

SEROMA CHRISTIAN HIGH SCHOOL.

TOPIC 8: ENERGY PRODUCTION

Comprehensive Notes for A-Level Human Geography

HOLIDAY WORK FOR TERM 2, 2026

S.6 GEOG 2

Competency: The learner devises innovative ways of developing and using energy through analysing the production, consumption and sustainability of the various sources of energy to balance energy use and environmental stewardship.

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INTRODUCTION TO ENERGY PRODUCTION

Energy is one of the most fundamental drivers of human civilisation. Every activity we engage in from cooking food in a Ugandan household, to powering industries in Germany, to running hospitals and schools depends on energy. Understanding where energy comes from, how it is produced, and the consequences of its use is therefore central to human geography. This topic, spanning 38 periods, explores the geography of energy: its resources, distribution, production, consumption, and the complex economic, environmental, and social factors that shape how energy is developed and used across the world.

For A-level students in Uganda and across East Africa, this topic is particularly relevant. Uganda sits on significant petroleum reserves in the Albertine region, possesses enormous hydroelectric potential along the River Nile (exemplified by the Karuma and Isimba dams), and enjoys abundant solar radiation throughout the year. Yet paradoxically, millions of Ugandans still lack access to reliable electricity, and the majority of households depend on firewood and charcoal for cooking — a pattern common across much of sub-Saharan Africa. This tension between energy resource wealth and energy poverty is one of the defining geographical questions of our time.

This set of teaching notes is structured around the six learning outcomes outlined in the course syllabus. Each section introduces key concepts with clear definitions, explores them through real-world examples (with a strong emphasis on Uganda and East Africa), and provides detailed analytical points for examination preparation. Students are encouraged to engage actively with maps, statistics, and case studies throughout this topic, as these form the backbone of strong geographical analysis.

LEARNING OUTCOME A: ENERGY RESOURCES AND THEIR SPATIAL DISTRIBUTION

Learning Outcome: *Demonstrate an understanding of energy resources and their spatial distribution to appreciate variations in energy production.*

1.1 Definitions and Key Concepts

Energy: Energy refers to the power that is harnessed from natural resources to drive economic activities, transport, industry, agriculture, and domestic life. Energy exists in many forms including heat, light, mechanical, electrical, and chemical energy. For a student in Kampala, energy is what powers the bodaboda motorcycle, charges a phone, lights a classroom, and cooks a meal over charcoal.

Energy Resources: Energy resources are naturally occurring materials or phenomena from which usable energy can be extracted or harnessed. They include solid fuels like coal and firewood, liquid fuels like petroleum, gaseous fuels like natural gas, as well as renewable phenomena like sunlight, wind, moving water, and geothermal heat. The type and quantity of energy resources available in a region largely determines its energy profile and influences its level of economic development.

Renewable Energy Resources: These are energy sources that are naturally replenished on a human timescale and are therefore theoretically inexhaustible. They include solar energy, wind energy, hydroelectric power, geothermal energy, tidal and wave energy, and biomass energy. For example, Uganda's solar energy is replenished daily as the sun rises. Renewable energy sources are increasingly important in the global effort to combat climate change, as they generally produce little or no greenhouse gas emissions during operation.

Non-Renewable Energy Resources: Non-renewable energy resources are those formed over millions of years through geological processes and exist in finite quantities on Earth. Once consumed, they cannot be replaced within any meaningful human timeframe. The primary non-renewable resources are fossil fuels: coal, petroleum (crude oil), and natural gas. Nuclear energy, which relies on uranium ore, is also classified as non-renewable.

Globally, over 80% of energy consumption still relies on non-renewable fossil fuels, even as renewables expand rapidly.

Spatial Distribution of Energy Resources: Spatial distribution refers to the geographical pattern of where energy resources are located across the Earth's surface. This distribution is highly uneven and is largely determined by geological history, climate, physical geography, and tectonic processes.

For instance, petroleum is concentrated in the Middle East (particularly Saudi Arabia, Iraq, and Iran) and along sedimentary basins like Uganda's Albertine Graben. Hydroelectric potential is concentrated in areas with large rivers and significant elevation changes, such as the Congo Basin or the River Nile.

Wind energy is concentrated in coastal and highland areas with consistent wind speeds. Understanding this spatial distribution is crucial for explaining why some countries are energy-rich and others are energy-poor.

1.2 Classification of Major Energy Resources

A) Non-Renewable Energy Sources

Coal is a solid fossil fuel formed from ancient plant matter compressed over millions of years. It was the primary fuel of the Industrial Revolution and remains a major source of electricity globally, particularly in China, India, the United States, and South Africa. In East Africa, coal deposits exist in Tanzania (Songwe-Kiwira) and Mozambique. However, coal is the most carbon-intensive of all fossil fuels and a major contributor to air pollution and climate change.

Petroleum (crude oil) is a liquid fossil fuel extracted from underground reservoirs and refined into products such as petrol, diesel, kerosene, and aviation fuel. It is the world's most traded commodity and powers the global transport system. In Uganda, oil was discovered in the Albertine Graben in 2006, with estimated reserves of over 6 billion barrels. Kenya, Tanzania, and South Sudan also have oil deposits in East Africa. Globally, the Middle East holds approximately 48% of proven oil reserves.

Natural gas is a gaseous fossil fuel composed mainly of methane. It is often found alongside petroleum deposits and is used for electricity generation, heating, cooking (as LPG — liquefied petroleum gas), and as a raw material in chemical industries. Tanzania has significant offshore natural gas deposits in the Indian Ocean. Natural gas emits less carbon dioxide than coal or oil when burned, making it a transitional fuel as countries move toward renewables.

Nuclear energy is produced through nuclear fission, the process of splitting uranium atoms to release enormous amounts of heat, which drives turbines to generate electricity. Nuclear power provides about 10% of the world's electricity and produces very low greenhouse gas emissions during operation. France obtains approximately 70% of its electricity from nuclear power — the highest proportion of any country in the world. Africa has very limited nuclear capacity, with South Africa operating the only nuclear power plant on the continent (Koeberg).

B) Renewable Energy Sources

Hydroelectric Power (HEP) is generated by harnessing the kinetic energy of flowing or falling water to turn turbines connected to electricity generators. It is by far the most important renewable energy source in Uganda and East Africa generally. The River Nile, flowing out of Lake Victoria at Jinja, has been harnessed since 1954 (Owen Falls Dam, now Nalubaale). More recent developments include the Karuma Hydropower Plant (600 MW) and the Isimba Hydropower Plant (183 MW). HEP accounts for approximately 90% of Uganda's electricity generation. The Democratic Republic of Congo (DRC), with the Inga Dam on the Congo River, has the largest hydroelectric potential of any country on Earth.

Solar energy is captured using photovoltaic (PV) panels that convert sunlight directly into electricity, or through solar thermal systems that use sunlight to heat water. Uganda and the rest of East Africa lie close to the equator and receive abundant solar radiation throughout the year — typically 4 to 6 kilowatt-hours per square metre per day — making solar energy a highly viable resource. Solar panels are increasingly being installed on rooftops, schools, health centres, and farms across rural Uganda where grid electricity is unavailable. Germany and China are global leaders in installed solar capacity.

