

Viable, Reliable, and Buyable: Propane for Electricity Generation in Haiti

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Abstract— Electricity production in Haiti largely relies on gasoline or diesel generators whose fuel supply is frequently threatened by political, civil, and economic unrest. Retail sellers have recurring shortages, which leaves black-market fuel sales as the more dominant fuel access network. Our research monitors the black-market “street” prices for gasoline and diesel for one year in the second largest city, Cap Haïtien. We have also monitored the price and availability of propane, which has not experienced the same shortages or price variability. Propane, therefore, is the least expensive and most readily available fuel for generating electricity at small scales. This data has encouraged us to deploy three small gasoline generators that have been modified to operate on propane in hopes of providing a viable, reliable, and buyable solution for individuals, organizations, and businesses that are experiencing energy poverty.

Keywords—Haiti, Propane, Electricity Generation, Black Market Fuel Sales, Energy Poverty, Energy Equity

I. INTRODUCTION

Other work has described the beleaguered operations of the state-run utility, Electricité d’Haïti, whose electric grid is largely inoperable [1]. For businesses and organizations that can afford them, solar photovoltaics with battery storage offers an effective off-grid electricity solution, but the initial deployment costs can be a barrier to many. The low entry costs of gasoline and diesel generators make them a popular alternative which results in a heavy reliance on imported fuels for the energy needs of public, private, and civil society sectors [2]. Frequent and widespread fuel shortages, often the result of heavily armed gangs seizing control of fuel distribution stations or hijacking delivery trucks

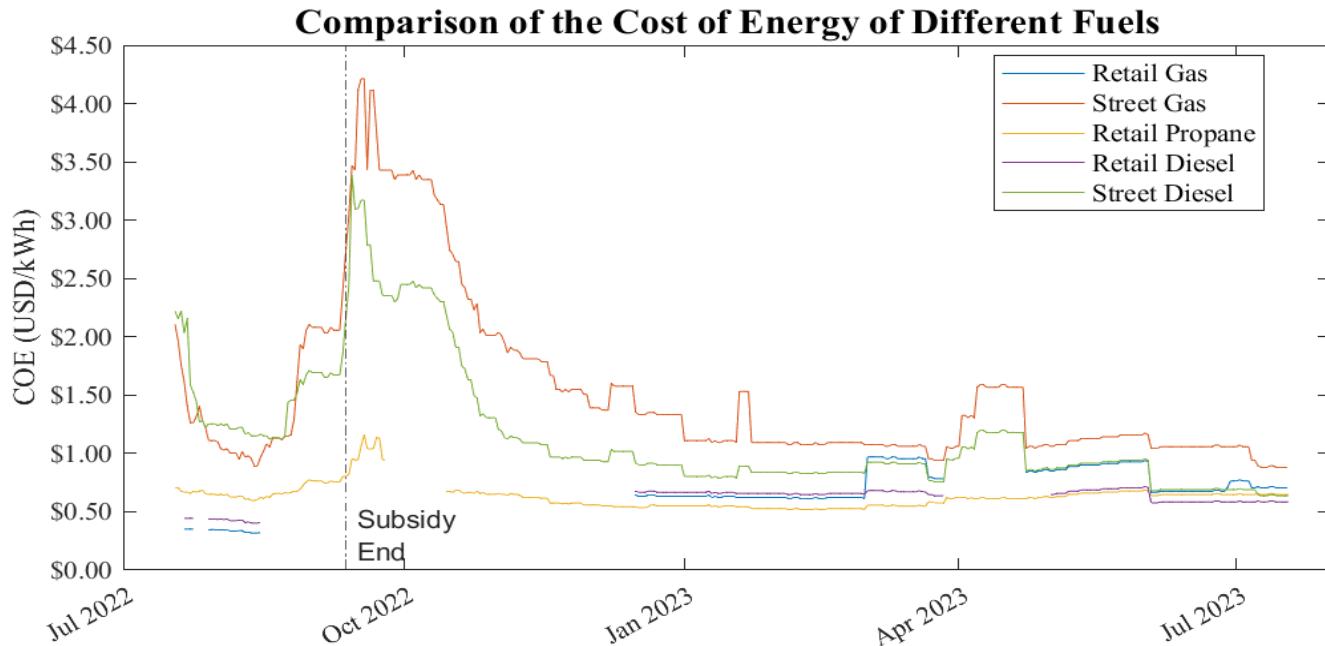


Fig. 1 Plot comparing the Cost of Energy (COE) over time for gasoline, propane, and diesel found at gas stations or propane refilling facilities (Retail) or being sold on the black-market (Street). Since subsidies were terminated, propane has the lowest average COE and greatest price stability.

on route to other cities, have caused multiple weeks-long shutdowns of the entire country in recent years [3]. To meet demand, a black-market exists in which sellers of gasoline and diesel charge exorbitant prices that exhibit high variability.

