Electricity Pricing Strategy for Ethiopia

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Summary

Optimal electricity pricing policy to realize the potential of energy as a major driver of prosperity in Ethiopia. A phased road map, starting with location-based differentiation, evolving to market-based pricing, can

- yield $3B/year in direct revenue from electricity by 2028,
- corresponding to $40B/year of long term GDP impact,
- and open a self-sustaining financial path to 10x increase in electrification by 2050.

Background

Energy is the key to prosperity. That has been true throughout history. In modern times, 1 kWh of electricity generates $0.40 of GDP[1,2]. The current rapid growth of power generation capacity in Ethiopia promises a bright future. Generation capacity is expected to reach 10GW in the next couple of years, with the GERD contributing about half of that. However the impressive achievements of the last few years are just the beginning. Global average capacity is more than 1kW per capita[3]. So **Ethiopia needs more than 100GW** to reach the current world average. That means growth must be sustained and accelerated for years to come. But power generation, transmission and distribution are very capital intensive. For example, while the GERD cost over $5B, the corresponding transmission and distribution is expected to cost almost twice as much. So in a country with many competing development priorities, how can we pay for another 10x growth in electrification? It must be a self-sustaining economic engine, a process that pays for itself as it grows.

The challenge

For self-sustaining long term growth, it is essential that generated electricity is consumed and producing revenue as soon as possible. But in all electric power grids, there are gaps between supply and demand at different points:

	Supply	**Demand**
Temporal	- seasonality of hydropower - weather impacts solar and wind	- time of day - day of week
Geographic	- new generation sites have excess power until distribution catches up	- urbanization - industrialization - population growth - economic growth

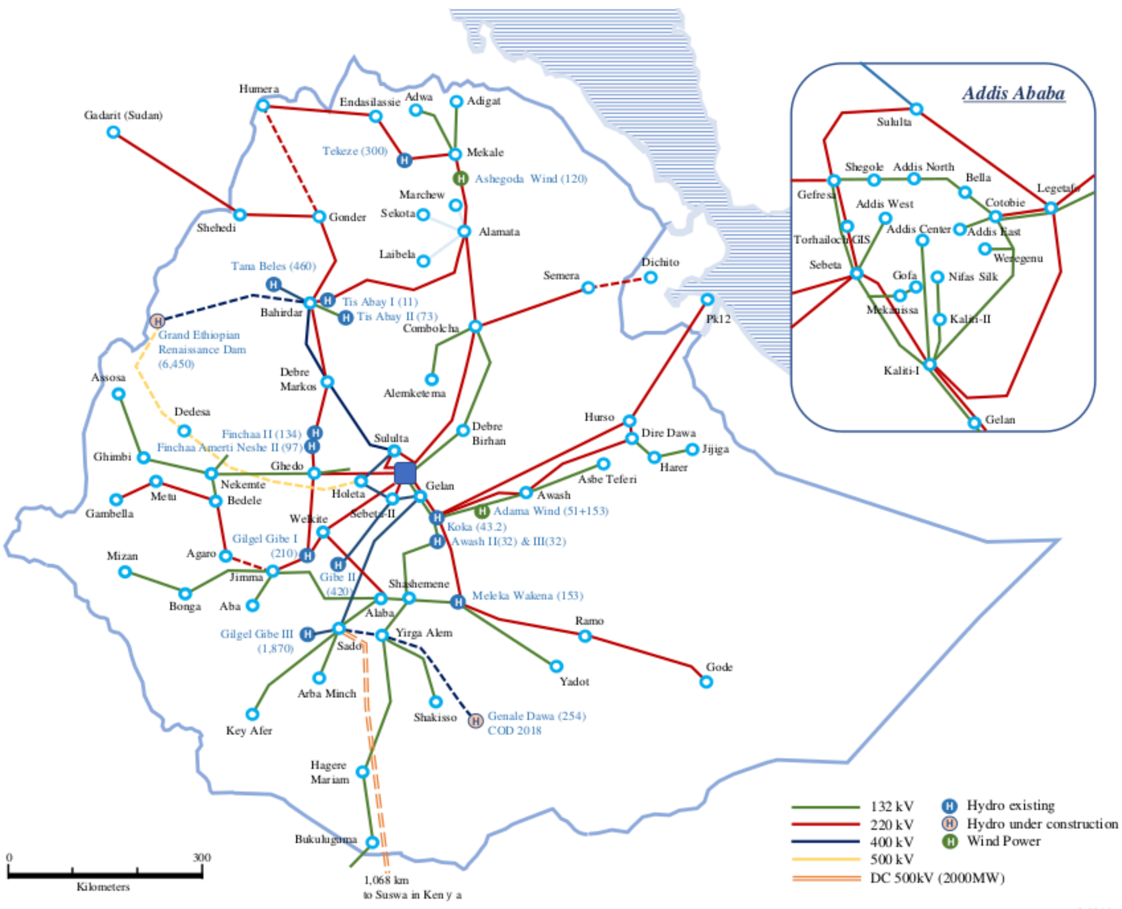
In Ethiopia today, due to the rapid rate of growth both on the supply and the demand side, the geographic gaps can be significant.