Wind energy is harnessed through wind turbines that convert the kinetic energy of moving air into electricity. Wind energy potential is greatest in coastal areas, open plains, and highland regions where wind speeds are consistently high. In Kenya, the Lake Turkana Wind Power Project Africa's largest wind farm with 365 turbines generates approximately 310 MW and supplies about 17% of Kenya's total electricity demand. In Europe, Denmark generates over 50% of its electricity from wind. Uganda's wind energy potential is more limited, concentrated in highland and lake-shore areas.

Geothermal energy uses heat from within the Earth's crust to generate electricity or provide direct heating. It is available in areas of volcanic or tectonic activity along plate boundaries. Kenya is Africa's leading geothermal producer, with the Olkaria Geothermal Complex in the Rift Valley generating over 700 MW about 46% of Kenya's electricity. Uganda also has geothermal potential at sites including Buranga in Bundibugyo and Kibiro in Hoima District, though these remain largely undeveloped. Iceland, which sits on the Mid-Atlantic Ridge, meets virtually all of its energy needs from geothermal and hydroelectric sources.

Biomass energy refers to energy derived from organic materials wood, agricultural residues, animal dung, and purpose-grown energy crops either burned directly for heat and cooking or converted into biogas or liquid biofuels. Biomass is the dominant energy source for the majority of Ugandan households, with over 90% of the rural population depending on firewood and charcoal. While biomass is technically renewable, unsustainable harvesting leads to deforestation, soil erosion, and ultimately to land degradation, making it one of Uganda's most critical environmental and energy policy challenges.

Ocean energy encompasses several forms including tidal energy (harnessing the movement of tides), wave energy (capturing energy from ocean waves), and ocean thermal energy conversion (OTEC, which uses temperature differences between warm surface water and cold deep water). These technologies are still largely in the experimental or early commercial stage globally. Tidal power stations exist in France (La Rance, operational since 1966), South Korea, and Canada. For landlocked East African

countries like Uganda, ocean energy is not directly applicable, though coastal states like Kenya and Tanzania have long-term potential.

Hydrogen energy, though technically an energy carrier rather than a primary resource, is increasingly discussed as a future energy solution. Hydrogen gas can be produced through electrolysis (splitting water using electricity) and, when consumed in a fuel cell, produces only water as a byproduct. 'Green hydrogen' — produced using renewable electricity — has the potential to decarbonise sectors that are difficult to electrify, such as heavy industry and long-distance shipping. While hydrogen energy remains largely in developmental stages in Africa, countries like South Africa are investing in green hydrogen production for export to Europe.

1.3 Spatial Distribution of Energy Resources: Key Factors

The spatial distribution of energy resources across the globe is not random; it is shaped by a combination of geological, physical, and climatic factors. Understanding these factors helps geographers explain why energy resources are concentrated in specific regions and why their distribution is so uneven.

Factors Influencing the Spatial Distribution of Energy Resources

The following ten factors explain the uneven spatial distribution of energy resources globally and in Uganda specifically:

1. **Geological History and Tectonic Processes:** The formation of fossil fuels — coal, oil, and natural gas — is directly linked to the geological history of a region. Petroleum deposits form in sedimentary basins where ancient marine organisms were buried under layers of sediment and subjected to heat and pressure over millions of years. Uganda's Albertine Graben (the western arm of the East African Rift System) created the ideal sedimentary conditions for oil formation, which is why significant petroleum reserves were discovered there in 2006. Similarly, the coal deposits of South Africa's Witwatersrand basin are a product of ancient swamp environments. Countries without sedimentary basins — such as those underlain entirely by ancient

crystalline basement rocks — have no fossil fuel potential regardless of their development status.

2. **River Systems and Hydrology:** The availability of large, perennial rivers with significant discharge volumes and elevation changes determines hydroelectric potential. Uganda is extraordinarily well-positioned in this regard. The River Nile, the world's longest river, originates at Jinja (from Lake Victoria) and flows through Karuma Falls and Murchison Falls, providing numerous sites for hydropower generation. Countries in the Congo Basin (DRC, Republic of Congo) and along the Zambezi (Zambia, Zimbabwe — home to the Kariba Dam) similarly benefit from powerful river systems. In contrast, countries like Burkina Faso and Niger, located in semi-arid areas with seasonal rivers, have limited hydroelectric potential.
3. **Solar Radiation and Latitude:** Solar energy potential is strongly determined by latitude and cloud cover patterns. Countries located close to the equator, such as Uganda (latitude 1°N to 4°N), Kenya, and Tanzania, receive intense solar radiation throughout the year with minimal seasonal variation. Uganda receives on average 4.5 to 6 kWh per square metre per day — among the highest solar potential figures in the world. In contrast, countries at high latitudes (e.g., Scotland or Norway) receive far less solar radiation, particularly in winter, making solar energy less viable as a primary source. Desert regions like the Sahara and the Arabian Peninsula also have exceptional solar potential due to low cloud cover.
4. **Tectonic Activity and Volcanic Features:** Geothermal energy is available only in regions of active or recent volcanism and tectonic activity, particularly along tectonic plate boundaries. The East African Rift Valley, which runs through Ethiopia, Kenya, Tanzania, and Uganda, provides significant geothermal resources. Kenya's Rift Valley hosts the Olkaria Geothermal Complex, which has been operational since 1981 and is one of the largest geothermal installations in Africa. Uganda's geothermal sites at Buranga (Bundibugyo), Kibiro (Hoima), and Katwe (Kasese) are located along the western Rift and are yet to be fully developed. Iceland, Japan, and New Zealand also exploit geothermal energy extensively due to their positions on tectonic plate boundaries.
5. **Wind Patterns and Topography:** Wind energy potential is concentrated in areas with consistently high wind speeds, typically coastal regions, open plains, and highland areas where surface friction is low and prevailing winds are strong. In East

Africa, the Lake Turkana area in northern Kenya experiences strong and consistent winds driven by the pressure gradient between the Indian Ocean and the interior of the continent, making it the site of Africa's largest wind farm. In Uganda, some highland areas such as the Rwenzori foothills and parts of Karamoja experience moderate wind speeds. Globally, the North Sea (off the coasts of the UK, Denmark, and Germany) has exceptional offshore wind potential, with wind speeds above 9 m/s on average.

6. **Climate and Vegetation:** The availability of biomass energy is closely related to climate and vegetation. Tropical regions with high rainfall and dense forest cover — such as the Congo Basin, Uganda's tropical rainforest zones (Bwindi, Budongo), and West Africa — have abundant biomass in the form of firewood and charcoal. Uganda's forest cover, though declining due to deforestation, historically made biomass the predominant household energy source. Sugarcane, which grows well in Uganda's tropical climate, can be processed for bioethanol production — an energy crop being explored as part of Uganda's renewable energy diversification. In contrast, arid regions have limited biomass potential.
7. **Coastal Location and Ocean Access:** Countries with coastlines have access to ocean-based energy resources including tidal energy, wave energy, offshore wind energy, and offshore petroleum deposits. Kenya and Tanzania, with coastlines along the Indian Ocean, have discovered significant offshore natural gas deposits (Tanzania's Lindi and Mtwara regions have reserves estimated at over 57 trillion cubic feet). Mozambique, also on the Indian Ocean, has become one of Africa's largest natural gas producers. Uganda, being a landlocked country, has no access to ocean energy and must rely on its internal resources — primarily hydropower, solar, geothermal, and petroleum from the Albertine region. This geographic reality makes Uganda's energy profile fundamentally different from coastal East African states.
8. **Mineral Deposits and Uranium Occurrence:** Nuclear energy potential depends on the availability of uranium ore, a relatively rare mineral found mainly in sedimentary and metamorphic rock formations. The world's largest uranium producers are Kazakhstan, Canada, Australia, Namibia, and Niger. Niger and Namibia are the only significant African uranium producers, making nuclear energy a realistic option only for countries with access to uranium or the financial resources to import it. South Africa's nuclear programme at Koeberg (near Cape

Town) relies partly on imported uranium. For most sub-Saharan African countries, nuclear energy is not a practical near-term option due to both the absence of domestic uranium and the high capital cost of nuclear power stations.

