UNIT 10 MICRO-ECONOMIC PERSPECTIVE AND MACRO LINKAGE

Structure

10.1 INTRODUCTION

You have learnt in Unit 9 that energy economics involves the study of energy resources and energy commodities. It includes: forces motivating firms and consumers to supply, convert, transport, use energy resources, and to dispose of residuals; market structures and regulatory structures; distributional and environmental consequences; economically efficient use.

It recognises that energy is neither created nor destroyed but can be converted among different forms; Human beings harness energy conversion processes to provide energy services. Energy demand is derived from preferences for energy services and depends on properties of conversion technologies and costs. Energy commodities are economic substitutes of each other. Energy resources are non-renewable or renewable and storable or non-storable. Human energy consumption leads to depletion of non-renewable resources, particularly fossil fuels.

In this unit, we discuss the economics of demand and supply of energy, and the macro linkages of energy and economy. You will also learn about the economics of climate change and mitigation of the negative environmental impact of energy use. We also acquaint you with some estimates of the costs of reducing carbon dioxide emissions on a worldwide scale.

In the next unit, we discuss an important dimension of energy and environmental economics, namely, energy infrastructure services and efficiency improvement.

Objectives

After studying this unit, you should be able to:

- discuss the economics of demand and supply of energy;
- analyse energy in relation to sustainability and explain the requirements governance and finance for sustainable energy; and
- discuss economics of climate change and reduction in CO_2 emissions.

10.2 ECONOMICS OF DEMAND AND SUPPLY OF ENERGY

Let us first understand the economics of demand of energy.

10.2.1 Economics of Energy Demand

Energy demand depends primarily on

- **demand for desired services,**
- **availability and properties of energy conversion technologies**, and
- **costs of energy and technologies used for conversion.**

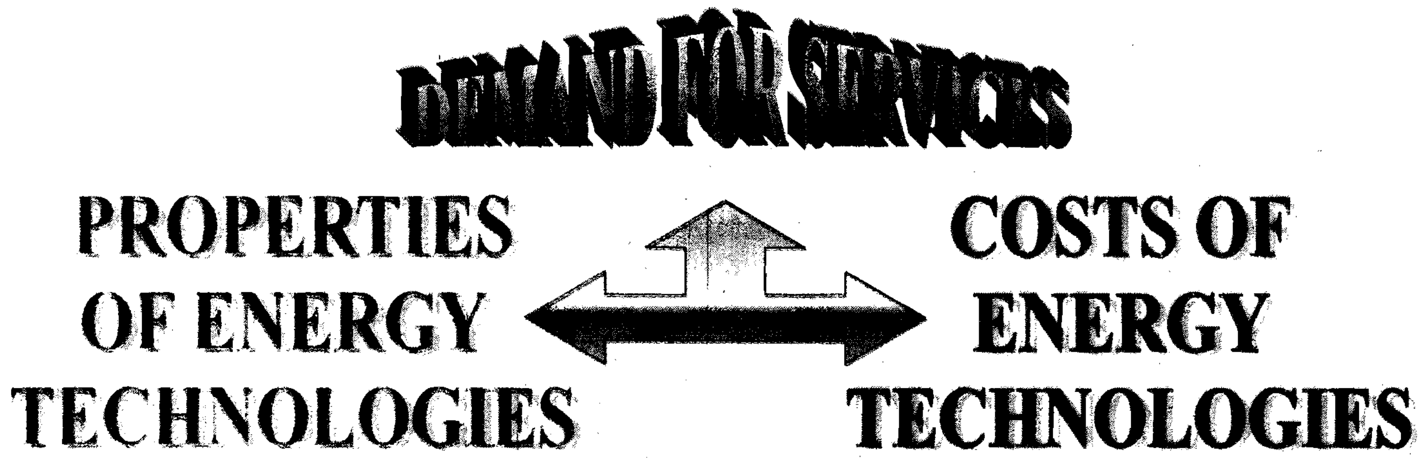

Fig.10.1: Factors influencing the energy demand

Let us explain these factors further.

- **Demand for Desired Services**

The **demand for energy** is a **derived demand** as it stems from wishes to use energy to obtain desired services. It is not derived from preferences for the energy commodity itself. For example, consumers use petrol to fuel automobiles or other motorised vehicles. The chemical energy obtained by burning the fuel (Petrol/CNG/gasohol) in the engine is converted into mechanical energy for running the vehicle. The amount of fuel used is proportional to the kilometres the vehicle is driven and inversely proportionate to the efficiency by which the fuel is converted to useful mechanical energy. This is measured as kilometres per litre (kpl) of the fuel used in the automobile. Demand for fuel is thus derived from choices about distances a vehicle is driven and its energy conversion efficiencies.

Similarly, electricity is purchased by consumers only to perform functions using electricity. Typical electricity uses include lighting, refrigeration, space heating, air conditioning, clothes washing, drying, dish washing, water heating, operating electronic equipment such as computers or televisions. Electrical energy is converted to mechanical energy (motors in refrigerators, air-conditioning units, vacuum cleaners), heat (space heating, clothes dryers, water heating), or radiation (lighting, television, computer monitors). Electricity demand is derived from demand for the underlying services – comfortable space, refrigeration, cleaning, entertainment, information processing.