[1]Csereklyei, Zsuzsanna and Rubio Varas, Maria del Mar and Stern, David I., Energy and Economic Growth: The Stylized Facts (November 1, 2014). CCEP Working Paper 1417, November 2014, The Australian National University.
[2]Ourworldindata.org, “GDP per capita vs. energy use, 1990 to 2015” Data source: International Energy Agency (2025); Data compiled from multiple sources by World Bank (2025).
[3]According to the US Energy Information Administration, global electricity capacity in 2022 was 9TW.

This is not unique to Ethiopia. Wherever and whenever rapid electrification occurs, there is a chicken-and-egg problem of generation and distribution. Eventually, as the country develops the infrastructure growth rate slows down, and energy supply and demand become more geographically balanced. But in the coming years, the geographic imbalance is a challenge for Ethiopia's energy equation leaving some generation capacity "stranded". But if this stranded energy can be used, the revenue will accelerate self-sustaining growth.

The strategy should thus be to **attract demand to where there is excess capacity, while balancing the load and available power where demand exceeds supply.**

The key to such a strategy is **pricing optimization**.



Principles of pricing mechanism design

Readers already familiar with game theory can skip this section.

Efficiency

The overarching goal of a pricing mechanism is to achieve an energy allocation which maximizes the total benefits to all participants, buyers and sellers, a sum sometimes referred to as “social welfare”. An allocation that maximizes social welfare is called **efficient**. Conversely, if some energy is allocated to something less valuable than something else that it could have gone to, it is an **inefficient** allocation.

Feasibility

But efficiency is just a goal, there’s no guarantee it can be achieved. To understand what can be achieved, we have to look at what it takes for an allocation to be **feasible**. To be feasible, a resource allocation has to be acceptable to all parties involved. Meaning the benefit they get from the result is not worse than zero.

Individual rationality

Feasibility is based on the idea that the benefit has to be greater than the cost or else the player can choose to not play. This is what game theorists call **individual rationality**: no player will willingly do something that has negative utility for themselves.

A couple of subtleties on the concept of rationality in the real world:

1) Some participants may be willing to lose in the short term if they believe it is beneficial in the long term. This is just **investment**, which is still rational when understood over the appropriate time scale.

2) When the provider is state owned, the time horizon of the investment may be much longer than it would for a typical private company, and the stakeholders may be citizens rather than shareholders, but the concept is similar from a mechanism design point of view. A state owned entity may willingly sell their service to the public at a loss as part of a broader social welfare objective. This is just a **subsidy**, which can be included in an individual rationality framework as equivalent to the government “giving” money to some buyers who can then use it for their purchase.

Thus the framework of rationality is not just useful for private business. It allows the design of an optimal pricing policy that achieves efficient resource allocation, using **commercial principles** to achieve the best results whether the participants are state or private entities.

Now let's consider what feasibility means for the buyer and the seller.

Buy-side feasibility and sustainability

Each buyer of energy, whether it is a home, an office or a factory, has their own underlying true value for energy, based on the activity it enables. If the price they pay is greater than this value, their net benefit becomes negative, and rationally, they will not buy at all. We say a price is **feasible** for the buyer if each additional unit of energy consumed generates more value than it costs, so the buyer can continue operating in the short term.

But when capital expenses are accounted for via depreciation, amortization, and interest, there's a lower break-even price of energy: the price at which the buyer can not only continue operating in the short term, but also recoup their initial investment in the long term. This is the price we call **sustainable** for the buyer. If the buyer can reasonably predict that the price of energy will be at or below that threshold, then they will be willing to continue investing.

Sell-side feasibility and sustainability

Similarly, the seller has a marginal cost for each unit of energy. If the selling price is above the marginal cost, then each unit has a positive profit, and the seller is better off selling than not selling. Such a price is **feasible** for the seller.

But a price point may be feasible in the short term but still not enough to recoup the fixed costs, e.g. capital investments in generation and transmission. So there's a higher price threshold where the producer can make enough marginal profit to recoup their investment over the long term. This is the price we call **sustainable** for the seller. If the producer predicts that they can sell above the sustainable price, they will be willing to invest in more generation and transmission.

