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HANDOUT

ECO622

Energy Economics

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ECO622 - Energy Economics

A structured study handout compiled from the course's lecture topics. Read each topic's objectives first, study the key concepts, then use the summary and exam tips for revision.

ECO622

Energy Economics

Based on 45 lecture topics

Compiled for VU students as a structured study guide

*Concepts are summarized in the writer's own words;
use alongside your lecture videos for best results.*

Contents

Unit 1: Energy Fundamentals and Market Features	3
Topic 1: Energy Sources and Measurement	3
Topic 2: Special Features of Energy Markets	4
Topic 3: Energy and Economic Growth	5
Topic 4: History of Energy Transitions	5
Topic 5: Energy Data and Balances	6
Unit 2: Demand, Supply, and Market Structures	7
Topic 6: Energy Demand Analysis	7
Topic 7: Energy Supply and Investment	8
Topic 8: OPEC and the World Oil Market	8
Topic 9: Natural Gas Economics	9
Topic 10: Electricity Markets and Regulation	10
Unit 3: Pricing, Subsidies, and Reform	11
Topic 11: Energy Pricing Principles	11
Topic 12: Energy Subsidies: Forms and Effects	12
Topic 13: Circular Debt: Causes and Solutions	12
Topic 14: Petroleum Pricing and Deregulation	13
Topic 15: Regulatory Economics: NEPRA and OGRA	14
Unit 4: Energy Security, Environment, and Renewables	15
Topic 16: Energy Security Concepts	15
Topic 17: Climate Change and Energy Policy	16
Topic 18: Economics of Renewable Energy	16
Topic 19: Energy Efficiency Economics	17
Topic 20: Nuclear and Thar Coal: Case Studies	18
Unit 5: Energy Planning and Development	19
Topic 21: Integrated Energy Planning	19
Topic 22: Rural Electrification and Access	20
Topic 23: Energy and Poverty Alleviation	20
Topic 24: Regional Energy Cooperation	21
Topic 25: The Future: Hydrogen, Storage, and Smart Grids	22
Glossary of Key Terms	23

Course Introduction

Energy Economics applies economic theory to the production, distribution, and consumption of energy - the lifeblood of modern economies. Every good and service embodies energy, so energy prices ripple through inflation, growth, and competitiveness.

The course begins with energy fundamentals: sources (renewable vs. non-renewable), units of measurement, and the special economic features of energy markets. It then studies demand and supply analysis, market structures from OPEC to competitive power markets, and the economics of oil, gas, coal, and electricity in depth.

Later units cover energy pricing and subsidies - a central issue in Pakistan's circular debt crisis - energy security, the economics of renewable energy and climate policy, and energy planning for developing countries. Students learn to analyze policies like fuel price adjustments and power tariffs with proper economic tools.

How to use this handout: Each topic lists its learning objectives, explains the key concepts in simple words, defines important terms, gives an example where helpful, and closes with a summary plus exam tips. Topics marked **Very important** deserve extra revision.

Unit 1: Energy Fundamentals and Market Features

Topic 1: Energy Sources and Measurement

Learning Objectives

- Classify energy sources
- Explain units of energy measurement
- Describe Pakistan's energy mix

Key Concepts

Energy sources divide into non-renewable (oil, gas, coal, nuclear - finite stocks) and renewable (solar, wind, hydro, biomass - flows that replenish). Primary energy (crude oil, sunlight) is converted into secondary energy (electricity, refined petrol) for end use.

Common units: joule (basic SI unit), kilowatt-hour (electricity - 1 kWh = 3.6 megajoules), BTU, and tonne of oil equivalent (toe) for comparing fuels. Energy intensity (energy per unit of GDP) measures efficiency; it falls as economies modernize.

Pakistan's mix: thermal (oil, gas, coal, LNG) dominates generation, with hydro significant, and growing solar/wind shares. Imported fuels (oil, LNG) make the economy vulnerable to world prices and exchange-rate swings - the energy import bill is a major balance-of-payments item.

Key Points

- Non-renewable (stocks) vs. renewable (flows); primary vs. secondary energy.
- Units: joule, kWh, BTU, tonne of oil equivalent.
- Pakistan depends heavily on imported oil/LNG - a macro vulnerability.

Key Terms

Primary energy: Energy in its natural form before conversion.

Energy intensity: Energy consumed per unit of GDP.

Tonne of oil equivalent: A common unit for comparing different fuels.

Example

- A 1.000 MW solar park's output is measured in GWh: its fuel cost is zero.

Summary: Classifying sources and measuring energy consistently is the foundation of all energy analysis.

Exam Tips

- ★ Very important: renewable vs. non-renewable with examples.
- ★ Remember Pakistan's import dependence.

Topic 2: Special Features of Energy Markets

Learning Objectives

- Explain why energy markets differ from normal markets
- Describe demand inelasticity
- Discuss externalities in energy

Key Concepts

Energy markets have special features. Demand is price-inelastic in the short run: people cannot quickly cut electricity or petrol use when prices rise, so price spikes transfer huge sums without much demand response. Long-run elasticity is higher as consumers buy efficient appliances or shift fuels.

Energy production needs massive, long-lived, sunk investments (a power plant lasts 30+ years), creating natural-monopoly segments (transmission grids) and boom-bust investment cycles. Supply can be disrupted geopolitically (oil), making security a policy concern.