- **Properties of Energy Conversion Technologies**

Energy demand is also determined by the efficiency of energy conversion equipment. Typically, energy conversion equipment is long-lived - automobiles, air-conditioning units, refrigerators, televisions, computer systems, furnaces. Consumers or firms can usually choose among alternatives with various conversion efficiencies; such choices significantly influence energy demand. To the extent that consumers and firms purchase these units with an understanding of their conversion efficiencies, expectations of future energy prices can influence choices of particular equipment. For example, high natural gas prices can motivate consumers to invest in home insulation.

Demand Substitution among Energy Commodities

Some **energy services can be provided by several different energy commodities**. Homes could be heated using electricity, natural gas, oil, or wood, since each can be converted to thermal energy. Cooking could use electricity, natural gas, propane, wood, or charcoal. Thus, **energy commodities are typically economic substitutes for one another**. There can be **demand substitution among energy commodities**. Thus, the demand for a particular energy commodity is an increasing function of prices of other energy commodities.

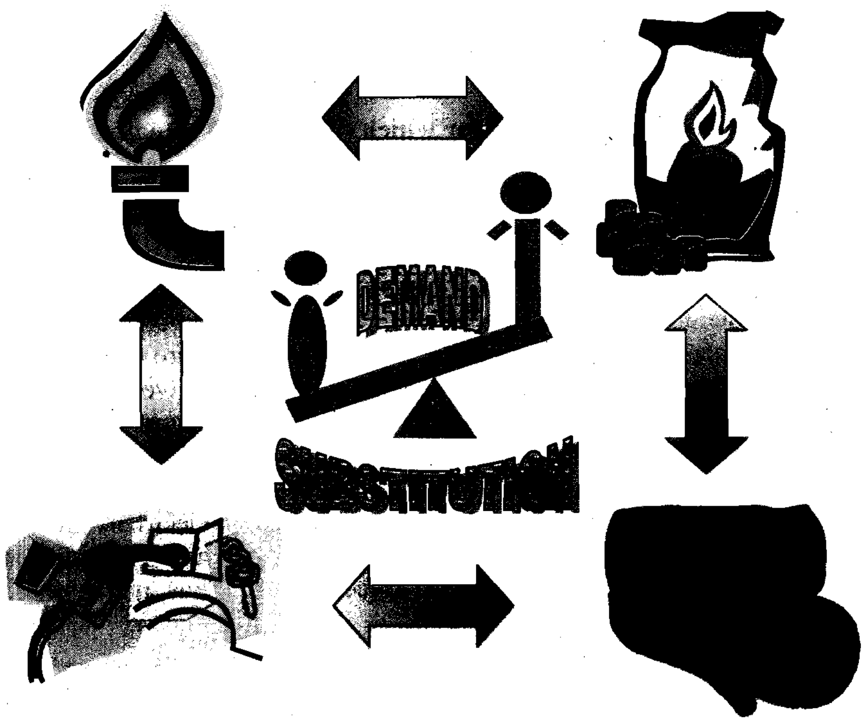

Fig.10.2: Energy commodities are economic substitutes for one another

This substitutability of energy is made possible by and is limited by the available set of energy conversion technologies. Typically one conversion technology can be used only for one particular energy commodity. For home heating, a natural gas furnace cannot use oil, electricity, or wood. Because conversion equipment typically is very long lived, substitution among energy commodities occurs only slowly, and only when new equipment is purchased.

Short-term substitution can usually occur only if several energy conversion technologies are simultaneously available for use by particular consumers, e.g., homes that have a central natural gas heating system plus portable electric space heating units. Thus, usually various energy commodities can be viewed as imperfect substitutes for one another, with much greater substitutability in the long term than in the short term.

The degree of substitutability can be sharply altered by development of new conversion alternatives. For example, automobiles historically were fuelled only by gasoline or diesel fuel, but technologies currently being developed would allow vehicles to be powered by electricity, natural gas, propane, hydrogen, or other energy commodities. Once such conversion technologies are successfully commercialised, petrol, diesel and other energy commodities could become substitutes for one another in transportation.

- **Costs of Energy and Energy Conversion Technologies**

In general, **increased energy prices reduce demand by reducing use of energy services and motivating selection of higher conversion efficiency equipment**. For example, fuel prices influence demand through vehicle kilometres and fuel efficiency of vehicles. Vehicle kilometres is influenced by cost per kilometre of driving, including per kilometre fuel costs, equal to the ratio Pg/kpl (where Pg is the fuel price), and other costs. Increased fuel prices lead consumers to purchase more fuel-efficient vehicles. Both factors imply that increased fuel prices reduce fuel demand, with the vehicle kilometres adjusting relatively quickly and vehicular fuel efficiency adjusting slowly as more vehicles enter the fleet.