Equilibrium

Any allocation that fails to satisfy the feasibility constraints may of course still exist, but it will be *unstable*. Unstable outcomes take many forms, e.g. chronic shortages, degradation of quality, or system collapse. Feasibility and sustainability for both buyers and sellers must be satisfied to achieve a ***realistic and stable*** economic outcome, also known as an **equilibrium**.

Incentive compatibility

Still, an equilibrium doesn't guarantee efficiency. To get *efficient* outcomes within the set of equilibria, the pricing mechanism needs to "know" the *true* value of all participants. So it has to ensure buyers and sellers reveal their true valuation of the resource. This is called **incentive compatibility,** namely the property that a "truthful" strategy is optimal for all players.

An example of the opposite – incentive incompatibility – is pricing by industry sector. For example, if agriculture gets lower prices than the information technology sector, that creates an incentive for farmers to host computers on their farm. If households get lower rates than industry, it creates an incentive for commercial activity to be hidden in the home. Of course this can all be policed to some degree, but that raises the total cost to society of the energy, thus reducing overall social welfare. In other words, it creates resource allocation inefficiencies. Thus, **price differentiation by industrial sector or type of buyer is incentive incompatible and therefore inefficient**.

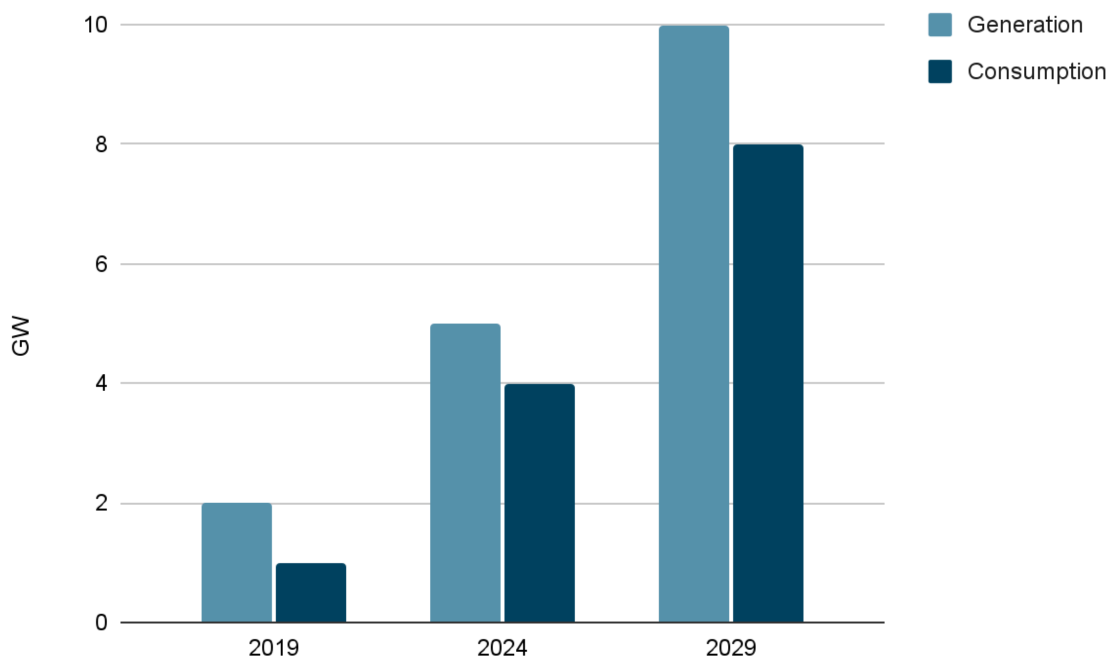
More fundamentally even if all participants are perfectly honest, it is impossible to centrally predict all of their valuations. For example, the value of energy for irrigation can change based on the weather or global food markets. Similarly the value of energy for cement can change based on the real estate market. Is 1kWh at a school more valuable than 1kWh used for refrigerating food? No one can objectively and correctly prioritize every possible use of energy in society. So imposing subjective preference can lead to misallocation of resources, and reduction of the overall social welfare. Therefore, fixing prices based on **subjective value judgements on different energy uses is generally inefficient**.

Therefore the best way to achieve efficiency, to truly maximize social welfare value of energy, is to set **prices based on demand** and make them responsive over some reasonable time scale.

And since storing and transmitting energy has a physical cost, the demand-based price of each unit of energy will generally change based on location and time.

