking, including the reductions in cost at Indrayani School, which have already covered the cost of cooking fuels.

A 4 week sample of electricity consumption data for the schools is given, excluding four Saturdays and two public holidays, leaving 22 days when meals were expected to be prepared (appendix p 18). Data indicated that eCooking became the primary cooking method after GSK interventions, with electricity use aligning with the power ratings of the induction stoves. This finding supports the conclusion that eCooking adoption is feasible even with irregular electricity supply characteristics, as observed at these schools (appendix p 19).

At Indrayani, the shift to eCooking saved 6000NPR monthly on LPG costs, which was equal to the amount previously spent on three 15 kg LPG cylinders. The overall electricity costs for the school decreased by 86·5% (US\$37 per month to \$5 per month) due to surplus solar generation, which was used to power non-cooking appliances and charge the battery backup system. For schools where firewood was the main fuel, eCooking increased cooking fuel costs, as firewood was collected locally rather than purchased. However, cost savings would be substantial in cases where schools purchased firewood, with savings of around 80%, or even 96% in some cases, depending on the proportion of solar power used (appendix p 20).

The GSK projects also provided economic benefits to the local community, as WFP trained local technicians to install and maintain the solar photovoltaic systems and eCooking appliances. This training could lead to future income-generating opportunities in repair and maintenance services. At Indrayani, surplus solar power was also used for irrigating the school garden, which created a local circular economy.

Key informant interviews showed positive impacts on health and the environment. GSK projects facilitated smoke-free cooking environments, which reduced health issues that were self reported by study participants, such as respiratory problems and eye infections. The need for students to collect firewood was also reduced substantially. At Singadha, students no longer had to bring firewood from home, and other schools only required small amounts of firewood once per week.

The reduction in firewood collection time was a major benefit, particularly for women, who were the primary collectors. Gathering firewood previously took 4–5 h,²⁸ but this time commitment was drastically reduced with eCooking. However, cooking times did not substantially decrease. Some cooks reported longer cooking times due to the need to prepare food in batches with the induction stoves, suggesting that larger or additional induction stoves could help reduce cooking times. At Singadha, cooking times decreased by 30 min as cooks became more familiar with the technology, and no longer had to maintain a fire.

Overall, the GSK project has led to notable improvements in energy efficiency, health, and local economies, and shows the potential for widespread adoption of eCooking in Nepal's schools. Table 2 summarises the sustainability impacts for the four case studies. Further details are available in the appendix (pp 2–21).

Discussion

This Personal View highlights how eCooking can contribute to providing sustainable schools meals in LLMICs. Successful transitions to eCooking occurred in all case studies, which became the dominant fuel component in most schools, including several that shifted entirely away from biomass. Electricity was used as a primary cooking fuel at schools that were connected to grid, off-grid, and used grid-tied solar photovoltaic systems, showing that effective eCooking transitions are feasible with various electricity sources across different degrees of supply reliability. Evidence from the Lesotho and Guinea case studies show how EPCs could accommodate voltage fluctuations and cook satisfactory meals. The Lesotho and Guinea case studies also emphasised the importance of integrated electricity supply and clean cooking planning in successful transitions to eCooking. In both studies, electricity systems were checked, upgraded, and matched with highly energy efficient EPCs. This finding supports the growing evidence base that eCooking transitions will make the greatest gains when the planning of electricity supply and clean cooking are jointly considered.²⁹

Although not all school meals were cooked on the eCooking appliances provided and some fuel and stove stacking occurred, none of the case study schools in any of the case studies reported changes to the menu, highlighting the compatibility of eCooking appliances