Except for firms selling energy resources or energy commodities, the same issues are important for industrial and commercial use of energy.

There is another dimension of the economics of demand: **Is energy an essential good?**

In economics, **an essential good is one for which the demand remains positive no matter how high its price becomes**. In the theoretical limit, for prices unboundedly high, consumers would allocate all of their income to purchases of essential good.

Energy is often described as an essential good because human activity would be impossible without energy: the act of living requires food embodying chemical energy. However, neither particular energy commodities nor any purchased energy commodities are essential goods. Particular energy commodities are not essential because consumers can convert one form of energy into another. Even the aggregate of all purchased energy cannot be viewed as an essential good. Experience from low-energy research facilities shows that an extremely energy efficient home needs relatively little energy. Solar energy could generate electricity or heat water. Travel could be limited to walking or riding bicycles. Solar-generated electricity or wood fires could be used for cooking. For high enough prices of purchased energy, demand for purchased energy by consumers could be reduced to zero. Thus, **purchased energy is not an essential good**.

SAQ 1

a) Why is marketed energy not an essential good? Explain.
b) The demand of energy is a derived demand. Justify.

10.2.2 Economics of Supply of Energy

The economics of supply of energy encompasses all stages from exploring the sources of energy to resource extraction and from energy commodity generation to reaching energy services to the consumer.

What sources does the energy supply depend on? You have learnt in Block 1 that depending on the speed of natural processes, we can classify primary energy resources as **non-renewable** and **renewable**. Non-renewable resources are those whose renewal speeds are so slow that it is appropriate to view them as made available once and only once by nature. Crude oil, natural gas, coal, and uranium fall in this category. Renewable resources are self renewing within a time scale important for economic decision making. To analyse the economic aspects, we further classify renewable resources into **storable** or **non-storable** resources.

Storable renewable resources typically exist as a stock, which can be used or can be stored. Biomass, hydro power, and some kinds of geothermal resources fall in this category. The amount used at one time influences the amount available in subsequent times.

Non-storable renewable resources such as wind, solar radiation, run-of-the-river hydro resources may be used or not at a given time, but the quantity used has no direct influence on the quantity available subsequently.

Most energy commodities are storable (refined petroleum products, processed natural gas, coal, batteries), but electricity is not storable as electricity.

Initially all human energy use depended on renewable resources, in particular biomass resources used for food, heat, or light. Even in the developed countries like the USA, renewable energy (human, animal, water, wood, and wind power) dominated energy supply through the middle of the 19th century. Only during the second half of the 19th century did coal, a non-renewable resource, surpass renewable resource use. Crude oil and natural gas started supplying large quantities of energy only in the 1920s. Now the dominant use of energy in developed nations is based on non-renewable resources, particularly fossil fuels.

But non-renewable resource use cannot dominate forever. Once particular resource deposits have been used, they cannot be reused. Therefore, a future transition from non-renewable resources, particularly from fossil fuels, is inevitable. However, which renewable energy sources will dominate future consumption is not yet clear. And there is great uncertainty about the timing of a shift to renewable energy resources. A related unresolved question is that of future energy adequacy. Will the renewable sources of energy be adequate to satisfy demands for energy, once the fossil fuel supplies move close to ultimate depletion?

In addition are activities associated with commercial conversion of energy from one form to another, particularly to electricity, from hydro power, coal, natural gas, oil, nuclear fission, wood and waste products, geothermal, wind, or solar radiation.

Energy conversion industries, for economic success, must be able to sell their product at a price higher than the cost of energy commodities used as inputs plus per unit capital and operating costs of the facilities. Energy conversion is never 100% efficient and some input energy is lost to the environment. Therefore, the price per unit of electricity must be substantially greater than the price of energy commodities used to generate electricity.