Externalities are central: fossil fuels impose climate and pollution costs not reflected in prices - the classic market failure justifying carbon taxes or cap-and-trade. Conversely, energy access has positive externalities for development. These features explain why governments regulate energy so heavily.

Key Points

- Short-run demand is price-inelastic; long-run more elastic.
- Huge sunk investments create natural monopolies and investment cycles.
- Fossil externalities (climate, pollution) justify intervention.

Key Terms

Price elasticity of demand: Responsiveness of quantity demanded to price.

Natural monopoly: One firm serving the market cheapest, e.g. grids.

Externality: A cost or benefit imposed on third parties.

Example

- When petrol prices jump 20%, consumption falls only slightly in the short run.

Summary: Inelastic demand, sunk costs, and externalities make energy markets uniquely policy-intensive.

Exam Tips

- ★ Very important: short-run vs. long-run elasticity.

- ★ Remember externalities as the market-failure rationale.

Topic 3: Energy and Economic Growth

Learning Objectives

- Explain the energy-growth nexus
- Discuss causality debates
- Describe energy poverty

Key Concepts

Energy consumption and GDP move together: growth needs energy, and energy availability enables growth. But causality is debated - does energy drive growth, or does growth pull energy use? Studies find bidirectional links varying by country and development stage.

Energy poverty - lack of access to modern energy - traps households in low productivity: no electricity means no machinery, study hours, or cold chains. Electrification strongly correlates with development indicators.

For Pakistan, load shedding has measurably cut GDP: industry runs below capacity, exports suffer, and firms invest in costly captive generation. Reliable, affordable energy is thus a growth policy, not just a utility issue.

Key Points

- Energy and GDP are strongly linked; causality runs both ways.
- Energy poverty blocks development; electrification enables it.
- Pakistan's load shedding directly reduces GDP and exports.

Key Terms

Energy-growth nexus: The two-way link between energy use and GDP.

Energy poverty: Lack of access to modern energy services.

Captive generation: Firms producing their own power due to grid failure.

Example

- *Textile exporters losing orders during load shedding shows energy's GDP impact.*

Summary: Energy is a binding constraint on growth in developing countries.

Exam Tips

- ★ Key point: the causality debate.
- ★ Remember load shedding's economic costs.

Topic 4: History of Energy Transitions

Learning Objectives

- Trace major energy transitions
- Explain drivers of transitions
- Discuss implications for fossil fuels

Key Concepts

Economies have transitioned through energy regimes: wood to coal (industrial revolution), coal to oil (transport, 20th century), and now fossil fuels to renewables and electrification. Each transition took decades because infrastructure, skills, and institutions adapt slowly.

Transitions are driven by price (oil shocks spurred efficiency), technology (cheap solar panels), policy (climate commitments), and scarcity. The current transition is policy-driven more than price-driven - governments mandate decarbonization.

For fossil-fuel producers and importers alike, transition means stranded-asset risk (oil reserves losing value) and opportunity (green hydrogen, critical minerals). Pakistan's transition planning must balance climate goals with energy access and fiscal reality.

Key Points

- Transitions: wood → coal → oil → renewables/electrification; each takes decades.
- Drivers: prices, technology, policy, scarcity.
- Risks: stranded assets; opportunities: new clean technologies.

Key Terms

Energy transition: Structural shift from one dominant energy source to another.

Stranded asset: An asset losing value before its expected life ends.

Decarbonization: Reducing carbon emissions from energy systems.

Example

- *Coal plants planned today may become stranded as solar gets cheaper.*

Summary: Energy transitions are slow, driven by multiple forces, and reshape winners and losers.

Exam Tips

- ★ Key point: why transitions take decades.
- ★ Remember stranded-asset risk.

Topic 5: Energy Data and Balances

Learning Objectives

- Read a national energy balance
- Explain key energy indicators
- Discuss data challenges

Key Concepts

A national energy balance tracks supply (production + imports - exports - stock changes) through transformation (refineries, power plants) to final consumption by sector (industry, transport, residential, agriculture). It is the accountant's map of the energy economy.

Key indicators: per-capita consumption (development proxy), energy intensity, import dependence, electrification rate, and fuel shares. Pakistan's per-capita use is low; import dependence high.

Data challenges in developing countries include unrecorded biomass use, electricity theft (line losses hiding consumption), and informal fuel markets. Good policy needs good data - hence improved metering and energy statistics matter.

Key Points

- Energy balance: supply -> transformation -> sectoral consumption.
- Indicators: per-capita use, intensity, import dependence, electrification.
- Theft and informal fuels distort data in developing countries.

Key Terms

Energy balance: An accounting of national energy flows.

Final consumption: Energy used by end-use sectors.

Transformation: Converting primary to secondary energy.

Example

- High 'transmission losses' in data often include large-scale electricity theft.

Summary: Energy balances and indicators make the energy economy visible and governable.

Exam Tips

- ★ Key point: the balance's three stages.
- ★ Remember why data quality matters.