	Kakuma refugee camp, Kenya	EPCs, Lesotho	Energising Home-Grown School Feeding, Guinea	GSK, Nepal
Average cooking time savings (%) per day	Firewood to EPC saved 43.89%; improved institutional firewood stove to EPC saved 44.77%	Firewood to EPC saved 36.6%; LPG to EPC saved 38.17%	EPCs take longer than firewood and improved cookstoves because both used EPCs to cook rice for 1.5 h and then used a single EPC to cook sauce for 1 h; wood-burning stoves with 100 L pots allowed rice and sauce cooking simultaneously	Cooking times broadly the same after the GSK interventions; increasing familiarisation with induction stoves anticipated to reduce future cooking times
Average cooking fuel cost savings (shifting from baseline fuel to EPCs)	Improved institutional firewood stove to EPC (40 L) saved 21.68% per kg of food, and 58.45% if ugali maize meal was excluded; EPC (21 L) saved 31%, and 56% if ugali maize meal is excluded; the fuel cost of cooking ugali with EPCs was higher than with improved firewood stove because of low capacity of EPCs for this specific dish	LPG to EPC saved 46.99% per day per student; firewood to EPC saved 83.33%	Firewood is collected free of charge, therefore cooking with EPC was more expensive	5 schools with firewood as baseline fuel collected wood free of charge, therefore induction cooking increases costs; at Indrayney School, the 3 LPG cylinders previously used every month (total cost 6000NPR) were replaced completely by eCooking; the percentage of cost saving depends on the proportion of grid electricity and solar power used
Average cooking fuel consumption per day per student	Data unavailable	0.0337 kg for firewood; 0.0062 kg for gas; 0.0465 kWh for electricity	0.180 kg for 3-stone stove (firewood) per day per student; 0.138 kg improved cookstove (firewood) per day per student; 0.031 kWh for EPCs per day per student	0.24 kg for firewood before GSK intervention per day per student; 0.022 kg for firewood after GSK intervention per day per student; 0.0135 kg for LPG before GSK intervention per day per student; data unavailable after GSK intervention as LPG no longer used; 0.012 kWh for electricity after GSK intervention per day per student (averaged over Shree Chaitepipal Basic School, Shree Singadha Secondary School, and Shree Tolidewal Danda Secondary School with smart meters)
Average water savings (water used in cooking)	Improved institutional firewood stove to EPC (40 L) saved 27.76% per kg of food; improved institutional firewood stove to EPC (21 L) saved 21.46%	Data unavailable	Firewood to EPC saved 24.15% per day; improved cookstove to EPC saved 6.46% per day	Data unavailable

EPC=electric pressure cooker. WFP=World Food Programme. GSK=Green School Kitchen. LPG=liquified petroleum gas.

Table 2: Results of case studies from Kenya, Lesotho, Guinea, and Nepal

with school meal programme dishes and cultural cooking practices. This finding supports the hypothesis that consistent and less complicated school menus (often designed to preserve nutrition and typically under budgetary and food availability constraints) are a particularly good fit for modern eCooking appliances. These appliances, which can regulate cooking via thermostats, timers, and automation, are effective for standardising processes such as batch cooking, which is commonly used in schools.³⁰

Challenges in the uptake of eCooking were often due to the insufficient consideration of specific and location-based school meal requirements. In Kenya, Guinea, and Nepal, some schools reverted to baseline fuels as the eCooking appliances provided were not large enough to cater for every school meal required. Soulankolo Primary School in Guinea reported that eCooking resulted in slower cooking times due to undersized appliances,

which meant that cooking took successive (rather than singular) batches. These issues were not reported in Lesotho, however, where the number of EPCs given to each school was determined by the number of students to ensure that additional cooking stoves would not be required. These contrasting experiences show the importance of a detailed needs assessment before an intervention.

Power cuts or deficits were another feature that limited some schools from fully transitioning to eCooking. The findings indicate that schools in Lesotho reverted to using baseline fuels when there were blackouts, and that schools in Kenya reverted when eCooking was impeded by solar photovoltaic system capacity. Therefore, considering fuel and appliance stacking during a school's transition to eCooking is key, particularly when schools do not have access to consistent power supplies. Data on fuel stacking are also important during transition periods

to understand why school cooks might revert to previously used cooking fuels.