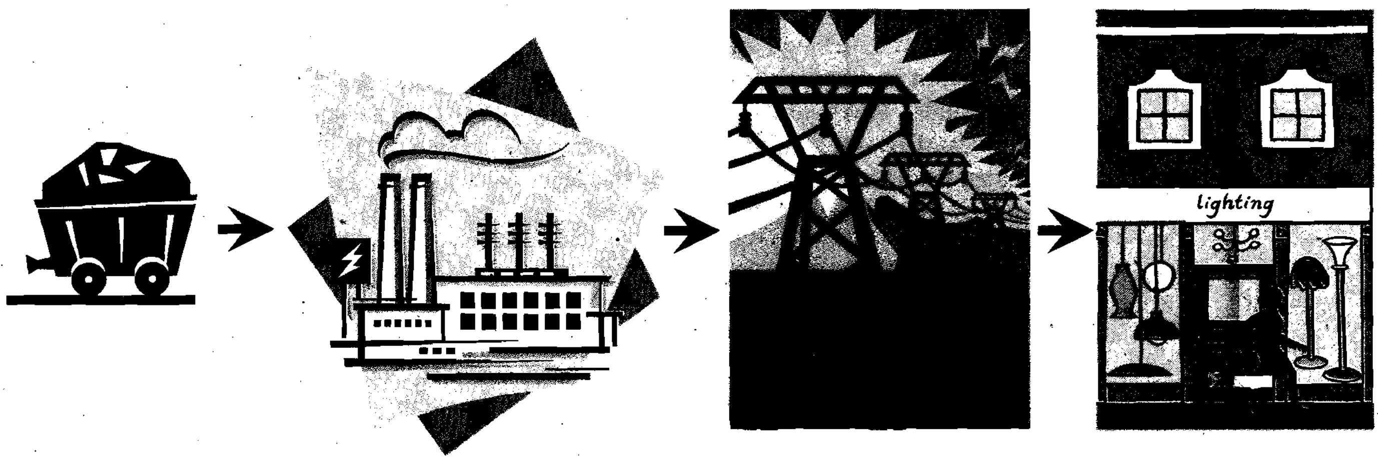

Fig.10.3: Supply chain of energy

In such a situation, technological advance can be very important. New technologies are becoming available that increase the conversion efficiency from natural gas or coal to electricity and which can be expected to have lower operating and capital costs. Such technological advances can be expected to bring **prices of these energy commodities closer together over time**. In addition to these technological changes, there are important ongoing changes in economic structure of the electricity production and distribution industry, throughout the world.

In many countries, state-owned industries generate, transmit, and distribute electricity. In others, private electricity suppliers are subject to special economic regulation. The reason for governmental ownership or control seems to stem from two factors:

- Firstly, electricity is fundamental to economic activity and many people have not trusted private industry.

- Secondly, production, transmission, and distribution of electricity have shown significant increasing returns to scale and the industry has been viewed as a natural monopoly. Fearful that an unregulated monopoly would exercise market power and overprice electricity, most nations have chosen to tightly control or own the industry.

Recently, however, smaller geographically distributed electric generating plants that could reasonably compete with one another have become economically attractive. Thus, the possibility for competition in electricity generation has been recognised. In addition, it is now realised that an electric utility sells two classes of products:

- electricity delivery services (transmission and distribution equipment transformers, wires, etc. and services operation and maintenance); and
- electricity.

Although traditionally these two classes of products were bundled together into a price per kilowatt hour of electricity, in principle, these two classes could be unbundled and sold by separate companies. Electricity delivery service is characterised by increasing returns to scale, but electricity itself is not. Therefore, the possibility is open for a competitive market structure to sell electricity to consumers, separately from the electricity delivery services.

Many important environmental damages stem from the production, conversion, and consumption of energy. The costs of these environmental damages generally are not incorporated into prices for energy commodities and resources; this omission leads to overuse of energy. Concern about this issue is common to energy economics, environmental economics, and ecological economics.

You have learnt in Unit 4 that energy production and use leads to environmental damages. Coal combustion, particularly high sulphur coal combustion, emits oxides of sulphur, which, through atmospheric chemical reactions, result in acid rain. Petrol combustion in automobiles releases oxides of nitrogen and volatile organic compounds, which, in the presence of sunlight, result in smog. Electric generating facilities often use much water for cooling and release the heated water into lakes or oceans, leading to local impacts on the ecosystem. Extraction of oil or mining of coal can lead to subsidence of the land overlying of the extracted deposits.

Environmental impacts currently receiving most attention are associated with the release of greenhouse gases into the atmosphere, primarily carbon dioxide, from combustion of fossil fuels. The three primary fossil fuels – coal, petroleum, and natural gas – each include carbon. You know that during combustion, carbon combines with oxygen to produce carbon dioxide, the primary greenhouse gas. Carbon dioxide accumulates in the atmosphere and is expected to result in significant detrimental impacts on the world's climate, including global warning, rises in the ocean levels, increased intensity of tropical storms, and losses in biodiversity.

Pervasive environmental impacts of energy use, accompanied by a virtually non-existent governmental intervention, imply that significant costs of energy use are not included in the price energy users face. These so-called externalities lead to overuse of energy and provide strong motivation for interventions designed to reduce energy use.

Energy economics and environmental economics attempt to assign monetary valuation of environmental impacts. However, ecological economics reject the idea that a monetary value could be placed on them.

SAQ 2

Discuss the factors that influence the cost and prices of energy use.

10.3 ENERGY, ECONOMIC GROWTH AND SUSTAINABILITY

Economic growth and social development in developing countries are hindered by a lack of adequate, efficient supplies of quality modern energy. The energy sector in many developing countries is dominated by state-owned monopolies that are often not operated along commercial lines; they are commonly characterised by relatively low levels of efficiency and frequently undermined by corruption. The result is underperformance, which translates into high costs. The high costs often lead to the adoption of untargeted, damaging, and distorting subsidies. This problem results in considerable economic waste and fiscal burdens at the macroeconomic level in many developing countries. It also inhibits the provision of energy to other sectors that require supplies of quality modern energy at the micro-economic level. How can these problems be addressed in a sustainable development framework?

10.3.1 Energy in Relation to Sustainability

Let us first understand how energy impacts economic growth.