Unit 2: Demand, Supply, and Market Structures

Topic 6: Energy Demand Analysis

Learning Objectives

- Model energy demand determinants
- Explain derived demand
- Discuss demand forecasting

Key Concepts

Energy demand is derived demand - wanted not for itself but for the services it provides (light, heat, mobility). Its determinants: income/GDP, energy prices, prices of substitutes, technology/efficiency, weather, and structural factors (urbanization, industrialization).

Econometric demand models estimate short- and long-run elasticities to forecast consumption and test policies. Residential demand responds to appliance stocks; industrial demand to output levels; transport demand to vehicle fleets and fuel prices.

Forecasting guides investment: over-forecasting builds idle plants (Pakistan's surplus capacity problem in some periods); under-forecasting causes shortages. Scenario analysis (high/low growth, efficiency gains) brackets uncertainty.

Key Points

- Energy demand is derived from demand for energy services.
- Determinants: income, prices, technology, weather, structure.
- Forecasts guide investment; errors cause surplus or shortage.

Key Terms

Derived demand: Demand arising from demand for another good/service.

Demand forecasting: Projecting future energy consumption.

Scenario analysis: Exploring outcomes under alternative assumptions.

Example

- *A hot summer raises residential electricity demand through air-conditioning.*

Summary: Demand analysis links economic drivers to energy needs for planning and policy.

Exam Tips

- ★ Very important: derived demand concept.
- ★ Remember determinants of energy demand.

Topic 7: Energy Supply and Investment

Learning Objectives

- Explain energy supply investment decisions
- Discuss lead times and lumpiness
- Describe resource depletion economics

Key Concepts

Energy supply investments are lumpy (a power plant adds big capacity at once), long-lead (5-10 years from plan to power), and irreversible - creating cycles of shortage (underinvestment) and glut (overbuilding). Investors need credible long-term price signals.

Project appraisal uses net present value and levelized cost of energy (LCOE - lifetime cost per unit output) to compare technologies. Risk factors: fuel price volatility, regulatory change, currency risk for imported equipment, and off-taker risk (will the buyer pay? - central in Pakistan's circular debt).

For exhaustible resources, Hotelling's rule says the resource price should rise at the interest rate - owners extract only if price growth justifies waiting. OPEC's market power modifies pure depletion logic.

Key Points

- Supply investment: lumpy, long-lead, irreversible - causing cycles.
- Appraisal via NPV and LCOE; risks include fuel, regulatory, off-taker risk.
- Hotelling's rule governs optimal depletion of exhaustible resources.

Key Terms

LCOE: Levelized cost of energy: lifetime cost per unit generated.

Hotelling's rule: Resource prices rising at the interest rate under optimal depletion.

Off-taker risk: Risk that the power buyer defaults.

Example

- *Pakistan's LNG plants face off-taker risk when distribution companies cannot pay.*

Summary: Energy supply economics centers on long-horizon investment under uncertainty.

Exam Tips

- ★ Key point: LCOE as the comparison tool.
- ★ Remember Hotelling's rule.

Topic 8: OPEC and the World Oil Market

Learning Objectives

- Explain OPEC's role

- Analyze cartel stability
- Discuss oil price determinants

Key Concepts

OPEC (plus allies, 'OPEC+') coordinates production among major exporters to influence prices. As a cartel, it restricts output to keep prices above competitive levels - but faces the classic cartel problem: each member gains by cheating (producing more), so quotas need monitoring and Saudi Arabia often acts as swing producer.

Oil prices reflect supply (OPEC decisions, shale output, disruptions), demand (global growth, especially China/India), inventories, speculation in futures markets, and geopolitics (wars, sanctions). Prices are volatile because both short-run supply and demand are inelastic.

For Pakistan, oil price spikes worsen the import bill, inflation, and fiscal deficit simultaneously - a triple blow making energy security a macro priority.

Key Points

- OPEC+ coordinates output; cartel stability is challenged by cheating incentives.
- Prices driven by supply, demand, inventories, speculation, geopolitics.
- Oil shocks hit Pakistan's imports, inflation, and budget together.

Key Terms

Cartel: Producers colluding to control supply and price.

Swing producer: A producer adjusting output to balance the market.

Futures market: Market for oil delivery contracts at future dates.

Example

- *OPEC+ production cuts in 2023-24 supported prices despite weak demand.*

Summary: OPEC manages but cannot fully control a volatile market shaped by many forces.

Exam Tips

- ★ Very important: the cartel cheating problem.
- ★ Remember oil shock transmission to Pakistan.

Topic 9: Natural Gas Economics

Learning Objectives

- Describe gas market features
- Explain LNG and its pricing
- Discuss Pakistan's gas sector

Key Concepts

Natural gas was historically regional (pipelines), but LNG (liquefied natural gas) created a global market: gas is cooled, shipped, and regasified. LNG prices link partly to oil (oil-indexed contracts) and partly to hub prices (Henry Hub, TTF), with spot volatility.

Gas is the 'bridge fuel' - cleaner than coal/oil for power and industry, but still fossil. Investment needs long-term contracts to finance liquefaction plants and terminals.

Pakistan's indigenous gas is depleting, forcing expensive LNG imports. Regulated wellhead prices historically discouraged exploration; circular debt plagues the gas sector too, with unaccounted-for gas (UFG - leakage and theft) raising costs. Pricing reform - moving toward market-based, weighted-average pricing - is ongoing and contentious.

