

MASTER OF ENERGY ECONOMICS & GOVERNANCE

ENERGY COSTING (EEG 815); AY: 2026/2027

YEAR TWO; SEMESTER: ONE

Topic two: **Principles of Energy Pricing**

- Energy pricing definition
- Why energy is different
- Perfect market models
- Market failures
- Externalities
- Public policy dilemma
- Energy pricing principles
- Clever pricing solutions

Learning Outcomes

By the end of this topic, the learner should be able to:

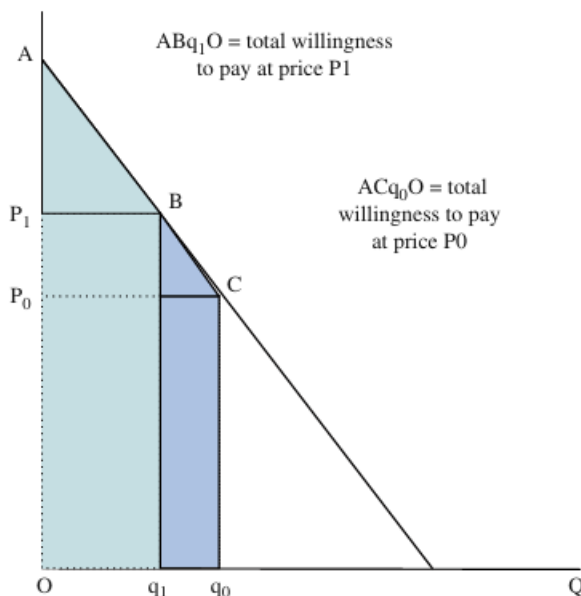
1. Explain the special economic characteristics of energy that make its markets and pricing different from those of ordinary goods.
2. State the objectives of energy pricing and explain the trade-offs among them.
3. Distinguish between market structures (perfect competition, monopoly, oligopoly, monopolistic competition) and identify where each applies in the energy sector.
4. Apply the principle of marginal cost pricing, distinguish short-run from long-run marginal cost and explain the natural monopoly pricing problem.
5. Derive and interpret second-best pricing rules, including average cost pricing, two-part tariffs and Ramsey pricing.
6. Explain the pricing of exhaustible resources using the Hotelling rule and the concept of user cost.
7. Evaluate tariff structures, subsidies, cross-subsidies and regulatory approaches, with reference to Uganda.

2.1 Energy Pricing definition

Energy pricing is the process of determining the cost of energy services for consumers. It involves evaluating the costs associated with energy production, including extraction, generation, and distribution, to establish a price that reflects the value of energy.

Energy pricing continues to be a very sensitive and contentious issue because of social and political implications. Regulators and price-setting agencies require considerable information to make correct pricing decisions. This includes: consumption of fuels by various consumers, consumption pattern by income groups, rural–urban divide in consumption and supply, cost of supply to various consumers, impact of price revision on consumers, etc.

The consumers maximise their utility subject to their budget constraints and producers maximise their profits subject to the constraints of production possibilities. There are numerous consumers and producers trying to transact in the market place. In a competitive market condition, all agents are price takers and there is no market power of any agent. In general, the demand for a good reduces as prices rise (i.e. inverse relationship with price) and vice versa.



(Bhattacharyya, 2011)

At the equilibrium, the willingness to sell equals the willingness to pay. At this condition, the demand matches the supply (optimal allocation).

2.2 Objectives of Energy Pricing

An energy price (tariff) is expected to serve several objectives at once. The core challenge of tariff design is that these objectives often conflict, so every pricing policy involves trade-offs.

Objective	Meaning	Typical pricing implication
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Economic efficiency	Allocate resources to their highest-value use; send correct signals for consumption and investment	Price at marginal cost (including externality costs)
Financial viability (cost recovery)	Generate enough revenue to cover operating costs, debt service and a return on capital, so the supplier can maintain and expand supply	Price at least equal to average cost; revenue requirement approach
Equity and affordability	Ensure basic energy needs of poor households are met; fair treatment of consumers	Lifeline tariffs, targeted subsidies, cross-subsidies
Environmental sustainability	Reflect environmental damage; encourage cleaner fuels and efficiency	Pigouvian taxes, carbon pricing, feed-in tariffs for renewables
Simplicity and transparency	Tariffs should be easy to understand, meter and administer	Limited number of blocks and customer classes
Stability and predictability	Avoid sudden large price changes that disrupt consumers and investors	Gradual adjustment; smoothing mechanisms; long-term contracts
Other macroeconomic goals	Control inflation, promote industrialisation or exports, raise fiscal revenue	Fuel taxes; industrial tariffs; export-sector concessions

The objectives pull in different directions. Marginal cost pricing in a natural monopoly leaves a deficit, which conflicts with cost recovery. Low lifeline prices serve equity but reduce revenue and, if poorly targeted, subsidise better-off households. Environmental taxes raise the price of energy, which conflicts with affordability. A good tariff structure resolves these tensions by using different instruments for different objectives. For example, the marginal price per unit can serve efficiency, a fixed charge can support cost recovery, and a targeted transfer can serve equity.