Economic Growth: Constrained by Inadequate Energy Inputs?

Energy is generally believed to be a limiting factor for economic growth in the developing world while it remains a fundamental resource for continuing economic prosperity in the developed countries. While some Asian economies do not face a constraint with respect to energy availability, most are still grappling with energy shortages. Even in economies where access has been enhanced, low per capita energy consumption, particularly in rural areas, has constrained development. Given their low energy consumption levels and the structure of their economies, the **linkage between energy consumption and economic growth is likely to remain strong in developing countries for some time.**

You have learnt in Block 2 that equitable and affordable access to clean energy is one of the major elements of energy policy in most developing countries. This has been sought to be achieved mainly through ambitious electrification programmes and through large subsidies on electricity and other fuels for some consumers (poor, rural, and resident) or uses (irrigation, goods transportation, fertiliser production, etc.). In the power sub-sector, governments have subsidised the sector through

- the provision of grants and low-interest loans to utilities;
- the provision of excessive equity without dividend expectations;
- the exemption of the utilities from taxes and duties; and
- the frequent rescheduling, and often cancellation, of debts owed to the governments by utilities.

In addition, governments have seldom allowed utilities to adopt tariffs that recover the full cost of supply and in most cases have required cross-subsidies from the industrial to the residential consumers and from the urban to the rural and agricultural consumers. Instances of utilities being compelled to supply electricity free of charge to certain classes of consumers such as farmers are a regular feature in our country.

Countries also have special programmes depending upon their local situations, such as the farm forestry programme in India in view of the dominance of biomass fuels and the promotion of localised renewable energy systems as in Bangladesh and India.

While the rationale behind the government-subsidy programmes is justified, the programmes themselves have typically been fiscally profligate with no hard targeting. This is evident in the perpetuation of energy shortages and consumption inequalities and in the growing number of people without access to energy. Despite subsidies, poor households in Asia pay a larger fraction of their incomes for energy than middle- and high-income households and continue to depend predominantly on traditional fuels.

In the agricultural sector, it is the rich farmers who typically benefit disproportionately from subsidies. Subsidies have led to a decline in the sector and have hampered the development of local energy projects built in consultation with local communities. Further, in many cases, rural electrification has bypassed the needs of women, low-income households and even, high-priority social services such as schools and health clinics.

With the process of sector reforms under way, economies need to examine alternative approaches to meet their social obligations. This includes review of criteria and administering mechanisms for lifeline rates, income transfers, micro-finance, and promotion of indigenous community-managed decentralised energy systems.

Energy Policies: integration of environmental and efficiency concerns

Whether on not environmental concerns have been integrated with energy policies of various countries, there is the issue of sub-optimal efficiency levels in energy supply and end-use due to energy policies. Price subsidisation has supported inefficient energy uses in certain countries and sectors, often with negative economic and environmental consequences.

Moreover, energy prices alone are not sufficient in internalising environmental costs. There is a need to look at a broader regulatory framework. Enforcement of legislation is another important factor as seen in the case of India.

Renewables: their present and future role in the energy scenario of Asia

You will agree that there is a need for a greater share of renewables given the problems of pollution associated with fossil fuels and the risks associated with nuclear energy. Moreover, a stronger role for renewables can help meet critical energy needs, particularly in rural areas, and enhance energy independence. Significant opportunities exist to increase the use of renewable sources of energy in the Asia-Pacific region. Photovoltaic systems are, for instance, already established as economically and environmentally efficient ways of providing electric power to areas not connected to electricity grids, especially in rural areas.

In future, the share of renewables is expected to increase given the common thrust towards energy self-sufficiency and environment-friendly fuels. However, in spite of their increased significance in the future, renewables will not fulfil the majority of the energy requirement.

Strong policy commitments are necessary to encourage more investments in this sector. Moreover, renewable energy technologies will play an increasing role as costs fall due to economies of scale. Among the various energy sources, wind, small hydro, and solar have been identified as better options compared to biomass (not necessarily a pollution-free source).

New institutional models are required that will channel market forces and specific policy instruments to foster the development of an appropriate mix of existing and renewable energy technologies.

The energy-growth linkage covering the scale and composition of output and the efficiency of energy use is well understood. You have learnt in Unit 1 that, in general, the energy intensity of economies rises with economic growth and increases in energy consumption (often related to a shift from non-commercial to commercial forms of energy and industrialisation), while the efficiency of energy use may be low. Beyond a certain level of per capita income, it begins to decline, indicative of the overall increase in the efficiency of energy use, the switch to more efficient fuels, and the structural changes towards less energy-intensive production.

Notwithstanding marked disparities within Asia, most economies have shown a downward trend in commercial energy intensities in the last 25 years. Notably, having benefited from the experience of the 'early' developers, energy intensity peaks in the 'later' developing countries at levels lower than those of the former (see Fig.10.4).