Ethiopia's Energy Reality

Ethiopia is in the midst of extraordinary growth in energy. The amount of electricity produced and consumed has tripled in the last 4 years. As noted in the introduction, there's no greater investment for economic development than energy, so the on-going growth in this sector is arguably the greatest force for prosperity in the country over the coming years.



At the same time, revenues and earnings have kept pace with production, with EEP revenues growing at 32% per year and EBITDA at 35% per year. This indicates that *operating margins* are fundamentally sound. Each unit of energy sold brings in more revenue than it costs to generate, transmit and distribute.

	EEP Financial Summary[4] ('000 Birr)					Annual growth rate
	2024	2023	2022	2021	2020	
Revenue	27,137,357	22,484,423	19,086,013	13,028,901	9,013,936	32%
EBITDA	23,595,843	7,352,654	7,916,956	6,935,768	7,124,046	35%
Depreciation	8,508,822	8,157,322	8,031,725	7,657,472	7,574,218	
Operating profit/(loss)	15,087,021	(804,668)	(114,769)	(721,704)	(450,172)	
Finance costs	25,234,574	24,034,129	29,987,169	22,072,834	29,201,297	
Net profit/(loss)	(10,147,553)	(24,838,797)	(30,101,938)	(22,794,538)	(29,651,469)	

[4]Ethiopian Electric Power, Independent Auditor's Report and Financial Statements, https://www.eep.com.et/?page_id=798

However there is a clear challenge. Because of financing costs, the net profit is still negative. So using our mechanism design terminology, the current situation is *feasible but not sustainable*.

While the bottom line is improving (net loss decreased from 30B to 10B birr in the last four years), generation and transmission being extremely capital intensive, if this growth is to be sustained and even accelerated, the challenge will remain..

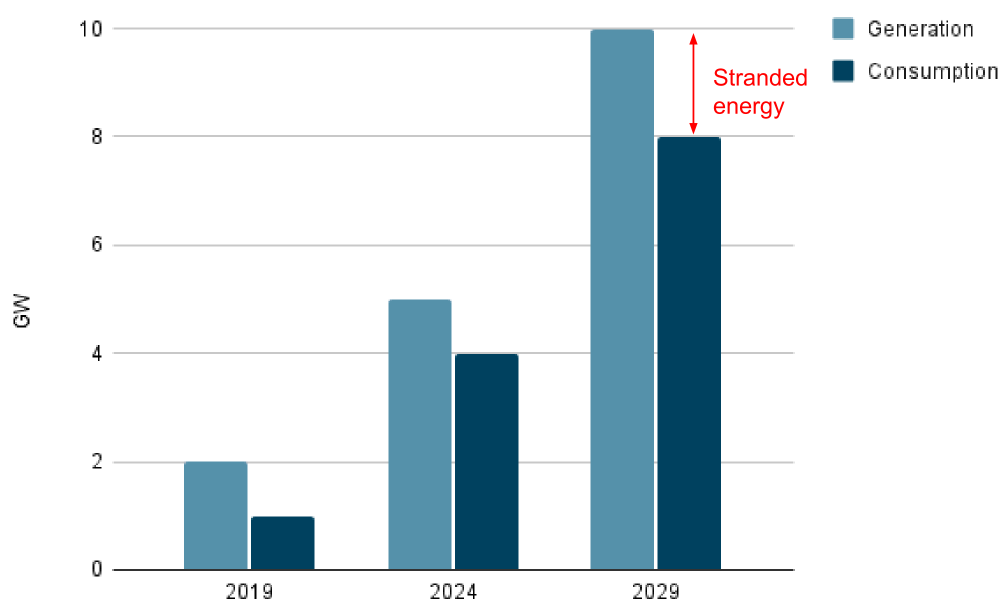
Going forward the choices are

a) *subsidize* the deficit from government funds, directly with budget support or indirectly with non-performing loans; which is not realistic, as electricity must be a source of growth, rather than a drag on the rest of society
b) *slow down* new investment to prioritize repaying debts more quickly; but delaying electrification is prolonging poverty.
c) *self-sustaining investment* in electrification; this is the way forward to development and prosperity. **The achievements of the last 5 years must be repeated 10x** for Ethiopia to become a middle income society. And that is only possible if done **in a self-sustaining way, where electrification can pay for itself**.