9. **Historical Discovery and Exploration:** The distribution of known energy resources is partly a function of the history of geological exploration. Countries that attracted early foreign investment and exploration activity — largely shaped by colonial history — have better-mapped resource bases. The discovery of oil in Uganda came relatively late (2006), in part because large-scale geological surveys of the Albertine Graben were conducted primarily from the 1980s onwards, with accelerated exploration from the early 2000s. In contrast, the Middle East's oil wealth has been well-documented since the 1930s. This means that some regions of Africa may harbour undiscovered energy resources, and as exploration expands, the known distribution of resources may shift significantly.
10. **Accessibility and Infrastructure:** The exploitability of energy resources — and therefore which resources contribute to energy production — depends not only on their physical presence but also on the infrastructure available to access and develop them. Uganda's petroleum reserves in the Albertine region remained largely unexploited for decades due to the absence of a pipeline for export. The East African Crude Oil Pipeline (EACOP), intended to transport crude oil from Hoima in Uganda to Tanga Port in Tanzania (1,443 km), is a major infrastructure project that, once complete, will fundamentally alter Uganda's capacity to commercialise its oil resources. Similarly, remote hydroelectric potential sites require transmission infrastructure — power lines, substations — to connect generation to consumption centres.

LEARNING OUTCOME B: WORLD ENERGY PRODUCTION AND CONSUMPTION

Learning Outcome: Compare energy production and consumption in countries at different levels of development to understand the need for wise use of energy resources.

2.1 Introduction to World Energy Production and Consumption

Energy production and consumption patterns vary dramatically between countries and regions of the world, and these variations are deeply intertwined with levels of economic development. In simple terms, richer, more industrialised countries known as More Economically Developed Countries (MEDCs) consume vastly more energy per person than poorer, less industrialised countries Less Economically Developed Countries (LEDs). However, the relationship between development and energy is not simply a one-way street: access to reliable, affordable energy is itself a prerequisite for economic development, improved health, and education.

The world's primary energy consumption is dominated by fossil fuels. According to BP's Statistical Review of World Energy, coal, oil, and natural gas collectively account for approximately 80-82% of global primary energy consumption. China is the world's largest energy consumer and also the largest producer of both coal and renewable electricity.

The United States is the world's largest oil producer (following the shale revolution of the 2010s) and the second-largest energy consumer. India is the third-largest energy consumer. In Africa, South Africa, Egypt, and Nigeria are the largest energy consumers.

Uganda's energy consumption profile reflects its status as a low-income developing country. Total electricity installed capacity stood at approximately 1,254 MW in 2022, with hydropower accounting for around 90% of this.

However, electricity access rates, while improving, remain around 41% of the total population (2022 data), meaning the majority of Ugandans particularly in rural areas remain without grid electricity. This energy poverty is simultaneously a consequence of and a contributor to economic underdevelopment.

2.2 Factors Explaining Differences in Energy Consumption Between Countries

The following points explain the key factors behind differences in energy production and consumption between developed and developing countries:

1. **Level of Industrialisation:** More economically developed countries have large industrial sectors — manufacturing, steel production, chemicals, mining — that are highly energy-intensive. The United States, Germany, Japan, and China consume enormous quantities of energy to power their factories, machine tools, smelters, and automated production lines. In contrast, Uganda's economy is predominantly agricultural, with industry contributing a relatively small share of GDP. Agricultural economies require less commercial energy because farming, particularly subsistence farming, relies more on human and animal labour than on fossil fuels. As Uganda industrialises — with the development of oil refining, cement production, and manufacturing — its energy consumption will rise significantly.
2. **Income Levels and Purchasing Power:** Higher incomes enable households, businesses, and governments to purchase more energy and energy-consuming goods — cars, air conditioners, refrigerators, industrial machinery. The average American consumes approximately 12,000 kg of oil equivalent energy per year, compared to around 140 kg for an average Ugandan. This staggering difference reflects not only different economic activities but also different lifestyles, consumption patterns, and access to energy infrastructure. As household incomes rise in Uganda, energy consumption patterns are shifting — more families are purchasing solar lanterns, mobile chargers, and increasingly, refrigerators and televisions, driving up electricity demand.
3. **Climate and Heating/Cooling Demands:** Countries in cold climates (e.g., Canada, Russia, Scandinavia) consume large quantities of energy for space heating — warming buildings, homes, and workplaces during winter months when temperatures can fall to -30°C or below. In contrast, Uganda's equatorial climate is warm year-round, meaning space heating is not required. However, as urban heat islands grow in cities like Kampala and as incomes rise, air conditioning demand is increasing, which will raise energy consumption. Countries in hot desert climates (e.g., Saudi Arabia, UAE) consume very high amounts of energy for air

conditioning, desalination, and industrial cooling. Climate thus shapes both the types and quantities of energy demanded.

4. **Technology and Energy Efficiency:** Developed countries tend to use more energy-efficient technologies, which can partially offset the effect of high income on energy consumption. Modern LED lighting, energy-efficient appliances, insulated buildings, hybrid and electric vehicles, and efficient industrial processes all reduce the amount of energy required to achieve a given level of economic output. The European Union has invested heavily in energy efficiency standards and labelling. In Uganda, many households use traditional three-stone fires for cooking — an extremely inefficient method that wastes up to 90% of the energy in firewood as heat lost to the atmosphere. The introduction of improved cook stoves, which can reduce wood consumption by 30-50%, is therefore a significant energy efficiency measure in the Ugandan context.
5. **Access to Energy Infrastructure:** Energy consumption is constrained by the availability of infrastructure to deliver energy to consumers: power grids, oil pipelines, gas networks, roads for fuel distribution, and so on. In Uganda, the national grid does not reach many rural areas, making it impossible for households and businesses in those areas to consume grid electricity regardless of demand. The Rural Electrification Agency (REA) of Uganda has been working to extend the grid to rural communities, but progress is slow and costly. In contrast, developed countries like the United Kingdom or France have near-universal energy infrastructure coverage, ensuring that virtually all households and businesses can access the full range of commercial energy sources.
6. **Population Size and Urbanisation:** Total energy consumption is influenced by population size. China, with 1.4 billion people, is the world's largest energy consumer even though its per-capita consumption is lower than that of the United States. Uganda's population of approximately 47 million is growing at about 3% per year — one of the highest growth rates in the world — which means energy demand will increase substantially even without any increase in per-capita consumption. Urbanisation also drives energy consumption: urban residents tend to consume more commercial energy than rural counterparts because they are more likely to be connected to the grid, use appliances, and participate in commercial activities. As Uganda's urban population grows (currently around 25%), national energy demand will accelerate.