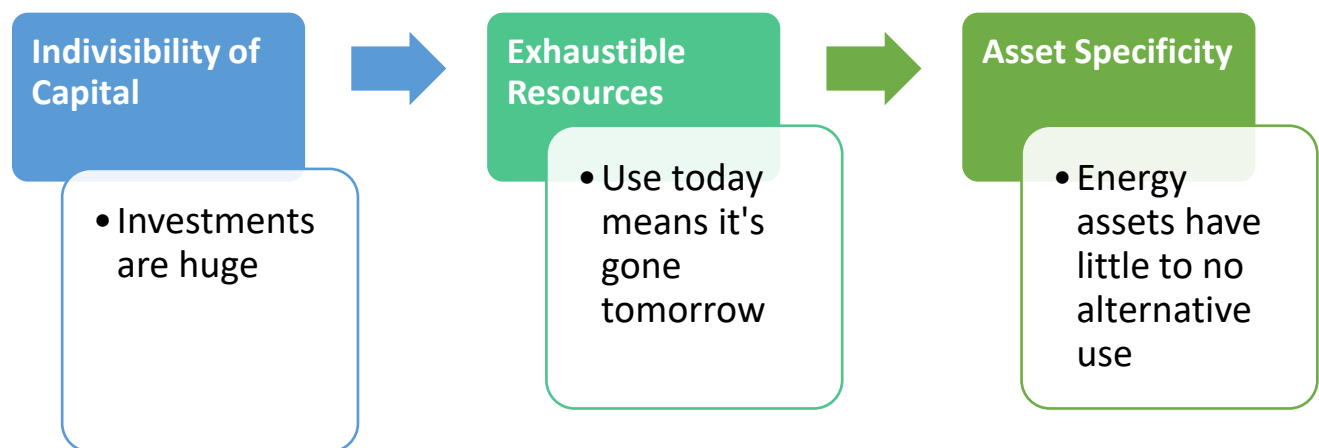
2.3 Why Energy pricing is different (Real World Complication)

Price is the signal that coordinates the decisions of energy producers and consumers. It tells producers how much to supply and whether to invest in new capacity, and it tells consumers how much energy to use, which appliances or vehicles to buy and whether to switch fuels. When prices reflect the true cost of supply, resources flow to their most valuable uses. When they do not, the economy suffers.

Prices set below cost encourage wasteful consumption, starve utilities of revenue and discourage investment. Prices set above cost suppress legitimate demand and transfer rents to suppliers or the state.

Energy pricing is also politically sensitive. Energy is an essential input for households, industry, transport and public services, so its price affects inflation, competitiveness, poverty and public finances. For that reason governments almost everywhere intervene in energy pricing through taxes, subsidies, regulated tariffs or state ownership. Energy economics therefore has to combine the theory of efficient pricing with the practical realities of cost recovery, equity and political economy.

2.3.1 Three main Key Differences (explain why energy is different from the normal goods)



Indivisibility of capital implies that capacity expansion takes place in discrete unit sizes of plant units, and investments are lumpy in nature. In the energy sector, this is a common feature.

Due to high capital costs, the **marginal cost** of energy is often much lower than the **average cost** of production. The existence of economies of scale often suggests that better cost advantages could be achieved by installing bigger sizes. The indivisibility of capital changes the shape of the supply curve, for instead of a continuous supply curve, we now have a supply curve for a fixed capacity and the addition of new capacities brings abrupt changes (or kinks) at the point where investments take place.

Depletion of Exhaustible Resources; As coal, oil and gas are non-renewable resources, consumption of one unit of these resources implies foregoing its consumption at any future date. This brings in another dimension of decision-making: whether to use the resource now or later. The price should depart from the marginal cost and include an additional item called the scarcity rent or user cost. This implies that finite resources have a value over and above their cost of production, which is due to their scarcity. If the reserve is very large and if the prospect of export

is negligible, the rent component will be practically insignificant, though theoretically it will still exist. Of the reserve is very limited, the estimation of the rent does not pose any problem either. The difference between the extraction cost of the resource and the price of the substitute fuel gives the rent cost. In all other intermediate cases, the rent can be significant and its evaluation is more uncertain and complex.

Asset Specificity and Capital Intensiveness

The energy sector employs highly specific assets in the sense of transaction cost economics. Assets are considered as highly specific if they have little alternative use. For example, a power generating plant has little alternative use. Similarly, investments made in an oil field could hardly be redeployed elsewhere in any other use. The asset specificity can arise because of a number of reasons—site specificity, specific investments in human capital, dedicated investment (or idiosyncratic investment) and physical (Williamson 1985). The level and nature of transaction costs depend on the frequency of transaction, the extent of uncertainty and the degree of asset specificity. The theory of transaction costs also identifies a number of alternative arrangements for performing transactions (Williamson 1985):

- Classical contracting which includes the textbook exchanges in the market place.
- Bilateral contracting using long term contracts;
- Trilateral relationship where a third party determines the damages/adaptation following some specified procedures (such as arbitration);
- Unified governance or vertical integration that internalises the transaction with the firm.

Depending on the transaction attributes it is possible to identify the governance arrangements that would be most appropriate.

In addition to specificity, energy sector assets tend to be capital intensive as well. Often the capital cost accounts for a large part of the average cost and consequently, per unit cost falls with higher sizes, showing economies of scale. An implication of such capital intensiveness and economies of scale is that the marginal costs tend to be low compared to the average costs and any pricing based on marginal cost would then lead to financial losses. But once in operation, as long as the firm is able to recover its variable costs, it would continue operating expecting to make up for the capital cost recovery at a future date. Thus, the firm would have a tendency to produce at its maximum capacity, considering fixed costs as sunk costs. This would lead to excess supply and the energy industry has an inherent tendency to be in excess supply situation. But continued over supply situation is not beneficial for the future of any industry as no new investment would be encouraged and continued financial loss could promote premature abandonment of certain facilities.

Energy supply depends on large, long-lived infrastructure: hydropower dams, thermal plants, oil refineries, pipelines, and transmission and distribution networks. Most of the cost of these assets is paid upfront, before a single unit of energy is produced. Once the investment is made, these costs are fixed and sunk. They do not change with the amount of energy produced, and they cannot be recovered by selling the asset (asset specificity).