Opportunity: self-sustaining & accelerating growth

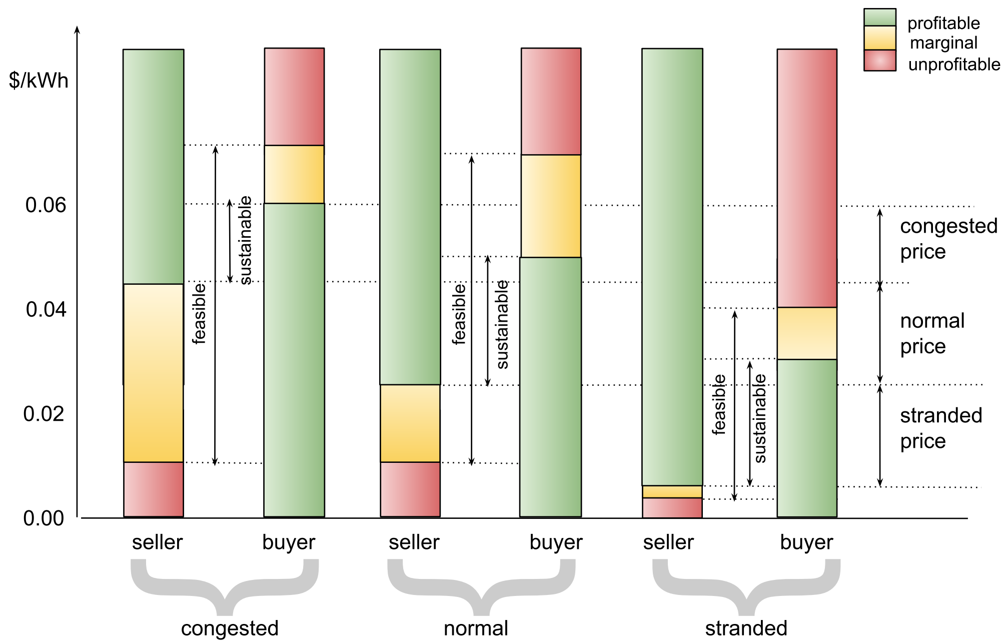
Simply increasing prices on all existing customers risks pushing many into the unsustainable range, decreasing revenue as well as social welfare. What is needed is optimized pricing. And there's a clear opportunity for optimization.

When there is rapid growth, energy generation is always one step ahead of transmission, distribution and therefore consumption. This creates, in some locations, a gap between supply and demand – called **stranded energy**. At the same time, other locations experience consumption outpacing distribution, creating **congested** areas with power instability.



If these gaps can be closed with new demand that can make use of stranded energy, revenue and profitability can increase without pushing existing customers to unsustainable levels. The stranded energy by definition has almost zero marginal cost for the seller, as the investment in generation has already been made. And there is very little fixed cost if the buyer is flexible enough to bring the demand to where the supply is. Therefore, from the seller's point of view, almost any price is *feasible* and *sustainable* if a willing buyer is found for *stranded energy*.

To simplify we can call "normal" the energy that can be distributed to users when and where the demand already exists (residential, agricultural, industrial demand). And "stranded" the energy that is being generated but cannot yet reach demand without additional investment in transmission and distribution. While "congested" refers to energy in areas where demand already exceeds capacity.



As illustrated above, prices ranging from 2.5¢ to 5¢/kWh for normal energy, 0.5¢ to 3¢/kWh for stranded energy, and 4.5¢ to 6¢/kWh for congested areas could be sustainable for buyer and seller[5]. By differentiating in this way, we

- minimize wasted energy
- ensure that high-value energy uses are not crowded out by low value uses
- maximize revenue for the provider
- maximize social welfare value of the energy

In other words, *optimal efficiency* can be achieved with the right kind of differentiated pricing.

[5]These figures are for illustration purposes. More precise methodology is discussed in the next section.

Implementation of efficient pricing

One way of achieving efficient pricing is dynamic supply and demand-based pricing.

Examples

ERCOT, the Texas grid with 150GW of installed capacity and 85GW average generation, is a well known example of a dynamic energy pricing market. Demand varies a great deal due to weather, time of day, etc. At the same time, with 15% of the generation being solar and 25% wind, ERCOT's supply side also varies a great deal with the weather. Supply and demand are calculated every 5 minutes across 17,000 pricing points in the grid. To balance the supply and demand, ERCOT offers customers different choices: real-time pricing where prices change every 5 minutes, day-ahead pricing where prices are set one day in advance in hourly chunks, and traditional fixed prices. Flexible load in low-demand areas average 3¢/kWh, while inflexible load in high demand areas averages 10¢/kWh. The most sophisticated buyers who only buy excess capacity achieve prices around 2¢/kWh.

NORDPOOL, the leading power market in Europe, with 120GW of generation capacity in 7 Nordic and Baltic countries, plus additional connections with 9 countries in western Europe, uses both real-time and day-ahead dynamic pricing. Average prices are around 2¢/kWh in low population areas, and around 7¢/kWh in high demand areas.