Although the use of EPCs increased fuel costs in cases where free firewood fuel had previously been used, the use of EPCs did reduce carbon emissions and could in future raise revenue for these school through a carbon financing scheme.

Further sustainability benefits

The case study analysis also identified multiple sustainable benefits across environmental, economic, health, and time-saving domains from schools transitioning to eCooking. Gender dimensions intersected all domains, highlighting how shifts towards eCooking can help address the impact of biomass cooking on gender.

Economic impacts

Cost reductions in cooking fuel expenditure from eCooking transitions were reported in all schools that had previously purchased their baseline fuel supply. Cost savings varied among schools depending on the daily cooking energy consumption before and after the intervention. Energy consumption was affected by multiple variables, such as the number of meals and dishes cooked, behavioural dynamics, and the appliances, cooking process, and proportion of different cooking fuels used.

In Kakuma, highly efficient EPCs reduced cooking fuel costs by 26–34% compared with improved stoves in all schools (57·2% if ugali maize meal is excluded; table 2), and in Lesotho, EPCs reduced costs by 27–69% compared with LPG and by 85% for three-stone fires.²² In Nepal, Indrayani Secondary School replaced LPG entirely with eCooking and reported a 100% fuel cost saving when using the school's solar photovoltaic generated electricity. There is potential for greater cost savings than observed here from eCooking transitions if the price of LPG and firewood increases in the future, as is widely anticipated.²² Use of larger eCooking appliances (rather than multiple smaller devices) and efficient cooking techniques can also enhance savings.

The case studies also highlighted how economic benefits from transitions to eCooking can extend beyond reduced fuel costs. The reported health benefits include potential economic benefits due to lower medical costs and reduced absence from work due to illness. eCooking was also shown to reduce the time spent collecting firewood, which was a substantial opportunity cost that fell predominantly on women. In Nepal, the provision of repair and maintenance training for eCooking appliances and supportive infrastructure is expected to create new income opportunities. There was also scope for supporting a local circular economy, which was shown by Indrayeni Secondary School in Nepal that used surplus solar generation (unused by eCooking) to irrigate the school gardens, providing food for school meals. In Guinea, additional solar photovoltaic capacity

was used to charge telephones and power refrigerators, which had the economic benefit of reduced food wastage.

Health and environmental impacts

Health benefits were reported by case study participants when shifting from biomass to eCooking. In Kakuma, cooks noted less eye irritation and heat exposure. In Nepal, the transition was described as pivotal, as the shift reduced smoke-related health issues and the burden of collecting firewood. These benefits were notably gendered as most cooking and fuel collection was done by women.

The transition to eCooking also shows the scope for key environmental benefits due to avoided deforestation and reduced carbon emissions.²² In Lesotho, the shift from LPG to EPCs saved schools approximately \$0·0037 per student per day in environmental costs based on the International Monetary Fund's methods, with an increase in monetary savings in cases where firewood was the baseline fuel (appendix p 9).³¹ Greater reductions in greenhouse gases are also likely conferred if the electricity supply relies on renewable sources,³² highlighting how integrating eCooking planning and electricity provision is crucial to ensuring more sustainable transitions and maximising environmental benefits.³²

Time savings and social impacts

In all case studies, eCooking transitions led to time savings, which have the scope to offer various social benefits. In schools that used manually collected firewood as a baseline fuel, time was saved by the reduced need for fuel collection, which was particularly pronounced in Nepal, where firewood collection previously took on average 4–5 h. In Kenya and Lesotho, cooks valued the time-saving opportunities enabled by the automation of EPCs, which allowed multitasking, thereby enabling the teachers involved in meal preparation to spend more time in class rather than monitoring open flame biomass stoves, thereby conferring wider educational benefits. Cooks in Kakuma also found EPCs easier and less time consuming to clean than biomass stoves.