2.3.2 Other Special characteristics of energy

Several other features distinguish energy from ordinary commodities and shape both the structure of energy markets and the principles used to price energy:

- **long asset lives.** Power plants, refineries, pipelines and transmission networks are very costly and last 25 to 60 years. Most of their costs are fixed and sunk once investment is made, so short-run and long-run costs diverge sharply.
- **Economies of scale and network effects.** Transmission and distribution of electricity and gas are network industries where one network serves an area at lower cost than two competing networks. This is the classic natural monopoly.
- **Non-storability of electricity.** Electricity must be generated at the same instant it is consumed. Because demand varies by hour and season, capacity must be built to meet the peak, and the cost of supply varies with time.
- **Externalities.** Energy production and use cause air pollution, greenhouse gas emissions, deforestation (in the case of charcoal and firewood) and other external costs not reflected in market prices.
- **Essential and strategic nature.** Energy is a basic need and a strategic input. Security of supply, affordability for poor households and national control of resources are prominent policy concerns.
- **International tradability.** Crude oil and petroleum products are traded globally, so their domestic value is set by world prices. Electricity and, to a large extent, biomass are largely non-traded and priced locally.
- **Low short-run price elasticity.** Consumers cannot quickly change their energy-using equipment, so short-run demand is inelastic. Prices can therefore rise sharply when supply is tight, and market power can be exercised easily.

2.4 Market models (structures) in the energy sector

The way a market performs depends on its structure: the number and size of firms, the nature of the product, barriers to entry and the availability of information. Energy activities cover the whole range of structures, often within a single supply chain. For example, electricity generation can be competitive while transmission remains a monopoly.

Structure	Key features	Pricing outcome	Energy examples
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Perfect competition	Many small firms; homogeneous product; free entry and exit; full information	Price taker; $P = MC$; zero long-run economic profit	Approximated in spot markets for crude oil, coal and wholesale power pools with many generators
Monopoly	Single seller; no close substitutes; high entry barriers	Price maker; sets $MR = MC$, so $P > MC$; deadweight loss	Electricity transmission (e.g., UETCL in Uganda); distribution concessions; pipelines
Oligopoly	Few large, interdependent firms; strategic behaviour	$P > MC$; outcome depends on strategy (Cournot, Bertrand, collusion)	OPEC+ in crude oil; oil majors in refining; LNG suppliers; fuel marketers
Monopolistic competition	Many firms; differentiated products; easy entry	Some price-setting power; $P > MC$ in short run	Retail fuel stations, LPG brands, solar home system and clean cookstove vendors
Monopsony	Single buyer	Buyer sets price below competitive level	Single-buyer power model: a national utility buying from independent power producers

2.4.1 Market failures in energy

The competitive market model discussed above assumes a set of strong assumptions. A market failure occurs when such assumptions cannot be satisfied. Some elements of the energy sector have the technical or other characteristics that amount to the violation of the basic assumptions of a competitive market model. The common sources of market failure are discussed below;

Monopoly Problems: The capital intensiveness of the energy sector requires large investments and as bigger installations provide economies of scale, few large suppliers tend to dominate the market. A profit-maximising monopolist will set her price at the intersection of marginal cost and marginal revenue. But as the monopolist faces a down-ward sloping demand curve, the marginal revenue will be less than price.

Even where competition is feasible, energy markets are prone to failures that justify intervention:

Natural Monopoly: This is a situation where production of a good or service by a single firm ensures least cost supply. The typical example is a single product where the long-run average cost declines for all outputs. As the average cost falls over the entire range of output, the marginal cost also falls. This is a case of permanent natural monopoly, because irrespective of market demand size, a single firm can produce the good at least cost.

A situation where production by a single firm ensures the least cost of supply for a good or service.

A natural monopoly exists when a single firm can supply the whole market at lower cost than two or more firms. It happens when the setup costs for an industry are so huge, that it makes absolutely no sense to have competition. It's more cheaper if one company builds all the infrastructure for everybody.

The technical condition is subadditivity of costs:

$$C(Q) < C(q_1) + C(q_2) + \dots (e$$

qn 2) for any division of output Q among firms.

Meaning; cost, that's the C, for one single firm to produce the total amount of goods, that's Q1 plus Q2, is less than the combined cost of two separate firms trying to do the same job, the cheapest way to get the job done. This is the natural monopoly but it creates massive problems.

This scenario usually arises from large fixed costs combined with low marginal costs, so average cost falls continuously over the relevant range of demand. Electricity and gas networks, water supply and pipelines are typical cases.

Natural monopoly creates a pricing dilemma. Left unregulated, the monopolist restricts output and charges a price well above marginal cost. If instead the regulator forces price down to marginal cost, the firm cannot recover its fixed costs because marginal cost lies below average cost. Section 4.4 examines this problem and its solutions.

Other explanations to market failures

- **Market power:** natural monopoly in networks and oligopoly in upstream oil and gas.
- **Externalities:** local air pollution, greenhouse gas emissions, and forest degradation from charcoal production.
- **Public goods:** security of supply and system reliability benefit everyone and are underprovided by private markets.
- **Information asymmetry:** consumers cannot easily judge the energy efficiency of appliances or buildings; regulators know less about costs than utilities do.
- **Missing or incomplete markets:** limited long-term financial markets and credit constraints in developing countries restrict investment in efficient equipment and access to modern energy.

2.5 Perfect market models

In a perfectly competitive market, all agents are "price takers," with no individual having power to influence the market price. There are many buyers and sellers.

Marginal cost (MC) is the extra cost of producing one more unit, such as one more kWh. For most energy facilities, it covers only the running costs: fuel (if any), variable operation and maintenance, and losses. For hydropower, solar and wind the fuel is free, so marginal cost is close to zero.

Average cost (AC) is total cost divided by total output. It includes the running costs plus a share of the huge capital cost, which covers loan repayment, interest, depreciation and a return on investment:

Because the fixed capital cost is so large, AC sits far above MC. As output rises, the fixed cost is spread over more units, so AC keeps falling towards MC but never reaches it. This is the defining feature of a **natural monopoly**. This gap creates a pricing dilemma.

Economic efficiency requires the price to equal marginal cost ($p^* = MC$). If an energy utility charged only its marginal cost, it could never recover its capital investment, would make continuous losses, and would be unable to repay its loans or invest in new capacity.