Key Points

- LNG globalized gas; pricing mixes oil-indexation and hub benchmarks.
- Pakistan's domestic gas depletes; LNG imports fill the gap at high cost.
- UFG losses and regulated prices distort the sector.

Key Terms

LNG: Liquefied natural gas for ship transport.

UFG: Unaccounted-for gas: leakage and theft.

Wellhead price: The regulated price paid to gas producers.

Example

- *Pakistan's LNG terminals import cargoes priced against Brent crude.*

Summary: Gas economics blends global LNG markets with Pakistan's depletion and pricing challenges.

Exam Tips

- ★ Key point: why LNG matters for Pakistan.
- ★ Remember UFG.

Topic 10: Electricity Markets and Regulation

Learning Objectives

- Explain electricity's unique features
- Describe market models
- Discuss Pakistan's power sector structure

Key Concepts

Electricity cannot be stored economically at scale, so supply must match demand instantaneously - requiring reserves and grid management. The value chain unbundles into generation (potentially competitive), transmission and distribution (natural monopolies), and retail/supply.

Market models range from single-buyer (one agency buys all power - Pakistan's traditional CPPA model) to wholesale competition (generators sell into a pool) to full retail choice. Restructuring aims at efficiency but needs strong regulation.

Pakistan's sector: generation mix of thermal, hydro, nuclear, renewables; NTDC transmits; DISCOs distribute (with high losses and low recovery); NEPRA regulates tariffs. The single-buyer model with capacity payments to IPPs created circular debt when tariffs lagged costs - the sector's defining crisis.

Key Points

- Electricity needs instant supply-demand balance; chain unbundles into competitive and monopoly parts.
- Models: single-buyer to wholesale/retail competition.

- Pakistan: IPP capacity payments + tariff lags = circular debt.

Key Terms

Single-buyer model: One agency purchasing all generated power.

Capacity payment: Fixed payment for plant availability regardless of dispatch.

NEPRA: National Electric Power Regulatory Authority.

Example

- *Capacity payments mean consumers pay for idle plants when demand is low.*

Summary: Power sector design - market structure plus regulation - determines cost and reliability.

Exam Tips

- ★ Very important: capacity payments and circular debt logic.
- ★ Remember the unbundled chain.

Unit 3: Pricing, Subsidies, and Reform

Topic 11: Energy Pricing Principles

Learning Objectives

- Explain marginal-cost pricing
- Discuss Ramsey pricing
- Describe tariff structures

Key Concepts

Efficient pricing sets price equal to marginal cost - the cost of the last unit. For electricity, this means time-of-use pricing: peak power (evening) costs far more to supply than off-peak, so peak tariffs should be higher, flattening demand.

Ramsey pricing addresses fixed-cost recovery: when prices must cover total costs, markups should be inversely related to demand elasticity - tax inelastic users more - minimizing distortion. Two-part tariffs (fixed charge + per-unit price) recover fixed costs without distorting usage.

Real tariffs blend these with equity: lifeline rates (cheap first units for the poor), cross-subsidies (industry pays more so households pay less), and slab structures. Pakistan's slab system subsidizes low consumption but distorts when slabs are poorly targeted.

Key Points

- Efficient price = marginal cost; time-of-use reflects peak costs.
- Two-part tariffs and Ramsey pricing recover fixed costs efficiently.
- Equity add-ons: lifeline rates, cross-subsidies, slabs.

Key Terms

Marginal-cost pricing: Pricing at the cost of the last unit produced.

Time-of-use tariff: Prices varying by time of day.

Cross-subsidy: One consumer group subsidizing another.

Example

- *Evening peak electricity costs 3x off-peak to supply: tariffs should reflect this.*

Summary: Good tariffs balance efficiency (marginal cost) with cost recovery and equity.

Exam Tips

- ★ Very important: marginal-cost pricing logic.
- ★ Remember lifeline rates and cross-subsidies.

Topic 12: Energy Subsidies: Forms and Effects

Learning Objectives

- Classify energy subsidies
- Analyze subsidy effects
- Discuss Pakistan's subsidy experience

Key Concepts

Subsidies take forms: price controls (selling below cost), tax breaks for producers, direct budget transfers, and underpriced state resources. They aim at affordability, competitiveness, or investment - but create distortions.

Effects: overconsumption and waste (cheap energy is used carelessly), fiscal burden, smuggling/adulteration incentives (subsidized fuel sold across borders), underinvestment (suppliers cannot recover costs), and regressive benefits - the rich, using more energy, capture most subsidy value. IMF studies consistently find fuel subsidies regressive.

Pakistan's history: untargeted electricity and gas subsidies ballooned fiscal costs and circular debt. Reform moved toward targeted subsidies (Ehsaas-linked, lifeline consumers) while raising general tariffs - politically painful but fiscally necessary.

Key Points

- Forms: price caps, tax breaks, transfers, cheap state resources.
- Harms: waste, fiscal cost, smuggling, underinvestment, regressive capture.
- Reform direction: targeted subsidies replacing untargeted ones.

Key Terms

Untargeted subsidy: A subsidy benefiting all consumers regardless of need.

Targeted subsidy: A subsidy directed at deserving groups.

Fuel smuggling: Illicit trade exploiting price differences.