Both ERCOT and NORDPOOL have sometimes seen *negative* prices! Mild winters in northern Europe significantly reduce heating demand, while cold weather in Texas reduces demand for air-conditioning. At the same time, industrial users adjust their demand based on price. Among Bitcoin mining data centers, the most sophisticated flexible demand-response buyers, some of the leading companies average around 2¢/kWh.

Closer to home, **Ethiopian Airlines** serves as an example of a state-owned enterprise successfully using efficient pricing on a commercial basis. Prices are dynamic, driven by competitive supply and demand on a given route at a given time, rather than by incentive incompatible features like customers' industrial sector. This approach exhibits many of the efficiency features discussed above: incentive compatibility between buyer and seller, and *optimized* resource allocation with sensitivity to marginal costs for *feasibility* and *sustainability* with respect to high-fixed costs assets.

Roadmap for Ethiopia

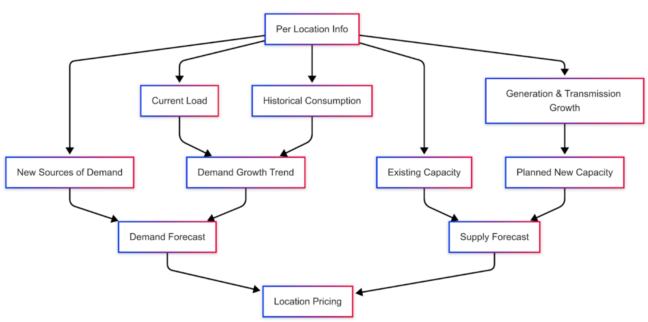
Each of the following phases would have to be rolled out while respecting contractual obligations, with changes applied to new power purchase agreements and renewals.

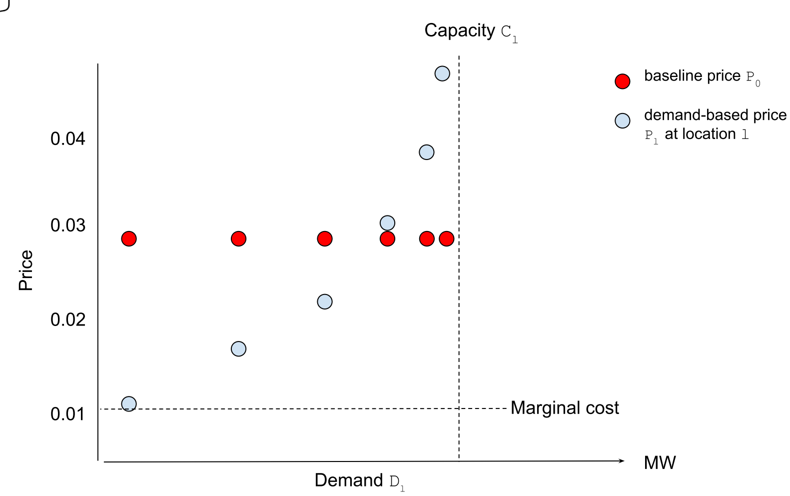
Phase 1: Geographic price differentiation based on supply and demand

A first step toward pricing optimization is to differentiate by location based on medium term demand and supply. The pricing locations could be defined as each of EEP's [192 substations] or broader regions encompassing multiple substations. Using forecast demand and capacity for each location, prices can be geographically differentiated, **making overloaded locations more expensive and locations with excess capacity cheaper**. The formula for demand-based price for a location could be something like:

$$P_l = P_0 \times \rho / (1-\rho_l)$$

where $\rho_l = D_l/C_l$ is the load factor for that location l, C_l and D_l the forecast capacity and demand for that location, $\rho = \Sigma_l D_l / \Sigma_l C_l$ is the average load factor across all locations, and P_0 is the "baseline" price without location differentiation. Roughly[6], this would yield the target average price P_0 but with strong geographic differentiation.





[6]This formula is oversimplified, a more accurate one would use the distribution of load factors, rather than the average ρ.

Implementation

- All **existing PPA** prices continue to be honored until their contracted expiration
- **New PPA**s are under the new pricing immediately. This encourages demand growth in locations with excess capacity and reduces pressure on congested areas, while increasing revenue and reducing lost opportunities due to inefficient pricing.
- Customers **renewing PPA**s for which the new price would represent a large increase (e.g. more than 20%) can be phased in to the new prices over multiple years. All other renewals get the new pricing immediately.

Phase 2: Market pricing

The next step in the evolution is dynamic market pricing, using actual demand directly revealed from customers rather than forecasts. In this phase, the market is not real-time but using an annual **auction** for available capacity at each location. Any customers who are unwilling or unable to participate in the auction (e.g. because of timing or other issues), would have the option to continue under the phase 1 pricing policy.