Energy pricing therefore needs other ways of recovering fixed costs: average cost pricing, two-part tariffs (a fixed charge plus an energy charge), capacity or demand charges for large users, or government subsidies.

Example: Karuma Hydropower Plant, Uganda (approximate figures)

Karuma has an installed capacity of 600 MW and cost about USD 1.7 billion to build. Assume:

Operating life of 40 years and a cost of capital of 10%. The annualised capital cost is then about USD 174 million per year.

An average capacity factor of 50%, so annual output is about $600 \text{ MW} \times 8,760 \text{ hours} \times 0.5 \approx 2,628 \text{ million kWh}$.

A running cost (operation and maintenance, water levies) of about USD 0.005 per kWh.

Then:

- **Capital cost per kWh** = $\text{USD } 174 \text{ million} \div 2,628 \text{ million kWh} \approx \text{USD } 0.066 \text{ per kWh}$
- **Marginal cost** $\approx \text{USD } 0.005 \text{ per kWh}$ (about UGX 18)
- **Average cost** $\approx 0.066 + 0.005 = \text{USD } 0.071 \text{ per kWh}$ (about UGX 263)

The average cost is about **14 times** the marginal cost. Producing one more kWh from Karuma costs almost nothing, but each kWh must carry about USD 0.066 of capital cost if the investment is to be repaid. A tariff set at marginal cost (about UGX 18 per kWh) would leave the plant's owners with a revenue shortfall of roughly USD 174 million a year. The gap would have to be covered by the Treasury, and ultimately by taxpayers, instead of by electricity users.

This also explains Uganda's recent tariff choices. With surplus capacity from Karuma and Isimba, the marginal cost of extra generation is very low, so selling more units at a discount (the cooking tariff of UGX 412 per kWh) still contributes to covering fixed costs. Unused capacity earns nothing, while every extra unit sold above marginal cost helps pay for the dam.

Competitive Equilibrium

Producers (sellers) maximize profits and consumers (buyers) maximize utility (satisfaction), leading to the most efficient social outcome.

Perfect state; The most efficient outcome is achieved when the **market price** equals the **marginal cost** of production ($p^* = MC$). The price you pay is equal to what costs the producer to make one extra unit.

Marginal cost (MC) is the extra cost of producing one additional unit, such as one more kWh of electricity or one more litre of fuel, **The market price (p^*)** reflects how much consumers value that last unit, because a buyer only pays the price if the unit is worth at least that much to them.

If the price differs from marginal cost, efficiency is lost:

- **If $p > MC$** , which is typical of a monopoly, too little is produced. Some consumers are willing to pay more than the cost of supplying them, but they are priced out. The benefit that is lost is called a *deadweight loss*.
- **If $p < MC$** , which is typical of a subsidised price, too much is consumed. Units are used that cost society more to produce than they are worth to the user, so resources are wasted.

Discussion question (6 Marks)

Uganda's domestic tariff charges UGX 250 per unit for the lifeline block, UGX 412 for the cooking block and UGX 756.2 for all other units. Using the principle that the most efficient outcome is achieved when price equals marginal cost ($p^* = MC$):

(a) Identify which blocks are priced below and which above the likely marginal cost of supply, and explain the efficiency consequences of each.

(b) Given Uganda's current surplus generation capacity, argue whether the cooking tariff of UGX 412 moves the market closer to or further from efficiency. Distinguish between short-run and long-run marginal cost in your answer.

(c) Should Uganda's domestic tariff move closer to strict marginal cost pricing? Weigh efficiency against affordability, cost recovery and environmental objectives, and propose one improvement to the current tariff design.

2.6 Public Ownership

An alternative solution to deal with the problems of natural monopoly is to transfer the ownership and operation rights to the government. This forms the basis for public sector involvement in production. The logic behind this is that the government will not be following the profit maximisation principle but will operate to maximise economic surplus. The pricing rule for a public enterprise under a budget constraint was studied by Boiteux (1956). His results indicated that the pricing policy should be same as Ramsey pricing. This implies that the state monopolist should behave like a discriminating monopolist in order to reach budgetary equilibrium. Both the options have been widely adopted in practice. In the USA, the regulatory approach was adopted while in Europe and many other parts of the world, the public ownership approach was followed.

2.6.1 Public Policy Dilemma

Efficiency vs. Survival

The public policy dilemma: how on earth do you regulate a company that works best as a monopoly without letting it abuse that power and charge you whatever it wants? The fundamental tradeoff,

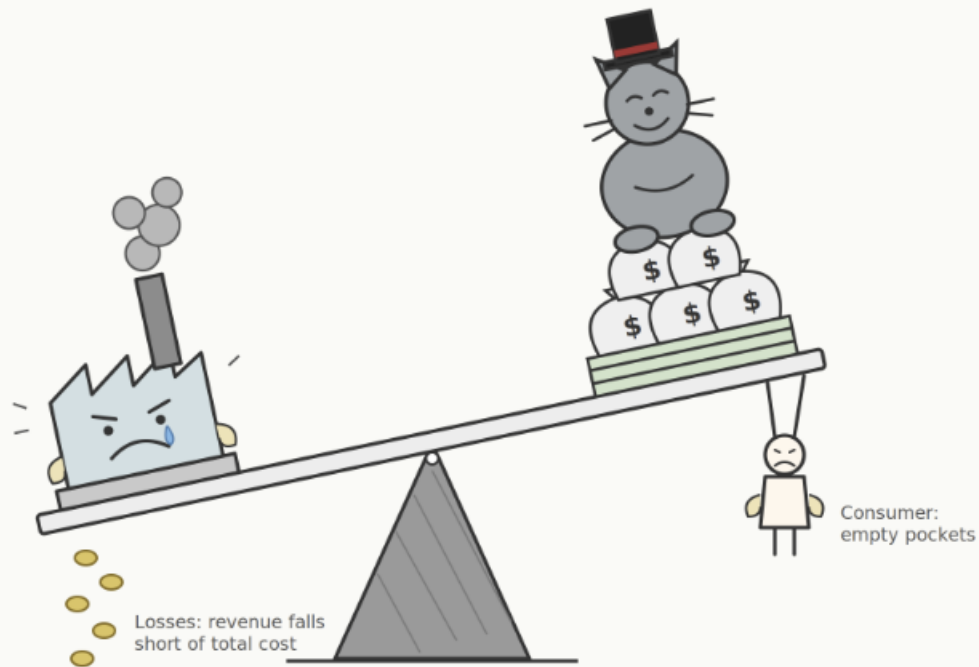
The Public Policy Dilemma: Efficiency vs. Survival