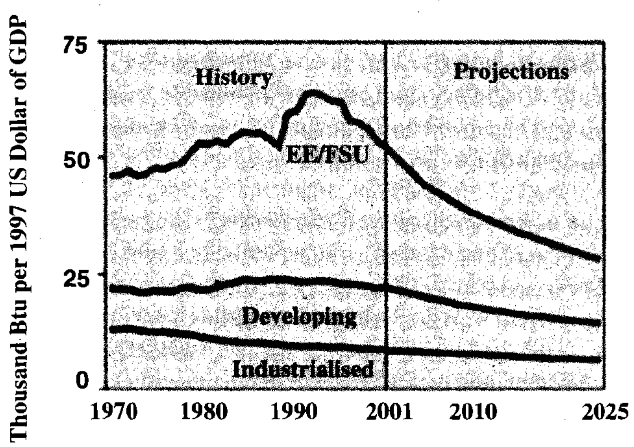

Fig.10.4: World energy intensity by region 1970 to 2020

The East, South, and South-East Asian Countries have achieved declines in commercial energy intensities, mostly over 50% during 1975-97. The case of China is exemplary, which, starting at more than twice the world energy intensity level [at 2.28 kgoe/$ PPP (kilogram of oil equivalent per dollar using purchasing power parity) against the world level of 0.81 kgoe/$PPP in 1975] attained the fastest decline to reach 0.30 kgoe/$PPP, close to the world level of 0.26 kgoe/$PPP level in 1997.

Here again the West Asian region provides an exception; select countries, particularly Saudi Arabia and the United Arab Emirates depicted an overall increase intensity through 1975-97, with fluctuating trends over time. In keeping with the general trend, the US Department of Energy predicts a 1.38% per annum decline in energy intensity of the GDP for the developing countries of Asia during 1999-2020.

The issues discussed so far lead us to the questions of governance and finance for sustainable energy.

SAQ 3

Explain how lack of energy inputs constrains economic growth of a nation.
What economic policies are required to overcome this constraint?

10.3.2 Governance and Finance for Sustainable Energy

The first question we consider is: **How do we foster governance in the energy sector?**

The ability to create a business environment that will attract the investments necessary to provide adequate, efficient supplies of quality modern energy is constrained by the following problems:

- Inefficient energy-sector institutions,
- Inappropriate energy-sector policies,
- Intermittent application of the rule of law,
- Immature markets for energy and environmental services,
- Weak local capital markets,
- Poor performance by business management in energy institutions,
- Lack of adoption of best practices and standards by energy institutions and the public sector,
- Lack of consumer knowledge about legal and commercial requirements for Sustainable Energy Services, and
- Lack of roles for civil society in formulating public policies for energy services.

Good governance, by addressing inadequacies in the administration of the energy sector by public and private sector institutions, can resolve these constraints. Generally, governance involves how decisions are made, implemented, and enforced within a sector as well as how disputes are resolved. Good governance embodies transparency, accountability, efficiency, and the rule of law. It leads to relatively low levels of corruption; consistent, cost-effective levels of service provision, and responsiveness to changing conditions and public needs.

Energy-sector governance is the institutional scaffolding (i.e., transparent, predictable, and enforceable political, social, and economic rules) of public administration that **enables transactions for energy products and services to be economically sustainable. Governance** (both public policy and corporate governance) **is a means to achieve the economic and financially viable provision of services by the energy sector**. There is a growing international acceptance of several basic principles that can promote sustainable development by all countries, anywhere in the world. These include

- Effective and democratic institutions.
- An independent and fair-judiciary.
- Sound monetary, fiscal, and trade policies that promote economic growth and encourage social development and environmental protection.
- Participatory roles for all members of civil society, and
- Sound policies informed by science and the scientific method.

The second question to look at is: **What is the energy governance-finance connection?**

The **growth of the energy sector** that is required to meet human needs **hinges on financing**, which in the present climate involves attracting investment.

Experience so far shows that both debt and equity are drawn to sale havens where funds are likely to grow and provide a return on investment. Legal, regulatory, and policy regimes that ensure a stable environment (i.e., transparent and predictable political, social, and economic market rules) characterise locations in which investments can flourish. Governance actions designed to mobilise financial investment in the energy sector include:

- Promoting transparency in the formulation, promulgation, and implementation of rules, regulations, and technical standards;

- Establishing non-discriminatory third-party access to and interconnection with energy networks and grids;
- Establishing independent regulatory authorities separate from and not accountable to any supplier of energy services;
- Establishing non-discriminatory, objective, and timely procedures for the transportation and transmission of energy;
- Requiring parties to undertake measures designed to prevent certain anticompetitive practices from occurring in energy sectors (e.g., engaging in anticompetitive cross subsidization or using information obtained from competitors that could lead to anticompetitive results); and
- Increasing the public's understanding of the market approach to providing energy services and its knowledge of ways in which it could effectively participate in this approach.

The issue of climate change – specifically the effects of global warming due to increasing atmospheric concentrations of human-made emissions of so-called greenhouse gases – is the subject of renewed interest. Policies to slow the rise in concentrations by controlling greenhouse gas emissions raise a number of economic issues. In the following section we review some of these issues.