7. **Energy Policy and Subsidies:** Government policies — including subsidies on energy, investment in energy infrastructure, and regulations affecting energy efficiency — shape both production and consumption patterns. Countries that subsidise fossil fuel prices (e.g., Saudi Arabia, Iran, Egypt, and to some extent Uganda with kerosene subsidies historically) encourage higher consumption by keeping energy artificially cheap. Policies promoting renewable energy, such as Germany's Energiewende (energy transition) programme, have dramatically increased the share of renewables in energy production. Uganda's Renewable Energy Policy (2007) and its associated investment plans aim to diversify the energy mix and increase access, though implementation challenges remain significant.
8. **Economic Structure and Dominant Sectors:** The composition of an economy — the relative importance of agriculture, industry, and services — shapes its energy intensity. Service-sector economies (dominated by banking, insurance, retail, education, healthcare) tend to be less energy-intensive than manufacturing economies. Many developed countries have shifted toward service-based economies, which has reduced their energy intensity (energy used per unit of GDP) even as their economies have grown. Uganda's economy is transitioning from agriculture toward services, with the services sector now contributing around 45% of GDP. However, the planned development of oil refining and petrochemical industries will significantly increase industrial energy consumption in the coming decade.
9. **Transport Systems and Mobility:** Transport is one of the most energy-intensive sectors in developed economies, accounting for approximately 25-30% of total energy consumption in OECD countries. Car ownership rates, the prevalence of aviation, the extent of freight transport by road versus rail (rail being more efficient), and the fuel efficiency of vehicles all affect energy consumption. In Uganda, while private car ownership is growing among middle-class urban residents, public transport (minibus taxis, bodaboda motorcycles) and walking remain the dominant modes for most people. The fuel efficiency of Uganda's vehicle fleet, which includes many ageing imported second-hand vehicles, is low, contributing to high fuel costs per kilometre travelled and significant urban air pollution.
10. **Energy Mix and Primary Resource Endowment:** The types of energy resources available in a country influence its energy production profile. Countries rich in oil

(Saudi Arabia, Nigeria) base their economies and export earnings on petroleum. Countries with major rivers (Norway, Uganda, DRC) rely heavily on hydropower. Countries with abundant coal (South Africa, China, Australia) use coal for the majority of their electricity generation. Energy-resource-poor countries that must import their energy — such as Japan, which imports almost all of its fossil fuels — are highly vulnerable to price fluctuations in global energy markets. Uganda, though currently dependent on hydropower, anticipates a major shift in its energy profile once petroleum production from the Albertine region commences, potentially transforming it from a net energy importer to an exporter.

LEARNING OUTCOME C: FACTORS AFFECTING DEVELOPMENT OF ENERGY RESOURCES

Learning Outcome: Analyse the influence of economic, environmental, and social factors on energy resource development to form opinions about challenges facing the energy sector.

3.1 Introduction

The mere existence of an energy resource does not guarantee that it will be developed and exploited. Many energy resources around the world – from Uganda's geothermal potential to the deep offshore wind energy of developing nations – remain untapped despite their physical presence.

The development of energy resources is governed by a complex interaction of economic, environmental, and social factors that determine whether exploitation is feasible, desirable, and politically acceptable. Understanding these factors is essential for analysing the energy challenges facing Uganda and other countries at different stages of development.

3.2 Economic Factors Affecting Energy Resource Development

The following points explain the major economic factors that influence whether and how energy resources are developed:

1. **Capital Investment and Financing:** Energy projects – particularly large-scale ones such as oil fields, hydropower dams, and nuclear power stations – require enormous upfront capital investment that must be secured before any revenue can be generated. The Karuma Hydropower Dam in Uganda, for example, cost approximately US\$ 1.7 billion, financed through a Chinese government loan (from Exim Bank of China) and the Ugandan government. Developing countries often struggle to secure the necessary financing because they may have poor credit ratings, limited domestic capital markets, and a history of project delays that make international investors cautious. Energy resources that are technically exploitable may therefore remain undeveloped for decades simply because the capital is unavailable or too expensive to borrow.

2. **Economic Viability and Cost of Production:** Energy development must be economically viable that is, the revenue generated from selling the energy must exceed the cost of its extraction, processing, and distribution over the lifetime of the project. The cost-competitiveness of energy sources changes over time with technology. For example, the cost of solar photovoltaic electricity has fallen by approximately 90% since 2010, making solar energy economically competitive with coal and gas in many markets.

Uganda's petroleum reserves present a particular economic challenge: the oil is waxy and of high pour-point, making it more expensive to transport than conventional crude oil. The viability of petroleum production in Uganda has been debated for years, and the development of the EACOP pipeline is a critical prerequisite for commercial production.

3. **Market Demand and Energy Prices:** The development of energy resources is strongly influenced by the price that the energy can command on domestic or international markets. High global oil prices (as seen in the early 2000s when prices rose to over \$100 per barrel) make previously marginal oil fields economically viable and stimulate exploration and investment. Conversely, the collapse of oil prices in 2014-2016 (when prices fell to around \$30 per barrel) led to the suspension of many oil development projects worldwide, including delays to Uganda's petroleum sector. Hydroelectric power in Uganda is sold to UEDCL (Uganda Electricity Distribution Company Limited) at regulated tariffs, which must be high enough to attract private investment in generation but low enough to keep electricity affordable for consumers — a difficult balance for government regulators.
4. **Infrastructure Development Costs:** Beyond the direct costs of energy extraction or generation, energy development requires extensive supporting infrastructure: roads to access remote sites, transmission lines to carry electricity to consumers, pipelines to transport oil and gas, ports to export liquefied natural gas, and so on. These infrastructure costs can be prohibitive, particularly in geographically remote or challenging areas. Uganda's oil reserves in the Albertine Graben are located in a relatively remote area adjacent to a national park, requiring roads and infrastructure that must be built from scratch at significant cost. Germany's investment in offshore wind farms in the North Sea similarly requires expensive

undersea cable connections to bring electricity onshore infrastructure costs that add significantly to the total cost of energy development.

5. **Foreign Direct Investment and Technology Transfer:** Many developing countries lack the domestic technology and expertise to develop complex energy resources such as deepwater oil, nuclear power, or advanced geothermal systems, and must therefore attract foreign direct investment (FDI) from multinational energy companies. Uganda's oil sector involves major international oil companies including TotalEnergies (France), CNOOC (China), and previously Tullow Oil (UK). While FDI brings capital and expertise, it also raises questions about profit repatriation (the extent to which revenues flow out of Uganda rather than being reinvested domestically), technology transfer (whether Ugandan engineers and technicians gain skills and expertise), and the terms of production-sharing agreements with the government. Saudi Arabia's development of its oil reserves through Saudi Aramco represents a model of strong national control over oil resources, contrasting with Uganda's more FDI-dependent approach.