These benefits had a notable gendered dimension, as women and children were the primary fuel gatherers and cooks in most case study settings, reinforcing the gender inequalities emphasised in evidence from studies on biomass cooking in household³³ and school settings.³⁴ Evidence from these case studies suggests that switching to eCooking could enable school cooks to save time spent on unpaid work and reduce gender inequalities.

Limitations

As most of these case studies are pilot projects, which are limited by size and length of study, results are context based and cannot be generalised. Contextual factors have

Search strategy and selection criteria

We searched ScienceDirect, Web of Science, Scopus, and published reports for full length articles that examined the role of electricity in providing school meals published before March 01, 2024 in English. We used the search terms "electricity", "electrifying schools", "schools electrification", "infrastructure", "school meals", "school lunches", "school feeding", "cooling", "refrigeration", "food storage", "clean cooking", "clean fuels", "electric cooking", "electric cookers", "polluting fuels", "solid fuels", "firewood", "wood fuel", "charcoal", "water pumping", "clean water", "drinking water", "hygiene", "WASH", "gender", "gender equality", "gender equity", "just transition", "health", "economic", "economy", "environmental impacts", "climate change", "deforestation", "nexus approach", "water-energy-food-nexus", "underdeveloped countries", "developing countries", "lower-income countries", "low-income countries", "developing nations", "global south", "food loss", and "food waste". Our literature search shows that the impacts of electrifying schools on educational outcomes have been widely explored globally, but that studies on the role of electricity in providing sustainable school meals and the economic, environmental, health, and gender impacts of these services in low-income countries are low. Existing studies on school meals have largely focused on the health and nutritional values of school meals without considering the energy used in their preparation, and associated impacts.

a substantial impact on the outcomes of these projects, but sharing the findings of each study could improve the delivery and effectiveness of these interventions for other schools. This Personal View has made efforts to collate evidence from the case studies in Kenya, Lesotho, Nepal, and Guinea in a structured manner to allow for comparisons. However, as these case studies each used different methods and addressed slightly different research questions, direct comparisons are not always possible.

Conclusion

The case studies in Kenya, Lesotho, Nepal, and Guinea show the benefits of increasing the role of electricity in providing school meals, and highlight the unique contexts of each school. Ensuring that transitions to eCooking are sustainable requires careful consideration of local contextual factors such as energy access, school infrastructure, the compatibility of eCooking with school menus, the number of students being served meals, and access to suitably sized eCooking equipment. Engaging school cooks in the implementation process, understanding individual needs and cooking practices, providing eCooking appliances that are compatible with local cooking practices, and training school cooks on eCooking are key to ensuring the success of eCooking interventions and maximising gender benefits (ie, time savings and

reduction in health impacts) for this largely female workforce. By integrating electrification and clean cooking during planning, projects can be designed to meet the extra electricity demand from eCooking, ensuring optimal and sustainable energy supply systems.^{35,36}

Contributors

YK, ML, and RS wrote the summary, introduction, results, and discussion sections, and reviewed and edited the manuscript. YK, RS, JN, and BO performed data analysis and interpretation. YK wrote the Guinea case study. RS wrote the Nepal case study. YK and JN wrote the Lesotho case study. BO wrote the Kakuma case study. KG contributed to the Kakuma case study. FFN and CR contributed to the introduction and discussion sections. RB reviewed the entire manuscript. All authors reviewed and commented on the final manuscript and were responsible for the decision to submit the Personal View.

Declaration of interests

ML has received consultancy fees for GAMOS for work on the Modern Energy Cooking Services programme. All other authors declare no competing interests.

Acknowledgments

We thank the World Food Programme teams in Lesotho, Guinea, and Nepal for their support and contributions to the data collection process. We also thank Nigel Scott and Will Clements for reviewing the calculations of the Guinea case study. This study was funded by the UK aid-funded programme, Modern Energy Cooking Services. Ethical approval and informed consent were obtained for each trial in this study. Data presented in this Personal View are available from the corresponding author upon request.

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