Example

- *Cheap petrol subsidies benefited SUV owners most - classic regressive capture.*

Summary: Subsidies are costly, distortionary, and regressive; targeting is the reform answer.

Exam Tips

- ★ Very important: why subsidies are regressive.
- ★ Remember Pakistan's targeted-subsidy shift.

Topic 13: Circular Debt: Causes and Solutions

Learning Objectives

- Explain Pakistan's circular debt mechanism
- Identify its root causes
- Evaluate solutions

Key Concepts

Circular debt is the chain of unpaid dues in the power sector: consumers/DISCOs do not pay fully -> DISCOs cannot pay CPPA -> CPPA cannot pay generators -> generators cannot pay fuel suppliers. The stock keeps growing because flows never balance.

Root causes: tariffs below cost recovery (political reluctance), high transmission and distribution losses (technical plus theft), low bill recovery, expensive generation mix (imported fuels, capacity payments), and governance failures in DISCOs.

Solutions form a package: cost-reflective tariffs with targeted protection, privatization or concession of DISCOs, loss reduction (metering, enforcement), cheaper generation (renewables, renegotiated IPP terms), and settling the stock through financing. Partial fixes fail - the circle needs breaking at every link.

Key Points

- Circular debt: unpaid chain from consumers through DISCOs to generators to fuel suppliers.
- Causes: below-cost tariffs, losses, theft, low recovery, costly mix.
- Fix needs tariffs, privatization, loss control, cheaper generation together.

Key Terms

Circular debt: Accumulating unpaid dues across the power supply chain.

Cost-reflective tariff: A tariff covering the full cost of supply.

AT&C; losses: Aggregate technical and commercial (theft) losses.

Example

- A DISCO recovering only 85% of billed amounts leaves a permanent 15% hole.

Summary: Circular debt is a flow problem needing simultaneous tariff, governance, and generation-mix reform.

Exam Tips

- ★ Very important: the circular debt chain and its causes - a top exam topic.
- ★ Remember: partial fixes fail.

Topic 14: Petroleum Pricing and Deregulation

Learning Objectives

- Explain petroleum price build-up
- Discuss deregulation debates
- Analyze price pass-through effects

Key Concepts

Retail fuel price builds from ex-refinery/import price plus freight, margins (OMC and dealer), petroleum levy, and sales tax. The government historically set prices fortnightly; the petroleum levy became a major revenue tool, and its changes drive pump prices.

Deregulation debates: market pricing improves efficiency and ends fiscal exposure, but exposes consumers to volatility; managed prices smooth shocks but recreate subsidies. Pakistan has moved toward more automatic pass-through with targeted protection debates ongoing.

Pass-through effects: fuel price rises raise transport costs, food prices, and inflation broadly (second-round effects), squeezing real incomes. Central banks watch fuel inflation closely; governments balance revenue needs against inflation pain.

Key Points

- Price = import/refinery cost + margins + petroleum levy + sales tax.
- Deregulation trades efficiency for volatility exposure.
- Fuel rises pass through to transport, food, and general inflation.

Key Terms

Petroleum levy: A tax on petroleum products, a key revenue source.

Pass-through: Transmission of fuel price changes to the wider economy.

OMC margin: Oil marketing company's regulated margin.

Example

- *A Rs. 10/litre levv hike raises freiaht costs and veaetable prices within weeks.*

Summary: Petroleum pricing balances revenue, efficiency, and inflation control.

Exam Tips

- ★ Key point: price build-up components.
- ★ Remember pass-through to inflation.

Topic 15: Regulatory Economics: NEPRA and OGRA

Learning Objectives

- Explain the regulator's role
- Describe rate-of-return vs. incentive regulation
- Discuss regulatory capture risks

Key Concepts

Regulators (NEPRA for power, OGRA for oil and gas) set tariffs, license operators, enforce standards, and protect consumers - substituting for competition where monopolies persist. Good regulation mimics competitive outcomes.

Regulatory models: rate-of-return (cost-plus - safe but dulls efficiency incentives), price-cap/incentive regulation (RPI-X - rewards cost cutting but risks underinvestment), and yardstick competition (benchmarking DISCOs against each other).

Challenges: information asymmetry (firms know costs better), regulatory capture (regulators favoring industry), and political interference in tariff notifications - Pakistan's delayed tariff determinations worsened circular debt. Independence, transparency, and technical capacity decide regulatory quality.

Key Points

- Regulators substitute for competition in monopoly segments.
- Models: rate-of-return vs. price-cap (RPI-X) vs. yardstick.

- Risks: information gaps, capture, political interference.

Key Terms

NEPRA/OGRA: Power and oil/gas regulators.

Price-cap regulation: Capping prices while letting firms keep efficiency gains.

Regulatory capture: Regulators serving industry over consumers.

Example

- *Delayed tariff notifications left DISCOs under-recovering for months.*

Summary: Regulatory design and independence determine whether monopolies serve the public.

Exam Tips

- ★ Key point: compare rate-of-return and price-cap regulation.
- ★ Remember regulatory capture.

Unit 4: Energy Security, Environment, and Renewables

Topic 16: Energy Security Concepts

Learning Objectives

- Define energy security
- List security indicators
- Discuss policy responses

Key Concepts

Energy security means reliable, affordable access to energy - the IEA's 'uninterrupted availability at affordable prices'. Dimensions: availability (physical supply), affordability, and increasingly sustainability.