Marginal Cost Pricing

$P = MC < AC$
Efficient, but the utility makes losses

Monopoly Pricing

$P > MC$
Profitable, but consumers overpay



Regulators search for the balance point: fair prices for consumers and a viable utility

With marginal cost pricing, the price is **less than** the average cost. The firm incurs a loss and requires a **subsidy to survive**.

2.7 Principles of Efficient Pricing

2.7.1 Marginal cost pricing

The fundamental principle of efficient pricing is that price should equal the marginal cost of supply. Marginal cost (MC) is the additional cost of producing one more unit. When $P = MC$, a consumer buys an extra unit only if its value to them, reflected in their willingness to pay, is at least equal to the cost society incurs to supply it. If $P > MC$, some consumers who value energy above its cost are priced out, and there is a welfare loss. If $P < MC$, units are consumed that cost more to produce than they are worth to the user, which is also wasteful.

Efficiency condition: $P = MC \Leftrightarrow \text{Marginal benefit} = \text{Marginal social cost}$

In energy, the relevant marginal cost must be defined carefully. It should be forward-looking (future costs, not historical or sunk costs), should include all components of supply (generation, transmission, distribution, and for depletable fuels, user cost) and, ideally, should include the

external costs of production and consumption. It should also be differentiated by time of use, location and voltage or pressure level, because the cost of supply varies along each of these dimensions.

2.7.2 Short-run versus long-run marginal cost

Short-run marginal cost (SRMC) is the cost of producing an extra unit with existing capacity. It includes fuel, variable operation and maintenance and, when the system is at full capacity, the cost of rationing or outages. When there is spare capacity, SRMC is low; when capacity is fully used, SRMC rises steeply because the only way to balance supply and demand is to raise price or ration.

Long-run marginal cost (LRMC) is the cost of meeting a sustained increase in demand when capacity can be expanded. It therefore includes both the capital cost of new capacity and the running cost. In theory, if capacity is optimally adjusted, SRMC = LRMC. In practice, capacity is added in large, lumpy increments, so SRMC fluctuates widely (very low just after a new plant is commissioned and very high just before the next one). Pricing at SRMC would make tariffs volatile and could deter investment. For this reason, utilities and regulators typically base tariffs on LRMC, which gives a stable signal of the cost of future supply.

The Average Incremental Cost (AIC) method

Because LRMC is difficult to measure directly, the World Bank and many regulators approximate it with the average incremental cost. AIC is the present value of the incremental investment and operating costs of the least-cost expansion plan divided by the present value of the incremental output that plan delivers:

$$AIC = \sum_t [(I_t + R_t) / (1 + r)^t] \div \sum_t [\Delta Q_t / (1 + r)^t]$$

where I_t is incremental capital expenditure in year t , R_t is incremental operating and fuel cost, ΔQ_t is incremental energy supplied relative to the base year and r is the discount rate. The result is a cost per kWh (or per litre, or per cubic metre) that can be used as the efficient price level for the tariff.

2.7.3 Welfare effects of different pricing rules

The consequences of pricing above marginal cost can be seen in the monopoly case. A profit-maximising monopolist chooses output where marginal revenue equals marginal cost and then charges the highest price consumers will pay for that output. Output is lower and price higher than under marginal cost pricing. The resulting welfare loss is the deadweight loss triangle between the demand curve and the marginal cost curve for the units not produced.

2.7.4 The natural monopoly pricing problem

For a natural monopoly, average cost declines over the relevant range of output, so marginal cost lies below average cost. If price is set equal to marginal cost, revenue ($P \times Q$) is less than total cost ($AC \times Q$), and the firm makes a loss equal to $(AC - MC) \times Q$. This is essentially the fixed cost that marginal cost pricing fails to recover. The regulator has several options:

- **Marginal cost pricing with a subsidy.** Price at MC and cover the deficit from general taxation. This is efficient in the energy market but requires public funds, which carry their own distortionary cost, and weakens the utility's incentive to control costs.
- **Average cost pricing.** Set $P = AC$ so the firm just breaks even. It is simple and financially sustainable, but output is below the efficient level and a (usually small) deadweight loss remains.
- **Two-part tariff.** Charge a fixed access or standing charge per customer to recover fixed costs, plus a per-unit energy charge equal to MC. Consumption decisions at the margin are then efficient. The drawback is that a high fixed charge may push low-income or low-use customers off the network.
- **Ramsey (inverse-elasticity) pricing.** Mark up prices above MC in different markets in inverse proportion to their price elasticity of demand, so that the revenue requirement is met with the smallest possible welfare loss (see Section 4.5).
- **Price discrimination and block tariffs.** Charge different prices to different customer groups or for different blocks of consumption, recovering fixed costs mainly from infra-marginal units.

2.8 Clever Pricing Solutions

Solving the dilemma.

The real World strategies that regulators and utilities came up with to try and find a workable middle ground.

2.8.1 Two-Part Tariff

It's a system that has two parts. A non-linear tariff system that uses a fixed fee (F) and a price per unit (p) component. A fixed monthly fee that everybody pays, no matter how much energy you use, and then a separate charge for every unit of energy you actually consume.