SAQ 4

What are the imperatives of good governance for the energy sector?

10.4 ECONOMICS OF CLIMATE CHANGE

You have studied in Unit 5 that there has been a growing concern about climate change in the recent past.

In 1995, more than 150 countries adopted the UN Framework Convention on climate change at the Earth Summit in Rio de Janeiro. The OECD countries, except Mexico, Korea and Turkey, and Russia, Belarus and the countries of central and Eastern Europe have committed to stabilising their CO_2 emissions. This Convention was a response to mounting scientific evidence collected by the Intergovernmental Panel on Climate Change (IPCC). As you may know, it was established in 1988 by the UN Environment Programme and the World Meteorological Organization in order to produce assessment reports written and reviewed by about 2000 scientists and experts world-wide. The general conclusion of the second IPCC report, published in 1995, was that "the balance of evidence suggests a discernible human influence on climate".

Subsequently, it became clear that industrialised nations would fall short of their commitments adopted in Rio, and the main objective of the Third Conference of the Parties to the Convention, held in Kyoto in December 1997, was to agree to legally binding quantitative targets. The result was the Kyoto Protocol, which, for the first time, commits industrialised nations to stabilise their emissions of greenhouse gases.

You know that the Kyoto Protocol covers six greenhouse gases: carbon dioxide, methane, nitrous oxide and three synthetic fluorinated compounds. It allows for emission trading among the signatories. Emissions reductions can be "banked", in the sense that countries that more than meet their commitments in the first commitment period can use the surplus reductions for future commitment periods. It also makes provision for joint implementation through a "Clean Development Mechanism", about which you have studied in Block 1.

Net emissions changes from land-use change and forestry are included in the Kyoto Protocol for activities undertaken since 1990. As far as the economic aspect of climate change is concerned, the whole range of issues boils down to one question: **What is the cost of reducing CO_2 emissions**? Let us find out.

10.4.1 Costs of Reducing CO_2 Emissions

The considerable uncertainty surrounding both costs and benefits of greenhouse gas emission abatement greatly complicates their assessment. An important source of uncertainty is the very long time periods over which climate change is expected to occur. Climate change and its effects may appear in the second half of the next century, and virtually nothing is known for sure about economic conditions and technological opportunities that far ahead. In addition, our knowledge of the links between emissions and atmospheric concentrations of greenhouse gases, and of the effects of climate change is still very incomplete, although improving.

This analysis is restricted to anthropogenic emissions of carbon dioxide (CO_2), mainly emissions from fossil-fuel combustion. Carbon dioxide accounts for more than one-half the total effect of greenhouse gases on climate change, but other gases are also important and have been explicitly included in the Kyoto Protocol.

Reducing Emissions Growth by 1 Percentage Point

It is estimated that a reduction in annual emissions growth of 1 percentage point by all countries (or regions) would stabilise the emissions of OECD countries at 1990 levels. However, CO_2 emissions of developing countries would continue to grow. Thus, world emissions would grow by 0.5 to 1 percent per year, depending on assumptions about economic growth and energy efficiency. Concretely, lower emissions growth could be brought about by

- tighter regulation,
- taxation of carbon or energy, or
- a system of tradable emissions permits.

Let us examine the latter two.

- **Taxation of Carbon or Energy**

Carbon taxes, i.e., a tax on whatever activity raises GHG emissions, would increase the cost of emitting, thereby providing an incentive to abate. If carbon taxes were uniform (per ton of carbon emitted), then this incentive would act to equalise the marginal cost of abatement across countries, industries, firms and plants.

The abatement efforts needed to reach a specific target path for emissions would have to intensify over time, at least until the carbon-free "backstop" became available.

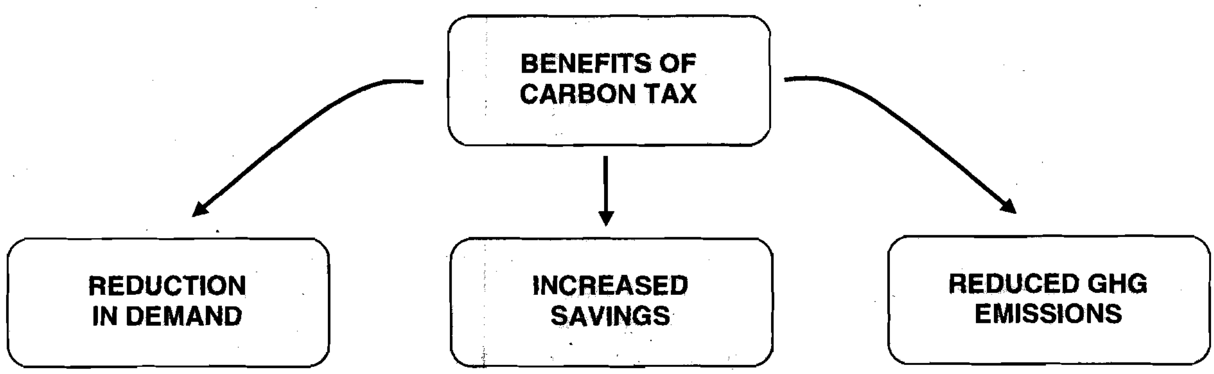

Fig.10.5: Some benefits of carbon taxation

Thus, **carbon tax rates** or the **price of emissions permits** would have to rise to induce further abatement. This is because initial cuts in carbon emissions come relatively cheaply through substitution of high-carbon fuels (such as coal), for low-carbon fuels (such as natural gas). As such substitution possibilities become fully exploited, further cuts become more costly and higher taxes are needed to induce them.