Indicators: import dependence, supplier concentration (Herfindahl index), reserve margins, diversity of the fuel mix, and strategic stocks. Pakistan scores poorly: high import dependence concentrated on few suppliers, thin reserves, and no strategic petroleum reserve worthy of the name.

Policy responses: diversify sources and suppliers, build stocks, invest in domestic resources (Thar coal, renewables, tight gas), improve efficiency (negawatts are the cheapest 'supply'), and integrate regionally (CASA-1000, TAPI pipeline - geopolitically fraught). Security justifies some cost premium over pure market logic.

Key Points

- Energy security: reliable, affordable, sustainable supply.
- Pakistan: high import dependence, concentrated suppliers, weak stocks.
- Responses: diversification, domestic resources, efficiency, regional links.

Key Terms

Energy security: Uninterrupted energy availability at affordable prices.

Import dependence: Share of energy supplied from imports.

Strategic reserve: Stockpiled fuel for supply emergencies.

Example

- *Thar coal development cuts import dependence despite environmental trade-offs.*

Summary: Energy security requires diversification, stocks, and domestic resources beyond market efficiency.

Exam Tips

- ★ Key point: the three dimensions of energy security.
- ★ Remember Pakistan's vulnerabilities.

Topic 17: Climate Change and Energy Policy

Learning Objectives

- Link energy to climate change
- Explain carbon pricing instruments
- Discuss Pakistan's climate vulnerability

Key Concepts

Energy (fossil combustion) causes most CO₂ emissions - the driver of climate change. The economics: emissions are a negative externality, so policy must price or limit them. Instruments: carbon taxes (price certainty), cap-and-trade/ETS (quantity certainty), and standards/subsidies for clean tech.

Pakistan contributes little to global emissions but is highly vulnerable - floods, heatwaves, glacial melt - making adaptation as important as mitigation. Its climate policy (updated NDCs) pledges expanded renewables conditional on finance.

Co-benefits motivate action regardless: cutting fossil use reduces import bills, air pollution deaths, and circular debt simultaneously. Climate finance (Green Climate Fund) can fund the transition.

Key Points

- Fossil energy drives emissions; price them via carbon taxes or cap-and-trade.
- Pakistan: low emitter, high vulnerability - adaptation matters.
- Co-benefits: import savings, health, debt reduction.

Key Terms

Carbon tax: A tax per tonne of CO₂ emitted.

Cap-and-trade: Tradable permits capping total emissions.

NDC: Nationally Determined Contribution under the Paris Agreement.

Example

- *Lahore's smog costs billions in health damage - a fossil externality.*

Summary: Climate policy prices the carbon externality; for Pakistan, adaptation and co-benefits lead.

Exam Tips

- ★ Very important: carbon tax vs. cap-and-trade.
- ★ Remember externality as the rationale.

Topic 18: Economics of Renewable Energy

Learning Objectives

- Explain falling renewable costs

- Discuss intermittency and integration
- Evaluate renewable policies

Key Concepts

Solar and wind costs fell ~90% in a decade through learning curves and scale - now the cheapest new generation in sunny/windy regions like Pakistan. Their marginal cost is near zero (free fuel), which depresses wholesale prices when they generate (merit-order effect).

Challenge: intermittency - solar/wind vary with weather, needing backup, storage, or grid flexibility. Integration costs (balancing, transmission to resource sites) partly offset cheap generation; system value exceeds plant-level LCOE comparisons.

Policies: feed-in tariffs (guaranteed prices - kickstarted the industry but proved costly), auctions/competitive bidding (now standard, driving record-low prices), net metering (rooftop solar - booming in Pakistan), and renewable portfolio obligations. Pakistan's ARE Policy targets a high renewable share.

Key Points

- Solar/wind now cheapest new-build; near-zero marginal cost.
- Intermittency needs storage, backup, and grid investment.
- Policies evolved from feed-in tariffs to auctions and net metering.

Key Terms

Learning curve: Cost falling with cumulative production experience.

Intermittency: Variable output of solar and wind.

Net metering: Crediting rooftop solar exports against consumption.

Example

- *Pakistani factories install rooftop solar under net metering. cutting bills 30-40%.*

Summary: Renewables win on cost; integration and smart policy decide how fast they scale.

Exam Tips

- ★ Very important: why renewables got cheap + intermittency challenge.
- ★ Remember feed-in tariff vs. auction.

Topic 19: Energy Efficiency Economics

Learning Objectives

- Explain why efficiency is underinvested
- Discuss the rebound effect
- Evaluate efficiency policies

Key Concepts

Energy efficiency (same service, less energy) is often the cheapest 'source' - a negawatt. Yet consumers underinvest due to market failures: split incentives (landlords buy appliances, tenants pay bills), information gaps, high implicit discount rates (myopia), and credit constraints.

The rebound effect: efficiency gains lower effective energy cost, inducing more use (a fuel-efficient car gets driven more) - typically offsetting 10-30% of savings, rarely all (backfire is rare).

Policies: minimum energy performance standards (MEPS - e.g. for fans, ACs), labeling (star ratings), building codes, audits for industry, and financing (ESCOs - energy service companies paid from savings). Pakistan's NEECA leads these efforts with large untapped potential.