3.3 Environmental Factors Affecting Energy Resource Development

6. **Environmental Regulations and Impact Assessments:** Before major energy projects can proceed, they are typically required to undergo Environmental and Social Impact Assessments (ESIAs) to identify potential negative environmental effects and propose mitigation measures. In Uganda, the National Environment Management Authority (NEMA) is responsible for reviewing ESIAs for energy projects. The Bujagali Hydropower Dam (250 MW, commissioned in 2012) underwent an extensive ESIA process, partly driven by international lender requirements from the World Bank and the African Development Bank. Strict environmental regulations in countries like Germany, the UK, and Canada have significantly raised the costs and timescales for energy development, as developers must invest in environmental mitigation and may face legal challenges from environmental groups. In contrast, weaker regulatory environments in some developing countries may allow energy development to proceed with fewer environmental safeguards.
7. **Physical Geography and Ecological Sensitivity:** The physical geography of a region can either facilitate or constrain energy development. Uganda's Albertine Graben is located in one of the world's biodiversity hotspots — an area that

includes national parks such as Murchison Falls National Park, Kibale National Park, and Queen Elizabeth National Park, which are home to chimpanzees, elephants, lions, and other wildlife. Oil development in this area raises profound concerns about habitat disturbance, oil spills in sensitive river and lake systems, and the fragmentation of wildlife corridors. Similarly, the proposed Batoka Gorge Hydropower Project on the Zambezi River in Zambia/Zimbabwe is located in an ecologically and scenically sensitive gorge downstream from Victoria Falls. These ecological constraints do not necessarily prevent development but add significant complexity and cost.

8. **Climate Change and Hydrological Variability:** Climate change is increasingly affecting the reliability and output of energy resources, particularly hydropower. Uganda has experienced periods of reduced rainfall and lower-than-normal water levels in Lake Victoria (its main reservoir for hydroelectric generation at Nalubaale and Kiira power stations), leading to power rationing and economic disruption. The droughts of 2005-2006 caused Lake Victoria to fall to historically low levels, severely reducing hydropower output and triggering an energy crisis in Uganda and Kenya. As climate change intensifies rainfall variability in East Africa, the long-term reliability of Uganda's hydropower-dominant energy system is called into question, reinforcing the importance of diversifying the energy mix to include solar, wind, and geothermal sources that are less climate-sensitive.

3.4 Social Factors Affecting Energy Resource Development

9. **Community Displacement and Land Rights:** Large energy infrastructure projects particularly dams and oil installations often require the resettlement of communities from project sites. This is one of the most contentious social issues in energy development globally. The construction of the Three Gorges Dam in China displaced approximately 1.3 million people the largest involuntary displacement associated with any infrastructure project in history. In Uganda, the construction of the Bujagali Dam required the resettlement of thousands of households, and communities along the proposed route of the EACOP pipeline face displacement from their land. When resettlement is poorly managed with inadequate compensation, loss of access to land for farming, or disruption of social networks it creates lasting resentment and can undermine the social legitimacy of energy projects.

10. **Political Will, Governance, and Corruption:** The development of energy resources requires strong and consistent political commitment, effective regulatory institutions, transparent contract management, and governance structures that ensure revenues are used for public benefit. Countries with weak governance and high levels of corruption often described as suffering from the 'resource curse' frequently fail to translate abundant energy resources into broad-based development. Nigeria, despite being Africa's largest oil producer, has seen oil revenues largely captured by elites while the oil-producing Niger Delta region suffers from severe environmental degradation and poverty. Uganda's government is aware of this risk and has established institutions such as the Petroleum Authority of Uganda (PAU) and the Uganda National Oil Company (UNOC) to manage oil revenues and ensure accountability.
11. **Labour Skills and Human Capital:** The development of sophisticated energy industries requires a trained workforce with expertise in engineering, geology, environmental science, project management, and technical operations. The absence of adequate skilled labour domestically means that developing countries must either import expensive foreign workers or rely heavily on foreign companies for highly technical tasks. Uganda's universities and technical institutions have been working to expand training in petroleum engineering, renewable energy technology, and electrical engineering, but there remains a significant skills gap. Germany's strong tradition of engineering education and vocational training has been a key factor enabling it to lead the world in solar and wind energy technology development and manufacture, exemplifying how human capital investment supports energy sector growth.

LEARNING OUTCOME D: ENVIRONMENTAL IMPACTS OF ENERGY PRODUCTION

Learning Outcome: Assess the impact of energy development on the environment to appreciate the benefits and problems associated with harnessing energy resources.

4.1 Introduction to Environmental Impacts

Every form of energy production has environmental consequences — none is entirely without impact. The harnessing of energy from natural resources inevitably involves some transformation of, or intrusion into, natural systems. The critical task for geographers, policymakers, engineers, and citizens is to evaluate the nature and magnitude of these impacts, identify appropriate mitigation strategies, and make informed decisions about which energy sources to develop in light of both their benefits and their environmental costs.

Environmental impacts of energy production operate at multiple spatial scales: local (e.g., dust, noise, and habitat disturbance at a hydropower construction site), regional (e.g., the drying up of wetlands downstream from a dam, or acid rain from coal-burning power stations), and global (e.g., greenhouse gas emissions from fossil fuels contributing to climate change). They also vary across time: some impacts are immediate and short-lived (construction disturbance), while others are long-term and potentially irreversible (climate change, radioactive waste from nuclear power).

4.2 Environmental Impacts of Major Energy Sources

The following fourteen points examine the environmental impacts of energy production from the major energy sources, with reference to relevant examples:

1. **Greenhouse Gas Emissions and Climate Change from Fossil Fuels:** The burning of coal, oil, and natural gas releases carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) the three primary greenhouse gases responsible for anthropogenic climate change. The Intergovernmental Panel on Climate Change (IPCC) has established beyond scientific doubt that human-induced greenhouse gas emissions are causing the Earth's average temperature to rise, leading to melting ice caps, rising sea levels, more intense hurricanes, disrupted rainfall

patterns, and increased frequency of extreme weather events. Globally, the energy sector is responsible for approximately 73% of total greenhouse gas emissions. Each time a coal-fired power station in China or a diesel generator in Kampala operates, it contributes however marginally to this global environmental crisis, the impacts of which are felt most severely by the poorest and most climate-vulnerable communities in countries like Uganda.

2. **Air Pollution from Coal and Biomass Combustion:** The burning of coal and biomass (firewood, charcoal) releases a complex mixture of pollutants including particulate matter (PM_{2.5} and PM₁₀), sulphur dioxide (SO₂), nitrogen oxides (NO_x), and carbon monoxide (CO). These pollutants cause serious respiratory and cardiovascular diseases. The World Health Organization (WHO) estimates that indoor air pollution from cooking with solid biomass fuels kills approximately 3.8 million people per year globally predominantly women and children in low-income countries who spend the most time near cooking fires. In Uganda, where over 90% of the rural population cooks with firewood or charcoal, indoor air pollution is one of the leading environmental health burdens. In China and India, coal-burning power stations and industrial facilities create severe outdoor air pollution ('smog') that regularly forces school and business closures in major cities like Beijing and Delhi.
3. **Deforestation and Land Degradation from Biomass Harvesting:** Uganda's heavy dependence on biomass energy particularly firewood and charcoal is a primary driver of deforestation. Uganda's forest cover has declined from approximately 24% of total land area in 1990 to around 9% by 2015, representing one of the highest deforestation rates in Africa. Charcoal production is particularly destructive: producing one tonne of charcoal requires approximately 6-12 tonnes of wood, and charcoal kilns simple earth mounds are highly inefficient converters of wood to energy. The loss of forest cover leads to a cascade of environmental problems: soil erosion (as tree roots no longer bind the soil), reduced water retention and increased flash flooding, loss of biodiversity (Uganda's forests are home to thousands of plant and animal species), and reduced rainfall through the disruption of local hydrological cycles. Ironically, the loss of forest reduces Uganda's long-term potential for biomass energy.
4. **Flooding and Ecosystem Disruption from Hydropower Dams:** The construction of large hydropower dams creates reservoirs that flood extensive areas of land