The fixed charge is your small contribution to help the company pay for all its massive fixed costs, then the per unit price you pay for consumption can be set much closer to the efficient

marginal cost, which encourages you not to waste power. It's a really clever (Energy Efficiency and conservation ACT).

2.8.2 Ramsey Pricing

Ramsey pricing (Frank Ramsey, 1927), and developed for public utilities by Boiteux, 1956) answers the question: if a utility must cover its total costs, how should prices depart from marginal cost to minimise the loss of efficiency? The answer is that the proportional mark-up over marginal cost in each market should be inversely proportional to that market's price elasticity of demand:

$$(P_i - MC_i) / P_i = \lambda / \varepsilon_i$$

where ε_i is the absolute price elasticity of demand in market i and λ is a constant (the Ramsey number, between 0 and 1) chosen so that total revenue equals total cost. Customers with inelastic demand bear larger mark-ups, because their consumption falls less when price rises, so less efficiency is lost. Customers with elastic demand, for example large industries able to self-generate, face prices close to marginal cost.

Ramsey Pricing Ramsey pricing is essentially a taxing method that was developed in an attempt to design a system that would lead to minimal deadweight loss. This has then been applied to the pricing issues as well as the basic problem in a natural monopoly subjected to marginal cost pricing is the recovery of losses in a less distorted manner. This principle has been analysed by a number of researcher under various conditions but Baumol and Bradford (1970) provide the most detailed and general analysis of the issue.

A pricing system that leads to minimal deadweight loss by setting prices based on demand elasticity, more advanced strategy but complex, It's all about charging different prices to different groups of customers based on how sensitive they are to price changes. what economists call their price elasticity of demand. The price shall be **higher** for **inelastic demand** and lower for elastic demand.

Ramsey Pricing, the more you absolutely need the service, and the fewer alternatives you have, the higher the price you'll pay. E.g huge factory that has to have power to run its machines might pay a different, higher rate than a residential customer who has more flexibility. It is a way of making sure the company covers its costs while causing the least amount of economic pain overall.

With **zero-cost renewables**, must our **pricing models** change?

2.8.3 Peak-Load Pricing

The problem

Electricity cannot be stored economically at scale, and demand varies predictably by time of day and season. In Uganda, for instance, the evening peak (roughly 7 pm to 11 pm) is driven by household lighting, cooking and entertainment. Capacity must be large enough to serve the peak. That capacity sits partly idle at other times. The question is who should pay for it.

The Boiteux-Steiner solution

Peak-load pricing theory (Boiteux, 1949; Steiner, 1957; Williamson, 1966) shows that the efficient solution is to charge different prices in different periods. Let b be the running (operating) cost per unit of output and β the cost of a unit of capacity per cycle. With a "firm peak", where off-peak demand never reaches capacity even at the lower price, the efficient prices are:

$$\text{Peak price: } P_p = b + \beta \quad \text{Off-peak price: } P_o = b$$

Peak users are the reason capacity is built, so they pay its full cost; off-peak users pay only the running cost. Capacity is set at the level where peak demand equals $b + \beta$. If the off-peak price of b would push off-peak demand above capacity, the peak "shifts". In that case both periods share the capacity cost according to their willingness to pay, and output is equal in both periods, with $P_p + P_o = 2b + \beta$ when the periods are of equal length.

Peak-load pricing underlies **time-of-use (TOU) tariffs**, in which prices are set in advance for peak, shoulder and off-peak periods. It also underlies seasonal tariffs, critical peak pricing (very high prices on a few system-stress days) and real-time pricing, where prices follow hourly wholesale costs. Uganda applies time-of-use energy charges to medium, large and extra-large industrial customers. This encourages factories to shift production to off-peak hours and raises the utilisation of generation capacity. Smart meters and battery storage are extending these possibilities to smaller customers.

2.9 Existence of Rent

The energy industry exhibits a number of differential rents arising from the differential advantages enjoyed by a production unit compared to other similar units. These rents appear as the producers' surplus and increase the profitability of the producers. In addition, the energy sector at certain times has seen monopoly rents due to the prevalent market structure. Similarly, the scarcity rent can also be applicable to non-fossil resources of energy. In theory, the government can capture this rent without affecting supply since the company continues to receive its normal profit. This is also assumed for an efficient operation of the markets. However,

in practice any fiscal measure implies an intervention of the government in the market and introduces distortions. This also implies a departure from the marginal cost-based pricing.

Pricing of Exhaustible Energy Resources

User cost and scarcity rent

For renewable flows or manufactured energy, marginal cost consists of the cost of production alone. For an exhaustible resource such as crude oil, natural gas or coal, extracting a unit today has an additional cost: that unit is no longer available for future use. This forgone future value is called the marginal user cost, also known as scarcity rent, royalty or Hotelling rent. The efficient price of an exhaustible resource is therefore:

$$P = \text{Marginal Extraction Cost (MEC)} + \text{Marginal User Cost (MUC)}$$

The Hotelling rule

Harold Hotelling (1931) showed that, in a competitive market with known reserves and no extraction cost changes, the owner of a resource is indifferent between extracting now and extracting later only if the net price (price minus marginal extraction cost) rises at the rate of interest. If the net price rose faster, owners would leave the resource in the ground; if it rose more slowly, they would extract everything immediately. In equilibrium:

$$(P_t - MEC_t) = (P_0 - MEC_0) \times (1 + r)^t$$

The rule implies that resource prices should rise over time, extraction should decline gradually, and extraction should end when the price reaches the "choke price" or the cost of a backstop technology (for example, renewable electricity or biofuels) that can substitute for the resource. In reality, oil prices have not followed a smooth Hotelling path because of new discoveries, technological progress that lowers extraction costs, market power (OPEC+), geopolitical shocks and policy changes. The rule nevertheless remains the starting point for thinking about the value of resources in the ground. It is directly relevant to Uganda as it begins commercial oil production in the Albertine Graben.