Key Points

- Efficiency is the cheapest energy source but faces market failures.
- Barriers: split incentives, information gaps, myopia, credit constraints.
- Policies: standards, labels, codes, audits, ESCO financing.

Key Terms

Negawatt: A unit of energy saved through efficiency.

Rebound effect: Increased use offsetting efficiency gains.

MEPS: Minimum energy performance standards.

Example

- *Replacing conventional fans with efficient ones nationwide would save gigawatts of peak demand.*

Summary: Efficiency policy corrects market failures blocking profitable energy savings.

Exam Tips

- ★ Key point: barriers to efficiency investment.
- ★ Remember the rebound effect.

Topic 20: Nuclear and Thar Coal: Case Studies

Learning Objectives

- Analyze nuclear power economics
- Evaluate Thar coal development
- Discuss trade-off frameworks

Key Concepts

Nuclear power: very high upfront cost, low operating cost, decades-long life, and zero carbon - economic where financing is cheap and demand stable. Pakistan's Chinese-built plants (K-2/K-3, Chashma) add low-carbon baseload but raise debt and waste-management questions.

Thar coal: vast domestic lignite reserves developed to cut import dependence - mine-mouth plants with lower fuel cost than imported coal/oil. Benefits: energy security, local jobs, cheaper power. Costs: high carbon emissions, water use, displacement - clashing with climate goals.

Trade-off analysis weighs security and cost against environment using cost-benefit tools, with honest accounting of externalities. Pakistan's pragmatic path: exploit Thar while aggressively adding renewables - a contested but economically reasoned mix.

Key Points

- Nuclear: costly to build, cheap clean baseload to run.
- Thar coal: import substitution vs. carbon and local costs.
- Decisions need full cost-benefit including externalities.

Key Terms

Baseload: Minimum continuous electricity demand.

Mine-mouth plant: A power plant at the coal mine, cutting transport cost.

Lignite: Low-grade brown coal abundant in Thar.

Example

- *Thar's mine-mouth tariff undercuts imported-RLNG generation.*

Summary: Domestic resources trade security and cost against environmental goals.

Exam Tips

- ★ Key point: nuclear cost structure.
- ★ Remember Thar's trade-offs.

Unit 5: Energy Planning and Development

Topic 21: Integrated Energy Planning

Learning Objectives

- Explain integrated resource planning
- Describe planning models
- Discuss Pakistan's planning gaps

Key Concepts

Integrated energy planning optimizes supply and demand together across fuels and sectors, rather than planning power, gas, and transport separately. Tools: energy system models (MARKAL/TIMES, LEAP) simulating decades of investment under scenarios.

Good planning needs consistent assumptions (GDP, prices), technology databases, and stakeholder process - and must be updated as reality diverges. Pakistan's planning has been fragmented: indicative generation capacity plans (IGCEP) exist, but gas, transport, and demand-side planning lag, and political cycles override technical plans.

Consequences of poor planning: capacity payments for unneeded plants, fuel-supply mismatches, and stranded investments. Institutional fix: an empowered, independent planning body with statutory backing.

Key Points

- Integrated planning optimizes across fuels, sectors, and decades.
- Models (LEAP, TIMES) test scenarios systematically.
- Fragmented planning causes costly mismatches.

Key Terms

Integrated resource planning: Joint optimization of energy supply and demand.

IGCEP: Indicative Generation Capacity Expansion Plan.

Scenario: A consistent storyline of future assumptions.

Example

- *Building LNG plants without secured gas supply chains created underutilized assets.*

Summary: Credible, integrated, enforced planning prevents expensive energy mistakes.

Exam Tips

- ★ Key point: why integrated beats siloed planning.
- ★ Remember IGCEP.

Topic 22: Rural Electrification and Access

Learning Objectives

- Discuss electrification economics
- Compare grid extension vs. off-grid
- Evaluate solar home systems

Key Concepts

Extending the grid to remote villages is costly per connection (long lines, few users) - yet the development returns are high. Economic appraisal compares grid extension, mini-grids, and solar home systems by cost per household and service level.

Off-grid solar has transformed access: cheap panels plus pay-as-you-go mobile payments bring light and phone charging where grids may never reach. Mini-grids serve denser settlements with productive loads (mills, pumps).

Pakistan's challenge: near-universal nominal electrification but unreliable supply - access without reliability delivers little. Policy must pair connections with adequate generation and DISCO performance.

Key Points

- Remote electrification: compare grid, mini-grid, solar home systems by cost and service.
- Pay-as-you-go solar expands access fast.
- Reliability matters as much as connections.

Key Terms

Mini-grid: A local electricity network serving a village cluster.

Pay-as-you-go: Mobile-money-enabled installment payments for solar kits.

Last-mile access: Connecting the final unserved households.

Example

- *Solar home systems light Tharparkar homes the grid cannot economically reach.*

Summary: Least-cost technology plus reliable supply delivers real energy access.

Exam Tips

- ★ Key point: grid vs. off-grid comparison.
- ★ Remember reliability alongside access.