upstream, permanently altering river ecosystems, destroying terrestrial habitats, and potentially displacing human communities. Lake Kyoga (formed behind Owen Falls/Nalubaale Dam) and the Bujagali reservoir flooded productive agricultural land and displaced communities along the Nile. The Karuma Hydropower Dam flooded sections of the Nile gorge upstream of Karuma Falls, altering a river ecosystem of significant ecological value. More dramatically, China's Three Gorges Dam created a reservoir 600 km long, flooding 13 cities, 140 towns, and 1,350 villages, and destroying critical habitat for the critically endangered Yangtze River dolphin (now functionally extinct) and the Chinese paddlefish (declared extinct in 2022). Dams also block fish migration routes, disrupting fish populations both upstream and downstream.

5. **Oil Spills and Petroleum Contamination:** Oil extraction, transportation, and refining all carry the risk of accidental spills that can cause catastrophic environmental damage. The Niger Delta in Nigeria has experienced decades of chronic oil pollution from pipeline leaks, operational spills, and sabotage, rendering vast areas of mangrove swamp, farmland, and river systems severely degraded and uninhabitable. Scientific studies estimate that oil spills in the Niger Delta have contaminated approximately 7,000 km² of land and water, affecting the livelihoods and health of millions of local people. On a global scale, the Deepwater Horizon oil spill in the Gulf of Mexico (2010) the largest marine oil spill in history released approximately 780,000 tonnes of oil, devastating marine ecosystems across a huge area. For Uganda, where oil development is planned adjacent to sensitive ecosystems in the Albertine region, the risk of oil spills particularly in the headwaters of the Nile — is a major environmental concern.
6. **Nuclear Accidents and Radioactive Waste:** Nuclear power, while producing very low greenhouse gas emissions in normal operation, carries the risk of catastrophic accidents and generates radioactive waste that remains hazardous for thousands to hundreds of thousands of years. The Chernobyl nuclear disaster (Ukraine, 1986) released massive amounts of radioactive material across Europe, created a 30 km exclusion zone that remains off-limits to this day, and has been linked to elevated cancer rates across Eastern Europe. The Fukushima Daiichi disaster (Japan, 2011), triggered by a tsunami, caused widespread radioactive contamination of land and ocean, the evacuation of 154,000 people, and long-lasting public loss of confidence in nuclear energy globally. The problem of nuclear waste disposal

safely storing radioactive materials for geological time periods remains unresolved worldwide, with no country yet having opened a permanent underground nuclear waste repository.

7. **Land Use Impacts of Solar Energy Farms:** While solar energy produces no emissions during operation, large-scale solar photovoltaic farms require significant land areas. A utility-scale solar farm producing 1 MW of electricity typically requires approximately 2-4 hectares of land. This raises concerns about the conversion of agricultural land, natural habitat, or rangeland to solar installations, particularly in densely populated countries where land is a scarce and contested resource. In Uganda, where land tenure is complex and smallholder farming is the backbone of rural livelihoods, the siting of large solar farms requires careful planning to avoid conflicts. However, innovative approaches such as agrivoltaics (combining solar panels with crop production on the same land) and locating solar farms on degraded or unproductive land can significantly reduce land use conflicts.
8. **Bird and Bat Mortality from Wind Turbines:** Wind turbines, while producing clean electricity, pose a risk to flying wildlife, particularly birds of prey (raptors) and bats, which can be struck by rotating turbine blades. This is a significant concern at poorly sited wind installations, particularly along bird migration routes or in areas with high raptor populations. In the Lake Turkana Wind Power Project in Kenya, environmental assessments identified potential impacts on migratory birds, and the project included monitoring programmes and shutdown protocols to reduce turbine strikes during peak migration periods. While wind energy's overall impact on bird populations is far lower than that of fossil fuels (which drive the climate change that is destroying bird habitats globally), careful site selection and mitigation design are essential to minimise localised wildlife impacts.
9. **Thermal Pollution from Power Stations:** Conventional thermal power stations whether coal, gas, or nuclear use water for cooling, and discharge this water back into rivers, lakes, or oceans at elevated temperatures. This thermal pollution can significantly alter aquatic ecosystems: warmer water holds less dissolved oxygen, threatening fish and aquatic invertebrate communities. In Uganda, the proposed heavy fuel oil power station at Tororo (and the existing Namanve thermal plants) draw on or discharge into water bodies, raising concerns about aquatic ecosystem health. In the United States and Europe, thermal pollution from nuclear

and coal power stations has been associated with fish kills and the proliferation of blue-green algae (cyanobacteria) in affected water bodies.

10. **Methane Emissions from Hydropower Reservoirs:** An often-overlooked environmental impact of hydropower dams in tropical regions is the emission of methane a greenhouse gas approximately 80 times more potent than CO₂ over a 20-year period from reservoir surfaces. When vegetation is flooded and decomposes under anaerobic (oxygen-free) conditions in warm tropical reservoir sediments, it produces methane, which bubbles up through the water and into the atmosphere. Studies of tropical hydropower reservoirs in Brazil, Ghana (Akosombo Dam), and Cameroon have found that some tropical reservoirs emit significant quantities of methane, substantially reducing their climate advantage over fossil fuels. This is a growing concern for Uganda's large tropical hydropower reservoirs, though it is generally acknowledged that well-designed tropical hydropower still has a considerably lower lifecycle carbon footprint than coal or gas power generation.
11. **Acid Rain and Transboundary Pollution from Coal:** The sulphur dioxide and nitrogen oxides emitted by coal-burning power stations combine with atmospheric water vapour to form sulphuric and nitric acids, which fall as acid rain. Acid rain acidifies soils and water bodies, damaging forests and killing fish, often hundreds or thousands of kilometres from the original emission source. During the 1970s and 1980s, acid rain from British and German coal-burning power stations damaged forests and lakes across Scandinavia. EU regulations have since dramatically reduced sulphur dioxide emissions in Europe through the introduction of desulphurisation equipment ('scrubbers') on power stations. South Africa, which generates approximately 90% of its electricity from coal, experiences significant acid rain impacts on surrounding ecosystems, particularly in Mpumalanga province (the 'Witbank' coal belt).
12. **Soil and Groundwater Contamination from Extractive Industries:** Oil and gas extraction, coal mining, and uranium mining can all contaminate soil and groundwater through leaks, spills, and the disposal of waste materials. Hydraulic fracturing ('fracking') for shale gas widely used in the United States involves injecting high-pressure water and chemicals underground to fracture rock and release gas; this process has been linked to groundwater contamination in some areas, as well as to induced seismic activity (small earthquakes). In the context of

Uganda's petroleum development, protecting the groundwater resources of the Albertine region which millions of people depend on for drinking water and agriculture is a critical environmental management priority. The Public Interest Litigation in Uganda and internationally has highlighted these risks and demanded stronger regulatory safeguards.