Implementation

- On a predetermined annual schedule, run a capacity auction for each location that has a large enough amount of available capacity (e.g. 100MW or more). Available capacity here is defined as the total capacity of the location minus currently contracted capacity.
- Available capacity would be made available for new and existing customers to bid on.
- Each buyer submits a sealed bid for their desired capacity at a price per kWh.
- Available capacity is divided into different quantities for different buyers, allocated and priced using an incentive compatible mechanism such as the Progressive Second Price Auction.
- The schedule would be staggered across locations, starting with the locations with the lowest price (most available capacity) and moving up to busier locations. This sequencing gives confidence for demand to migrate to less congested areas.
- Locations where available capacity is too small (e.g. less than 100MW) are excluded.
- Reserve price equal to marginal cost guarantees that price is feasible for the seller.
- Winning bidders get allocated some quantity and a per unit energy price by the auction. The allocated quantity is the new contracted capacity for that buyer.
- A modest contracted capacity fee independent of energy usage would be applied to prevent abuse from large allocations with low usage.
- This system can be realized with a relatively simple software platform to manage scheduled auctions.

Phase 3: Real-time market

Evolve to real-time, where the same process as phase 2 is applied on a daily then hourly basis.

Implementation

- Real-time energy metering and data collection
- Real-time auction platform with APIs for bidding, pricing and allocation
- Real-time price and energy metering data collection feeds into monthly billing

Phase 4: Cross-border integrated dynamic markets

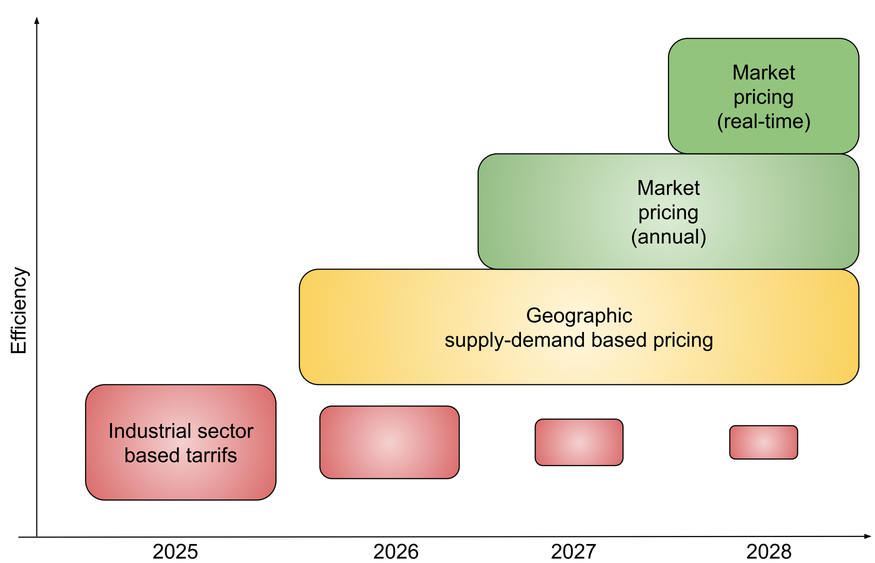
Extend the system of phase 3 to cross-border markets in the context of the Eastern Africa Power Pool. Implementation is the same as phase 3, but extended and standardized across borders.

Conclusion

This phased approach to pricing efficiency could lead to

- revenues of **$500M/year from stranded energy**,
- **$3B/year total direct revenue from electricity by 2028**, more than 10x 2024 revenue,
- balancing the grid in congested areas
- sustainably capturing higher prices from high-value inelastic demand
- keeping average prices affordable for the consumer.

The efficiency gain will compound to accelerated growth, setting the country on a path to **20GW by 2035**, and approaching **100GW by 2050**.



Appendix A: Subsidizing low-income consumers

With demand-based pricing, prices will rise wherever and whenever demand grows faster than supply; and fall where supply is growing faster than demand. In a country where per capita income is less than $1,000 per year, this raises fears that domestic consumers could get crowded out by large commercial users of energy. However, it turns out that this is not a significant danger when you consider that

- First, with respect to large commercial users, not only do they use a larger quantity of energy, but also energy is a larger fraction of their total cost. So, looking at this "competition" among buyers on a per unit basis, even lower income consumers may not actually be crowded out. For example, a household may be able to spend 500 birr for 100kWh of energy per month. But a business that consumes 1 million kWh per month but only be able to afford to pay 1M birr per month. So while the business is a bigger user, per unit the valuation of the household is 5 birr/kWh while the factory's is 1 birr/kWh. Indeed throughout the world, generally, **even low-income domestic consumers have a higher per-unit valuation than energy-intensive industries.** Consumer demand pushes large commercial energy users to less populated areas, rather than vice-versa.