Topic 23: Energy and Poverty Alleviation

Learning Objectives

- Link energy access to poverty reduction
- Discuss targeted energy assistance
- Evaluate lifeline tariffs

Key Concepts

Energy poverty deepens income poverty: without electricity, home businesses cannot run; without clean cooking, health suffers (indoor smoke kills millions globally, mostly women and children). Clean cooking (LPG, biogas, electric) is a major health intervention.

Targeted assistance beats blanket subsidies: lifeline tariffs (cheap first 50-100 units), BISP-linked energy support, and efficient-appliance programs help the poor without distorting the whole market. Targeting needs data - NADRA-linked databases enable it in Pakistan.

Gender dimension: women bear fuel-collection and smoke burdens; electrification frees their time for education and income. Energy policy is thus social policy.

Key Points

- Energy poverty traps households; clean cooking saves lives.
- Targeted help (lifeline tariffs, linked transfers) beats blanket subsidies.
- Women gain most from modern energy access.

Key Terms

Lifeline tariff: Subsidized rate for small consumption blocks.

Clean cooking: Stoves/fuels avoiding indoor air pollution.

BISP: Benazir Income Support Programme.

Example

- *Lifeline consumers using under 100 units pay a fraction of the cost-reflective tariff.*

Summary: Pro-poor energy policy targets support precisely while fixing system-wide pricing.

Exam Tips

- ★ Key point: targeted vs. blanket subsidies.
- ★ Remember the gender dimension.

Topic 24: Regional Energy Cooperation

Learning Objectives

- Explain gains from energy trade
- Describe regional projects
- Discuss barriers

Key Concepts

Energy trade exploits comparative advantage: Central Asian hydro for South Asian demand (CASA-1000), Iranian gas for Pakistan (IP pipeline), regional power pools smoothing peaks. Trade improves security through diversification and lowers costs.

Projects: CASA-1000 (Kyrgyz/Tajik hydro to Pakistan via Afghanistan), TAPI gas pipeline (Turkmenistan-Afghanistan-Pakistan-India), and potential Iran-Pakistan gas - all geopolitically complex. Power trade with India remains hostage to politics despite obvious economic logic.

Barriers: geopolitics, transit-country risk, financing, and pricing disputes. Progress needs diplomacy as much as economics - energy cooperation can itself build peace dividends.

Key Points

- Regional trade diversifies supply and cuts costs.

- CASA-1000, TAPI, IP pipeline: big potential, geopolitical hurdles.
- Transit risk and politics are the main barriers.

Key Terms

CASA-1000: Central Asia-South Asia power transmission project.

TAPI: Turkmenistan-Afghanistan-Pakistan-India gas pipeline.

Transit risk: Danger from dependence on intermediate countries.

Example

- *CASA-1000 would bring cheap summer hydro to Pakistan's peak season.*

Summary: Regional energy integration offers large gains blocked mainly by politics.

Exam Tips

- ★ Key point: name two regional projects and their logic.
- ★ Remember transit risk.

Topic 25: The Future: Hydrogen, Storage, and Smart Grids

Learning Objectives

- Introduce emerging energy technologies
- Discuss their economics
- Assess relevance for Pakistan

Key Concepts

Green hydrogen (from renewable electrolysis) may decarbonize steel, chemicals, and heavy transport - currently costly but falling; Pakistan's solar potential could make it a future producer. Battery storage costs plunged, enabling solar/wind to serve evenings - the key to high renewable shares.

Smart grids use digital tech for demand response (consumers shifting use to cheap hours), efficient balancing, and integrating distributed solar. Electric vehicles shift transport energy to the power sector - raising electricity demand while cutting oil imports, a double win for Pakistan if charged on clean power.

Economics: these technologies follow learning curves - early support buys future cheapness. For Pakistan, the strategy is selective adoption: storage with solar auctions, EV policy tied to grid cleaning, and watching hydrogen without overcommitting.

Key Points

- Hydrogen, batteries, smart grids, EVs reshape energy systems.
- Storage unlocks high renewable penetration; EVs cut oil imports.
- Learning curves justify selective early support.

Key Terms

Green hydrogen: Hydrogen produced from renewable electricity.

Demand response: Consumers adjusting usage to price signals.

Smart grid: A digitally managed electricity network.

Example

- *Evening battery storage lets daytime solar power night-time demand.*

Summary: Emerging technologies will define the next energy transition; smart sequencing captures their benefits.

Exam Tips

- ★ Key point: why storage matters for renewables.
- ★ Remember EVs' double win for Pakistan.

Glossary of Key Terms

Energy intensity: Energy consumed per unit of GDP.

Derived demand: Demand arising from demand for energy services.

LCOE: Levelized cost of energy: lifetime cost per unit generated.

OPEC: Organization of Petroleum Exporting Countries coordinating output.

LNG: Liquefied natural gas enabling global gas trade.

NEPRA: National Electric Power Regulatory Authority.

Circular debt: Accumulating unpaid dues across the power supply chain.

Capacity payment: Fixed payment for generation availability.

Marginal-cost pricing: Pricing energy at the cost of the last unit.

Cross-subsidy: One consumer group subsidizing another's tariff.

Carbon tax: A tax per tonne of CO₂ emitted.

Intermittency: Variable output of solar and wind power.

Net metering: Crediting rooftop solar exports against consumption.

Energy security: Reliable, affordable, sustainable energy access.

Hotelling's rule: Optimal depletion: resource prices rise at the interest rate.