13. **Noise and Visual Pollution from Energy Infrastructure:** Energy infrastructure wind turbines, power lines, substations, drilling rigs, and industrial plants generates noise and visual intrusion that can affect the quality of life of nearby communities and reduce tourism revenue in scenic areas. Wind turbines produce a characteristic low-frequency 'whooshing' sound that can be audible up to 1-2 km away and has been a source of significant community opposition in the UK, Germany, and the United States. Oil drilling rigs are noisy, operate around the clock, and require extensive lighting. In Uganda's Albertine region, the proximity of oil installations to national parks and wildlife conservancies raises concerns about noise disturbance to wildlife and the aesthetic impact on Uganda's tourism product. Tourism is Uganda's largest foreign exchange earner, generating over US\$ 1 billion per year, and any degradation of the wildlife tourism environment could have serious economic consequences.
14. **Downstream Hydrological Changes from Dams:** Large hydropower dams not only create reservoirs upstream but fundamentally alter the flow regime, sediment dynamics, and ecology of rivers downstream. The regulation of river flow reduces seasonal flood pulses that many downstream ecosystems and human communities depend on. The Nile downstream of Aswan High Dam in Egypt now carries only 2% of its original sediment load to the Mediterranean Sea, causing coastal erosion of the Nile Delta, loss of agricultural fertility in the floodplain (farmers once depended on the annual Nile flood to deposit rich silt), and collapse of Mediterranean fisheries that depended on Nile-derived nutrients. For Uganda, changes in Nile flow regimes due to dams could affect downstream communities in Sudan and Egypt a point of significant geopolitical sensitivity, as Egypt regards the Nile as an existential resource and has historically opposed any dam construction in upstream countries that might reduce its water flow.

LEARNING OUTCOMES E & F: SUSTAINABLE UTILISATION OF ENERGY RESOURCES

Learning Outcome E: Evaluate policies and strategies aimed at ensuring access to sustainable sources of energy to understand ways of reducing energy poverty.

Learning Outcome F: Argue out the case for sustainable utilisation of energy resources at local, regional, and global scales to promote energy security.

5.1 Introduction to Sustainable Energy Utilisation

Sustainability in energy refers to the ability to meet present energy needs without compromising the ability of future generations to meet their own energy needs. This concept, rooted in the Brundtland Commission's 1987 definition of sustainable development, has become the central framework for global energy policy in the 21st century. Sustainable energy has three interrelated dimensions: environmental sustainability (using energy sources that do not irreversibly damage ecosystems or destabilise the climate), economic sustainability (ensuring energy is affordable and available to drive economic development), and social sustainability (ensuring equitable access to energy for all people, including the poorest and most marginalised).

Energy poverty defined as the lack of access to modern energy services including electricity and clean cooking fuels affects approximately 733 million people globally (IEA, 2022), the vast majority of them in sub-Saharan Africa and South Asia. In Uganda, energy poverty manifests as reliance on biomass for cooking (with associated health costs from indoor air pollution), lack of electricity for lighting, refrigeration, and productive activities in rural areas, and high dependence on expensive imported fossil fuels (petrol, diesel, kerosene) for transport and backup generation. Addressing energy poverty is not merely a technical challenge but a social justice imperative, as energy access is a prerequisite for educational attainment, health outcomes, economic productivity, and gender equality.

Energy security, a closely related concept, refers to the reliable and affordable availability of energy with minimal vulnerability to supply disruptions or price shocks. A country with high energy security has a diversified energy mix, strong domestic energy production capacity, strategic reserves, and robust energy infrastructure. Uganda's current energy security is challenged by its heavy dependence on a single source

(hydropower, which is vulnerable to drought) and its reliance on imported petroleum products for transport.

5.2 Uganda's Energy Policies and Strategies

Uganda has developed a series of national energy policies and strategies since the early 2000s aimed at addressing energy poverty and promoting sustainable energy use. The following points evaluate these policies and their effectiveness:

1. **The Energy Policy for Uganda (2002):** The 2002 Energy Policy was Uganda's first comprehensive national energy policy, setting out the government's vision for the energy sector over a 20-year horizon. It identified the key challenges low electricity access rates, overdependence on biomass, limited rural energy access, and underinvestment in the sector — and proposed strategies to address them including the expansion of hydropower capacity, the promotion of renewable energy, the reform of the electricity sector (leading to the unbundling of Uganda Electricity Board into separate generation, transmission, and distribution entities), and the attraction of private investment through a more transparent regulatory framework. While the 2002 policy provided an important strategic foundation, implementation was slower than anticipated, and many of the capacity expansion targets were not met within the original timeframes.
2. **The Renewable Energy Policy for Uganda (2007):** Recognising the need to diversify beyond hydropower and promote solar, wind, geothermal, and biomass-based renewable energy, Uganda adopted a dedicated Renewable Energy Policy in 2007. The policy set a target of increasing the installed renewable energy capacity (excluding large hydro) to 61 MW by 2017. Key strategies included fiscal incentives for renewable energy investment (import duty exemptions on solar panels and wind turbines), feed-in tariffs to guarantee a minimum price for renewable electricity fed into the national grid, and support for rural electrification through off-grid solar systems. By the 2010s, Uganda had succeeded in attracting investment in small solar installations and mini-grids, though the large-scale renewable diversification targets proved more challenging to achieve. The declining cost of solar panels globally has since accelerated solar adoption in

Uganda, with the rooftop solar market growing rapidly in Kampala and other towns.

3. **The Renewable Energy Investment Plan for Uganda (2008):** The 2008 Renewable Energy Investment Plan complemented the 2007 policy by providing a detailed roadmap for attracting private sector investment into the renewable energy sector. It identified specific investment opportunities in small hydropower, solar, biomass cogeneration (using sugarcane bagasse from sugar factories to generate electricity), geothermal, and wind energy, and provided financial analysis to demonstrate the viability of these opportunities to potential investors.

Sugarcane bagasse cogeneration has been one of the most successful outcomes, with companies such as Kakira Sugar Works and Kinyara Sugar Works installing bagasse-fired power plants that supply electricity to the national grid, contributing to both energy diversification and improved sugar industry economics. The Investment Plan also identified the need for geothermal exploration drilling at Buranga and Kibiro, though funding for this has been slow to materialise.

4. **The National Biomass Energy Demand Strategy (2001-2010):** Given that biomass accounts for approximately 90% of Uganda's total energy consumption (when both rural and urban households are included), the National Biomass Energy Demand Strategy was critically important. It focused on reducing demand for biomass through energy efficiency improvements particularly the promotion of improved cook stoves that burn wood more efficiently and produce less smoke as well as sustainable biomass supply through agroforestry and community woodlot programmes. The strategy also sought to promote alternative cooking fuels (biogas, LPG, electricity) to reduce pressure on forest resources. Implementation was mixed: improved cook stove dissemination achieved significant reach through NGO programmes, but the transition away from firewood and charcoal has been slow because alternatives are often more expensive upfront, even if they save money in the long run. The government's later ban on charcoal burning in certain districts and tree-cutting regulations have been controversial and difficult to enforce.
5. **Rural Electrification Programmes and the Rural Electrification Agency (REA):** The Rural Electrification Agency, established under the Electricity Act of 1999, has been responsible for extending electricity access to rural Uganda. Its programmes

include grid extension to rural trading centres and sub-county headquarters, the installation of solar-powered streetlights and institutional solar systems (for health centres and schools), and support for private operators of mini-grids and solar home systems in off-grid areas. Access to electricity in Uganda has grown from approximately 5% of the population in 2000 to around 41% in 2022, representing genuine progress. However, the rural electrification rate remains well below the urban rate (approximately 72% urban vs. 20% rural), and many newly 'electrified' households in rural areas have only basic low-wattage connections insufficient for productive use or appliances. Universal access to electricity in Uganda remains a distant goal requiring sustained and accelerated investment.