Herein, we provide the methodology and results for collecting black-market fuel prices and availability over one year period. Based on these results, we propose that small propane-fueled generators may be deployed as a more cost-effective and reliable solution to meet immediate energy needs in Haiti. In addition, we discuss the increased safety and shelf life of propane as an added benefit to the unique energy landscape of Haiti.

II. METHODOLOGY

A. Price and Availability of Fuels

To collect pricing data, the School of Engineering and Computer Science at Baylor University and the nonprofit organization JustEnergy collaborated to employ a Haitian colleague as a research assistant who lives near Cap Haïtien. He used his personal networks to collect the daily selling price of black-market gasoline and diesel. He also monitored the availability of fuel at retail gas stations and retail propane refilling stations.

The official unit of currency in Haiti is the Gourde (HTG). However, fuel pricing is usually transacted in a super unit called the Haitian Dollar (HD) where 1 HD = 5 Gourde (HTG). To calculate fuel prices Google Finance was used, where Haitian Dollars were first converted to Gourde and then to USD on a daily basis. The average conversion rate over this time was 137.8 HTG/USD.

Figure 1 shows the cost of energy (COE) based on the pricing of retail and black-market gasoline and diesel. Gaps in the data indicate unavailability of the fuel source. The cost of energy is calculated by dividing the cost per unit volume by the energy density for each fuel. A generator efficiency of 18% was assumed for all fuel types. As an example of this calculation, consider a gallon of gasoline selling for \$10 (USD), as shown in (1). Energy densities used for gasoline, diesel and propane were 43.7, 48.3 and 32.1 kWh/gallon, respectively [4]. The unit, gallons, was used in calculations instead of SI units due to the nature of the actual sales of fuel.

$$\text{COE} = (10 \text{ \$/gal}) / (0.18 * 43.7 \text{ kWh/gal}) = 1.27 \text{ \$/kWh} \quad (1)$$

It is noteworthy that this method of calculating COE *does not* include the costs of the generator itself, nor does it include maintenance, paying an operator, or any distribution infrastructure. Furthermore, as a point of reference, the average retail sales price of electricity in the United States during April of 2023 was \$0.165 (USD/kWh), a price which *does* include all generation, transmission, and distribution costs, and yet is a fraction of the Haitian costs [5].

III. RESULTS AND DISCUSSION

A. Political and Economic Context

Until September 11, 2022, the retail prices of gasoline and diesel were fixed at subsidized rates of 50 and 70 HD per gallon corresponding to about \$2.10 and \$2.94 (USD). However, on September 11, interim Prime Minister Ariel Henry announced that the subsidized rates would be discontinued to divert funds to social programs (shown in the vertical line in Fig. 1). Ending the subsidies would save “about 20% of the country’s \$2 billion annual budget” [6]. At the time this was announced, retail gas stations in Cap Haïtien had already been without fuel for nearly a month. The next day, September 12, heavily armed gangs took over the fuel distribution port, Varreux, in Port-Au-Prince and held it for six weeks, essentially holding the energy sector hostage and halting transportation, business, education, and medical care [7].

B. Black-market Fuel Sales

Our Haitian research assistant reports that instead of fuel trucks unloading at retail gas stations, the loads are often delivered to clandestine sites where fuel is stored in 55-gallon water drums and similar containers. Furthermore, it is widely believed that the operators of the clandestine sites are also the owners of the retail gas stations. A private network of “street sellers” is allowed to collect fuel to be sold on street corners to motorcyclists and those in automobiles. On at least one occasion, police officers have moved to the head of the line to refuel their motorcycles without cost, presumably in exchange for not enforcing existing laws about illicit fuel sales. To buy fuel in the larger volumes that might be needed to operate a generator, buyers must bring their own large containers to collect it. The large majority of end users purchase fuel in this way. At other times when fuels have been more readily available at retail gas stations, day-long lines and heated arguments were the norm and often resulted in violence.