Opportunity-Cost Pricing: Traded and Non-Traded Energy

The opportunity cost principle

The economic value of a resource is its opportunity cost, the value of the best alternative use forgone. For energy that can be traded internationally, the opportunity cost is determined by

world prices, not by the domestic cost of production. For energy that cannot be traded, the opportunity cost is the marginal cost of domestic supply.

Tradable energy: border prices

Import parity price (IPP). For an importing country, the economic value of a unit of oil product is what it costs to bring an extra unit into the country and deliver it to the point of use. This is the free-on-board (FOB) world price, plus freight, insurance, port charges, storage, inland transport and a normal marketing margin. If domestic production (for example, a local refinery) exists, its output should still be valued at import parity because every litre produced locally saves a litre of imports.

Export parity price (EPP). For an exporting country, the value of a unit consumed at home is the net revenue forgone by not exporting it. This is the FOB export price minus the costs of transporting it to the border or port (the netback). Selling domestically below export parity is an implicit subsidy even if the price covers production cost.

$$IPP = FOB + Freight + Insurance + Port\ and\ storage + Inland\ transport + Margins$$

$$EPP\ (netback) = FOB\ export\ price - Transport\ to\ port - Handling\ costs$$

Non-traded energy

Electricity (apart from limited cross-border trade), distributed natural gas and most biomass are non-traded. Their economic price is the long-run marginal cost of domestic supply, measured by methods such as the average incremental cost. For fuels that are partly traded, the relevant benchmark depends on the country's trade position at the margin. If a country imports at the margin, it uses import parity. If it exports at the margin, it uses export parity. If it is self-sufficient and not trading, the relevant price lies between the two and is set by domestic supply and demand.

Economic versus financial prices

Financial prices are the prices actually paid in the market, including taxes and subsidies. Economic prices measure the real resource cost to society. Taxes and subsidies are transfers between groups within the economy, not resource costs, and are therefore excluded when estimating economic costs. Distortions in foreign exchange or labour markets may require shadow prices. Economic prices are used to assess whether an energy project or pricing policy is beneficial to society. Financial prices determine whether the supplier is viable and what consumers actually pay.

2.10 Externality and Public Goods

Energy products impose different costs on society, a part of which are supported by producers and consumers, while the rest, known as external costs, remain unaccounted for and are borne by the society. In economic terms, an externality is said to exist if any activity of an economic agent imposes positive or negative effects on the welfare of any other agent or groups of agents and when economic agents neither receive nor pay any compensation equal to the costs inflicted or the benefits conferred upon them. It is important to note here that the presence of an externality introduces distortion in economic decisions and its correction requires government intervention either through taxation or through regulation.

Similarly, the provision of public goods related to the supply of energy needs to be highlighted. Public goods are those whose provision to one person or party makes them automatically available to all at zero additional costs. In the energy sector, a number of such examples can be easily cited: recreational or other benefits arising from the construction of a dam, downstream benefits as a result of upstream reforestation, etc. At the same time, ensuring adequate and secure energy supplies, adequate long-term R&D and other economic and socially desirable outcomes also share public good features. Markets may not provide these public goods left to it and as these are important issues related to energy, governments intervene.

2.10.1 Environmental Externalities and Full-Cost Pricing

A negative externality occurs when an activity imposes costs on third parties who are not compensated. Emissions from diesel generators, vehicle exhaust in Kampala, and carbon dioxide from fossil fuel combustion are examples. When such costs are ignored, the private marginal cost (PMC) is lower than the marginal social cost (MSC), the market price is too low, and consumption exceeds the socially optimal level.

$$\text{Marginal Social Cost} = \text{Marginal Private Cost} + \text{Marginal External Cost}$$

The efficient response, following Pigou (1920), is to raise the price to marginal social cost through a tax equal to the marginal external cost at the optimum. Alternatives and complements include cap-and-trade emission permit systems (which set the quantity and let the permit price adjust), carbon taxes, fuel quality and emission standards, and support for cleaner alternatives such as feed-in tariffs, renewable energy auctions and e-mobility or electric cooking tariffs. Full-cost pricing ensures that energy choices reflect their true costs to society, but the resulting higher prices raise affordability concerns that must be managed with targeted support.

2.11 Government Intervention and Role of Government in the Sector

The energy sector fails to satisfy the requirements of a competitive market in a number of ways. The presence of natural monopoly and existence of rents require corrective intervention to remedy the problems. Externality, is also quite pervasive in the sector, and requires further intervention. In addition, energy being of critical importance in the modern world, social, equity related and security-related issues cannot be ignored either. This so-called market failure argument is used to justify government intervention in the energy sector. Consequently, the government presence in the sector is quite widespread, both in developed and developing countries, despite waves of liberalization of the market.

Governments use a wide range of instruments or measures to control the functioning of the energy sector. IEA (1996) categorises them in five following categories:

- economic and fiscal instruments;
- trade instruments;
- administration, management and ownership;
- regulation; and
- research and development (R&D).