6. **The East African Power Pool (EAPP) and Regional Energy Integration:** Energy security for individual East African countries can be significantly enhanced through regional power pooling sharing electricity across national grids to optimise the use of the region's diverse energy resources and reduce the vulnerability of any single country to supply disruptions. The East African Power Pool (EAPP), established in 2005, aims to create a regional electricity market linking Ethiopia (which has enormous hydropower potential from the Blue Nile), Kenya, Tanzania, Uganda, Rwanda, Burundi, and other countries. Uganda is already connected to Kenya via a 132 kV transmission line and exports electricity to Rwanda and the Democratic Republic of Congo. Planned regional interconnections will enable Uganda to sell surplus hydropower from Karuma to regional markets while accessing Kenya's geothermal power during dry periods. Regional energy integration is a key strategy for enhancing energy security across East Africa.
7. **The Case for Renewable Energy in Developing Countries:** The global debate about whether developing countries should prioritise renewable or non-renewable energy sources for long-term energy security is one of the most important policy debates in contemporary geography. The case for prioritising renewable energy rests on several strong arguments: renewables (particularly solar and wind) have no fuel cost once installed, are immune to the price volatility of global fossil fuel markets (which exposes fossil-fuel-importing countries to serious economic risk), produce no greenhouse gas emissions (aligning with climate commitments under the Paris Agreement), create local jobs in installation and maintenance, and are increasingly cost-competitive. The IEA's 2021 report 'Net Zero by 2050' concluded that no new oil and gas fields should be developed globally if the world is to limit

warming to 1.5°C a finding with profound implications for Uganda's planned oil development.

8. **The Case for Non-Renewable Energy in Developing Countries:** Conversely, developing countries argue that they should not be denied the right to utilise their fossil fuel resources when wealthy developed countries built their prosperity on exactly such exploitation. Uganda's oil if developed and managed well could generate billions of dollars in government revenue to finance schools, hospitals, roads, and other infrastructure that the country desperately needs.

The 'development imperative' argues that energy poverty kills: lack of electricity means hospitals without reliable power for life-saving equipment, children studying by candlelight, and farmers with no refrigeration for produce. While renewable energy is increasingly cost-competitive for electricity generation, it does not yet provide economical solutions for all energy needs (aviation, heavy industry, shipping), and fossil fuels may continue to play a transitional role in the energy mix of developing countries even as the global energy system decarbonises.

9. **International Energy Policy Examples: Germany's Energiewende:** Germany's Energiewende (energy transition) policy, launched in 2000 and significantly accelerated after 2010, represents the world's most ambitious national renewable energy transition. Germany set a target of obtaining at least 80% of its electricity from renewables by 2030 and phasing out both nuclear (achieved 2023) and coal power. By 2023, Germany was generating approximately 59% of its electricity from renewables predominantly wind (both onshore and offshore) and solar PV.

Lessons for Uganda include: the critical importance of government policy consistency and long-term commitment; the value of feed-in tariffs and renewable energy auctions in attracting private investment; the need for significant investment in grid modernisation and energy storage to accommodate variable renewables; and the social and economic dimensions of the energy transition (the 'just transition' — ensuring that workers and communities dependent on fossil fuel industries are supported as those industries wind down).

10. **International Energy Policy Examples: Zimbabwe's Energy Challenges:** Zimbabwe's energy sector provides a cautionary tale about the consequences of political instability, economic mismanagement, and underinvestment on energy security. Zimbabwe once had reliable electricity supply from the Kariba South hydropower

station on the Zambezi and the Hwange coal power station. However, years of economic crisis, hyperinflation, and lack of investment in maintenance have led to chronic electricity shortages, with load-shedding (planned power cuts) of up to 18 hours per day becoming a regular feature of Zimbabwean life in the 2010s and 2020s.

The Kariba reservoir also experienced critically low water levels due to drought. Uganda can draw lessons from Zimbabwe's experience: the importance of diversifying the energy mix, maintaining infrastructure through adequate reinvestment, maintaining political stability and regulatory credibility to attract investment, and building regional energy partnerships to buffer against domestic supply shocks.

11. **The Role of Technology Innovation in Sustainable Energy:** Technological innovation is rapidly transforming the global energy landscape, opening new possibilities for sustainable energy access. The falling cost of solar PV panels (falling 90% between 2010 and 2022), lithium-ion batteries (falling 97% since 1991), LED lighting, and smart grid technologies are making clean energy increasingly affordable even for low-income communities. In Uganda, the Pay-As-You-Go (PAYG) solar home system model pioneered by companies like M-KOPA, BBOXX, and Fenix International (now part of ENGIE) has enabled hundreds of thousands of rural households to access solar electricity through mobile money instalments, bypassing the need for expensive grid infrastructure.

This business model innovation, combining solar technology with mobile payment systems, represents a uniquely African adaptation that is now being replicated across South and Southeast Asia. Looking forward, technologies such as green hydrogen, advanced geothermal drilling, floating offshore wind, and solid-state batteries have the potential to further expand the range and affordability of sustainable energy options for countries like Uganda.

CONCLUSION: THE GEOGRAPHY OF ENERGY IN THE 21ST CENTURY

This topic has explored the geography of energy production from multiple perspectives the physical geography of resource distribution, the economic geography of production and consumption, the political geography of policy and governance, and the environmental geography of impacts and sustainability. Across all these dimensions, a consistent theme emerges: energy is not simply a technical matter but a profoundly geographical one, shaped by the uneven distribution of resources, the unequal capacity of countries to develop and use those resources, and the globally shared consequences of humanity's energy choices.

For Uganda and East Africa, the coming decade will be a pivotal one in the geography of energy. The commissioning of the Karuma and Isimba hydropower plants has significantly expanded electricity generation capacity. The planned development of petroleum from the Albertine region promises both new revenue opportunities and serious environmental responsibilities. The rapid expansion of solar energy from large utility-scale projects to small off-grid systems serving rural households is transforming energy access for millions of people. And Uganda's geothermal, wind, and biomass resources, still largely underutilised, offer further opportunities for diversification.

The overarching challenge for Uganda, for Africa, and for the world is to navigate the energy transition in a way that is simultaneously economically sustainable (supporting development and poverty reduction), environmentally sustainable (minimising ecological damage and contributing to climate stability), and socially sustainable (ensuring equitable access and just distribution of benefits and burdens). This is the core challenge of energy geography in the 21st century, and it demands the kind of critical, evidence-based, spatially informed thinking that A-level geography uniquely develops.

END