Propane, however, is not sold on the black-market in Cap Haïtien. Its primary use in Haiti is as a cooking fuel. Buyers may have to wait in line occasionally, but these lines are less problematic than those for gasoline and diesel. Figure 2 shows a propane refilling station in Cap Haïtien.



Fig. 2, A propane refilling station in Cap Haïtien, the sign translates to “it’s for you gas.” This station used a gasoline generator to operate its propane pump (July 2023)

C. Interpreting the Data

Over the last 365 days we have gathered data and found that gasoline was only available from retail gas stations 209 days (57%) but has been continuously available on the black-market. Propane, however, was available 346 days (95%). Once the subsidies were shut down by Henry on Sunday, September 11, 2022, the street price for black-market fuels rose significantly. By the following Sunday, September 18, street prices for gasoline had increased by 76% and diesel by 71%. Retail propane rose less, in comparison, by 44% while retail gasoline and diesel were not available at all. For much of the time since the subsidies ended, propane has been the least expensive fuel on a USD/kWh basis.

Across the dataset, it is shown that regardless of political, economic, or civil unrest, propane remained the most stable source in both price and availability. Although there are slight fluctuations in propane price, these changes are more in line with expected market variation. The instability of diesel and gasoline in both street market prices and retail availability presents a significant barrier to individuals and organizations that rely on this fuel to conduct their day-to-day operations and business. On average, the price of diesel and gasoline exceeded \$10 (USD) and exhibited pricing spikes over \$25 (USD) per gallon. These extreme swings in pricing create an atmosphere of uncertainty in the supply chain – which further exacerbates unrest and tensions within the public.

D. Deployment Costs

As a proof-of-concept, we have deployed three propane generators in Haiti. Fig. 3 shows one of the Honda EU2200i gasoline inverter generators converted to run on propane using a conversion kit from Greenergy-us.com. We chose the Honda EU2200i because it is a very popular portable generator with a built-in inverter. The inverter allows the engine to operate at variable speeds while maintaining a steady 60 Hz at a rated 1.8kW output power (120 VAC and 15 A). The generator has a mass of approximately 22 kg which allows it to be under the checked bag weight limit for most airlines, allowing for a wider range of delivery methods. The cost for each Honda EU2200i generator was \$1,200 (USD) and \$290 (USD) for each conversion kit from Greenergy.



Fig. 3, Converted Honda EU2200i generator and propane tank deployed in Haiti (May 2023)

Empty propane tanks were purchased in Haiti for \$200 (USD), as rentals are not available.

Field Testing

Generator 1 has logged 352 hours of operation with a family and small business, Generator 2 has logged 75 hours at a church, and Generator 3 has logged an as yet unknown number hours at a children's home and school. There have been no problems in operation. Maintenance in the form of oil changes, air filter cleaning, spark plug changes, and spark arrester cleaning is being performed by qualified Haitian personnel associated with the JustEnergy nonprofit organization.

E. Increased Safety and Shelf Life of Propane

Fuels are often hoarded to prepare for future shortages in Haiti using unregulated containers. For example, plastic containers originally holding vegetable oil are commonly used to store gasoline in private homes for future usage. Storing fuel in these containers is like putting money in a savings account.

This particular expression of energy poverty in Haiti led to a horrific tragedy in December of 2021 when a gasoline tanker overturned in Cap Haïtien and began leaking. Impoverished residents of nearby homes came to collect the gasoline from the leaking tanker in makeshift containers for its economic value. Surrounded by people, the tanker eventually exploded resulting in the deaths of over 77 people. Nearby homes with stored fuel exacerbated the fire [8].

Propane is difficult or impossible to store in improvised containers because of the high pressures required for it to remain a liquid. Furthermore, propane does not degrade in quality over time like gasoline, which has a shelf life measured in months.