Taxes, royalties and subsidies constitute the common form of economic instruments used in the energy sector. Although fiscal instruments can be used for various purposes including internalisation of externalities, revenue generation remains the most important motive for their widespread use. A number of trade-related instruments are used in controlling movement of energy resources and include tariffs an

2.12 Tariff Design in Practice

9.1 Forms of tariff

Tariff form	How it works	Assessment
Flat (uniform) rate	Same price per unit for all consumption	Simple; ignores differences in cost by time and volume
Increasing block tariff (IBT)	Price rises for successive blocks of consumption	Protects small users and discourages waste; poor targeting when poor households share meters
Decreasing block tariff	Price falls for larger consumption blocks	Reflects economies of scale; historically used to encourage use; discourages conservation

Lifeline tariff	Low price for a small first block of consumption, often limited to low users	Supports affordability for poor households; needs a threshold to limit leakage
Two-part tariff	Fixed (service/standing) charge plus energy charge per unit	Recovers fixed costs with efficient marginal price; burdens small users
Three-part tariff	Fixed charge + energy charge (per kWh) + demand charge (per kVA of maximum demand)	Used for large users; reflects the capacity each user requires
Time-of-use / seasonal	Different prices by time of day or season	Applies peak-load principles; requires suitable meters
Real-time pricing	Prices change hourly with wholesale market costs	Most efficient; requires smart meters and responsive consumers
Prepaid tariff	Consumers buy units in advance (e.g., Yaka in Uganda)	Improves collection and budgeting; the tariff structure applies per purchase cycle

Uganda's domestic electricity tariff

Uganda's domestic tariff combines several of these principles. The Electricity Regulatory Authority (ERA) sets end-user tariffs and reviews them quarterly through an automatic tariff adjustment mechanism. This mechanism updates tariffs for changes in the exchange rate, domestic and US inflation and fuel prices, which affect the cost of supply.

Component	Charge (Q4 2025)	Pricing principle
Service charge	UGX 3,360 per month (first purchase)	Fixed charge towards customer-related costs (two-part tariff)
Lifeline block: first 15 kWh	UGX 250 per kWh (for customers averaging $\leq$ 100 kWh/month over six months)	Lifeline/equity; targeted by consumption threshold
Cooking block: units 81 to 150 in a month	UGX 412 per kWh	Environmental and policy objective: switching from charcoal and firewood to electric cooking; also uses spare capacity
Normal block: other units	UGX 756.2 per kWh	Cost-reflective energy charge

Source: Uganda Business News (November 2025), summarising ERA tariff schedules.

The structure shows how tariff design reconciles competing objectives. The lifeline block protects low-consumption households, the eligibility threshold limits leakage to wealthier users, the normal block recovers cost, and the discounted cooking block supports environmental goals. It

also helps absorb the surplus capacity created by new hydropower plants such as Karuma and Isimba. The fixed service charge contributes to recovering customer-related costs.

2.13 Subsidies and cross-subsidies

A subsidy exists when consumers pay less than the economic cost of supply, or producers receive more than the market would give them. Subsidies may be explicit budget transfers, or implicit through below-cost tariffs, tax exemptions, cheap credit or selling domestic resources below export parity. A cross-subsidy occurs when one group of customers pays above cost so that another group can pay below cost, for example commercial customers subsidising households, or urban customers subsidising rural ones.

Subsidies can be justified to meet basic needs, to promote access to modern energy (for instance, connection subsidies under rural electrification programmes), or to correct for positive externalities such as the health benefits of clean cooking. However, energy subsidies are often regressive because richer households consume more energy and therefore capture most of the benefit. They also burden public finances, encourage waste, and weaken utilities that are not compensated. Good subsidy design follows several principles: target the intended beneficiaries; subsidise access (connections) rather than consumption where possible; keep the subsidy transparent and budgeted; preserve the marginal price signal; and set a clear exit or review plan.

2.14 Regulation of Energy Prices

Where energy is supplied by a monopoly, an independent regulator sets or approves prices to protect consumers while allowing the utility to remain viable. The main approaches are:

Approach	Mechanism	Strengths and weaknesses
Rate-of-return (cost-of-service) regulation	Revenue requirement = operating costs + depreciation + (allowed rate of return × regulated asset base). Tariffs set to recover this.	Secures investment and cost recovery; weak incentive to cut costs; risk of over-capitalisation (Averch-Johnson effect)
Price-cap (RPI – X) regulation	Average prices may rise by inflation minus an efficiency factor X for a period of 3 to 5 years	Strong incentive to reduce costs because the firm keeps savings; risk of quality decline; X is hard to set
Revenue-cap regulation	Total allowed revenue is capped and indexed; prices adjust with volume	Removes incentive to increase sales, so it supports energy efficiency
Yardstick / benchmarking	Allowed costs based on performance of comparable firms	Mimics competition; needs comparable firms and good data

Performance-based regulation	Rewards and penalties tied to targets for losses, reliability and customer service	Aligns incentives with outcomes; complex to design
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The Averch-Johnson effect refers to the tendency of a firm regulated on its rate of return to over-invest in capital when the allowed return exceeds the true cost of capital, since each extra shilling of assets raises allowed profit. In practice, many regulators, including ERA in Uganda, use hybrids: a multi-year revenue requirement set on a cost-of-service basis, with performance targets (for example, maximum allowable distribution losses), and automatic quarterly indexation for exchange rate, inflation and fuel costs.

References

- Baumol WJ, Bradford DF (1970) Optimal departures from marginal cost pricing. *Am Econ Rev* 60(3):265–283
- Boiteux M (1956) Sur la gestion des monopoles publics astreints a l'équilibre budgétaire. *Econometrica* 24:22–40
- Diamond PA, Mirrlees JA (1971) Optimal taxation and public production, II: Tax rules. *Am Econ Rev* 61:261–278
- Feldstein MS (1972) Distributional equity and the optimal structure of public prices. *Am Econ Rev* 62:32–36
- IEA (1996) The role of IEA Governments in energy, International Energy Agency, Paris. http://www.iea.org/textbase/nppdf/free/1990/role_energy1996.pdf
- Leibenstein H (1966) Allocative efficiency vs. x-efficiency. *Am Econ Rev* 56:392–415
- Munasinghe M (1985) *Energy Pricing and demand management*. Westview Press, Boulder
- Rees R (1984) *Public enterprise economics*. Subhes C. Bhattacharyya (2011). *Energy Economics Concepts, Issues, Markets and Governance*
- Weidenfeld and Nicolson, London
- Williamson O (1985) *The economic institutions of capitalism: firms, markets, relational contracting*. The Free Press, New York
- World Bank (2004) *Reforming infrastructure: privatisation, regulation and competition*. World Bank