- Second, to the extent that the government wants to subsidize household energy as a social welfare objective, the **subsidy is better downstream, nearest to the consumer**. E.g. direct rebates, or price subsidies for consumers at EEU, explicitly funded as a social subsidy, rather than implicitly through inefficient pricing upstream. That way, the social objective can be achieved, while also achieving the macro objective of efficient pricing and rapid energy growth for development.

Appendix B: Data centers and Bitcoin mining

Bitcoin mining is location-agnostic, unlike any other large customer of energy. Moreover, Bitcoin being an open network that anyone anywhere can join at any time, every miner is competing with every other miner. Thus, the competitive dynamics make Bitcoin mining essentially a global hunt for the lowest priced energy. And the lowest feasible price is where the marginal cost to the seller is near zero, i.e. stranded energy. So, the natural evolution of Bitcoin mining is to migrate to where there's stranded energy, *if and only if the pricing is efficient*.

Thus with the right pricing, energy providers and Bitcoin miners can have a win-win relationship. The Bitcoin miner gets the price necessary to compete with peers, and the energy provider increases revenue by monetizing stranded energy. Given Ethiopia's rapid growth, we have a historic opportunity to leverage the Bitcoin mining industry to accelerate the electrification of the country. But for this opportunity to be realized, the **pricing has to be sustainable for both buyer and seller**.

	Share of global Bitcoin hashrate[7]
USA	36%
Russia	16%
China[8]	14%
UAE	3.8%
Paraguay	3.5%
Canada	3%
Ethiopia[9]	2%

The feasible prices from the buyer's perspective are constrained by the fact that Bitcoin miners are competing globally. For reference, large US Bitcoin miners, using sophisticated energy markets, achieve prices ranging from ¢1.0 to ¢4.0/kWh.

	Capacity (MW)	Energy price per kWh	Reference
Core Scientific	1,300	¢2.4	CORZ Fiscal Q4 2024 report
Riot Platforms	1,200	¢1.0 - ¢3.9	RIOT June 2024 report
IREN	500	¢3.0	CLSK Fiscal Q1 2025 report
CleanSpark	750	¢4.0	IREN Fiscal Q2 2025 report

Considering the higher cost of doing business in Ethiopia, due to more expensive logistics, more complex regulations, higher taxes and the perception of risk in Africa, to be attractive to these buyers the price of energy in Ethiopia must be below **what Bitcoin miners get on average globally**.

There is a contrast here between traditional IT data centers and Bitcoin mining, even though they are superficially similar. For traditional IT, like websites, corporate databases, and consumer services, bandwidth and location tend to be important. So they are best suited for IT parks, industrial parks and urban areas. Just like other industrial and commercial customers. For Bitcoin mining and high energy computation, energy price is the dominant issue, while

[7] Estimate by Hashrate Index, December 2024.
[8] Four years ago, China accounted for 40% of hashrate. Despite a "ban" in 2021, a lot of Bitcoin mining continues in the country.
[9] In October, estimates had Ethiopia at around 2.5% but global hashrate has been growing and this estimate is more up to date.

bandwidth and location are less important. Indeed a Bitcoin miner will choose to go to the middle of the Sahara or Antarctica if the energy price is low enough.

Without strong geographic differentiation of pricing, energy hungry Bitcoin mining data centers will be competing for power with traditional IT data centers, electric car charging, and other growing sources of demand. Trying to segregate these customers by industry type risks turning a mutually beneficial relationship into an adversarial cat and mouse game, and ultimately making energy less efficient, more expensive and delaying growth. The key, to **sustainably** serving high-priced traditional sectors, while also satisfying these new low-price high-volume customers, is incentive compatibility: location-based differentiation in pricing.

If efficient optimized pricing is implemented, EEP could generate up to **$500M/year of additional revenue** from Bitcoin mining data centers without any effect on existing, growing and new customers in other industries.

	Normal energy	Stranded energy
Location sensitive	• IT parks • Industrial parks • Electric Vehicles • Homes • Offices	NOT SUSTAINABLE FOR SELLER
Location agnostic	NOT SUSTAINABLE FOR BUYER	• Bitcoin mining data centers

The optimal strategy, which will avoid an over-loaded grid, and avoid losing the revenue from Bitcoin miners, is to implement strong **location-based price differentiation**.