IV. GOALS AND OBJECTIVES

The work described above aims to help further progress in the United Nations Sustainable Development Goals (SDGs), namely Goal 7 (to increase modern energy access with emphases on affordability, reliability, and sustainability) while being tangentially related to additional goals: “Energy access is the ‘golden thread’ that weaves together economic growth, human development and environmental sustainability... Energy is also at the heart of many of the other SDGs, including those related to gender equality, poverty reduction, improvements in health and climate change” [9]. More specifically, Target 7a mentions “cleaner fossil-fuel technology” and Target 7b highlights the need to address the energy needs of “small island developing States” such as Haiti [10].

This work seeks to understand what role propane may have in increasing energy access in Haiti’s unique electricity generation landscape. The use of propane as a fuel source also presents new opportunity to consider potential environmental and public health benefits.

V. CONCLUSION

Small-scale electricity generation from propane, shows much promise in Haiti based on multiple criteria: the price and availability of fuels, lower (than solar) initial deployment costs, increased safety, and shelf life during storage. Our initial field tests show promise but will require additional time to fully observe the feasibility of this as a long-term deployment. Thus far, our Haitian partners are optimistic and grateful for the respite in the fight for fuel.

Some considerations for our work moving forward include further contextualizing the implications of using propane – a fuel traditionally used for cooking. More widespread use of propane for electricity generation could increase demand enough to make it no longer affordable as a cooking fuel. There remains the ethical question about the unintended consequences of this specific energy intervention. Regarding environmental and public health, the combustion of propane emits slightly less CO₂ than gasoline or diesel (0.22, 0.26, and 0.25 kgCO₂/kWh, respectively [11]) and propane also has fewer other pollutants. However, it is also true that smaller generators (such as those used within this study) tend to have lower efficiencies. The 1.8 kW Honda generator running on gasoline has an efficiency of about 18% at full load, whereas a 100 kW diesel generator could achieve 35%.

A more thorough literature search for case studies of using propane for electricity generation could further inform this work moving forward. Additionally, we hope to develop and better understand efficiency vs. load curves for generators using gasoline, diesel, and propane. This also brings to question the scalability of propane run generators – could this be a fuel solution to a 100kW generator operating a hospital? Given the previous work of JustEnergy in solar energy deployment in Haiti, we would want to compare the net present cost of operating generators to that of solar photovoltaics with energy storage. This would help us to better describe the leveled cost of energy over the lifetime of the equipment which has broader

implications in terms of sustainability and infrastructural development.

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REFERENCES

- [1] Boston University Institute of Sustainable Energy, "Assessment of Haiti's Electric Sector," 2018. [Online]. Available: <https://www.bu.edu/ise/files/2018/03/FINAL-Haiti-ElectricityReport-March-2018.pdf>
- [2] B. Thomas, K. Garrett, *Installing Solar for Haitian Civil Society with Emphases on Maintenance and Empowerment*, IEEE Global Humanitarian Technology Conference, 2022
- [3] M. Wilner, J. Charles, "U.S. considering request for international intervention in Haiti as fuel crisis spirals," Miami Herald, Miami, Oct. 9, 2022.
- [4] The Engineering Toolbox, "Fossil and Alternative Fuels – Energy Content," www.engineeringtoolbox.com/fossil-fuels-energy-content-d_1298.html
- [5] US Bureau of Labor Statistics, "Average energy prices for the United States, regions, census divisions, and selected metropolitan areas," https://www.bls.gov/regions/midwest/data/averageenergyprices_selected_areas_table.htm
- [6] J. Charles, "Haiti's decision to raise fuel prices met with fire, fury, paralysis," Miami Herald, September 13, 2023
- [7] E. Dupain and H. A. Alam, "Critical Haiti gas terminal freed after weeks of talks with G9 gang leader," CNN, November 6, 2022
- [8] J. Charles, "At least 77 dead in Haiti gas explosion. Death toll could rise," Miami Herald, December 15, 2021
- [9] IEA. "World Energy Outlook Special Report." Energy Access Outlook 2017, International Energy Agency, Oct. 2017, www.iea.org/reports/energy-access-outlook-2017.
- [10] UN General Assembly, "Transforming our world: the 2030 Agenda for Sustainable Development," Oct. 2015. Accessed: Mar. 24, 2022.
- [11] The Engineering Toolbox, "Combustion of Fuels - Carbon Dioxide Emission," https://www.engineeringtoolbox.com/co2-emission-fuels-d_1085.html