Likewise, assuming that each region makes the same percentage cuts implies that abatement efforts and costs will vary across regions. Those that rely relatively extensively on high-carbon energy – such as China, India and Russia – can reduce emissions relatively cheaply in comparison to those, which have already substituted extensively away from coal – notably the OECD countries. Such equi-proportionate emissions cuts are economically costly relative to a programme in which more of the abatement takes place in countries that can abate cheaply.

Abating emissions would reduce real income, or GDP, by distorting resource use and economic activity. This should not, however, be seen as a net loss to society as a whole, because abatement would also bring benefits in terms of less global warming. Emissions abatement and global warming would generate both transition costs and longer-term costs once a new equilibrium had been reached. Ideally, abatement would be carried to the point where its benefits are maximised and its costs are minimised.

Depending on the underlying assumptions enumerated above, by 2050 the assumed emissions cuts would entail costs ranging from 0.6 to 1.7 percent of GDP in OECD countries and from 1.2 to 2.3 percent in non-OECD countries (see Fig. 10.6). Overall, the level of world GDP would be lower by 0.9 to 1.8 percent in 2050.

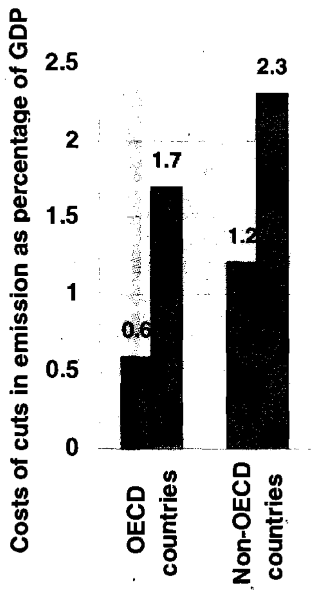

Fig.10.6

- **Tradable Emissions Permits**

The same incentive as for carbon taxes would operate in the case of tradable emissions permits, but would be less direct. Permits would be issued allowing emissions of a fixed amount of carbon, with the total amount equal to the emission-reduction target. Decisions on abatement would depend on the market price of the permits: at any price, those with relatively high abatement costs would prefer to buy permits and increase emissions, whereas those with low abatement costs would find it profitable to sell permits and abate more. In a well functioning market, this process would continue until marginal abatement costs in each country (and industry, and so forth) equalled the world price of permits.

Thus, both taxes and permits would yield the same economically efficient outcome, at least in theory. They differ in other respects, however. Consider first the issue of the distribution of the burden of abatement costs: equalisation of marginal abatement costs would result in developing countries bearing more of this burden than would equi-proportionate reductions, and even the latter might impose an unacceptable burden on them. This burden could be shifted, however, through a system of international transfers, which would probably have to be quite large. Such transfers could be implemented in either a tax or a permit system. In the case of a carbon tax, they would have to be explicit. In the case of permits, however, redistribution would be implicit in the initial distribution and subsequent sale of permits. The effects of an abatement programme on national incomes would then depend on both the amount of abatement undertaken (which would affect GDP) and the explicit or implicit transfers.

A second difference between taxes and permits involves uncertainty. Governments do not know the marginal abatement costs of countries, industries, firms and plants with certainty and there are obvious incentives for emitters to exaggerate them. A carbon tax adds a known amount to the cost of emitting and thus would pin down the marginal costs of abatement. However, the amount of abatement cannot be known with certainty *ex ante*: for example, if marginal costs rose faster than governments had expected, then the point at which the marginal cost of abatement equalled the tax would be reached at a lower level of abatement than planned. By contrast, limiting emissions through permits would make the level of abatement much more certain, as it would simply be the number of permits issued, enforcement issues aside. However, the cost of achieving that abatement would not be certain.

A third difference involves the role of the public sector. In both cases, there are important issues of monitoring and enforcement (tax collection in one case and emissions in excess of permits held in the other). However, for a tradable emissions permit system to deliver the desired result, there must be an active and efficient secondary market for permits. The limited practical experience with permits suggests that a relatively large number of traders and minimal governmental regulation of trades both help to ensure a "deep" market and low transactions costs.

It is increasingly accepted that economic instruments are more effective than regulations for controlling pollution externalities, including those associated with green-house gas emissions. In a nutshell, economic instruments allow firms and households to meet environmental goals in a least-cost way, whereas regulations often lock in technologies or market practices that turn out to be inefficient. In this section, we have discussed two economic instruments most actively considered in the context of global warming due to CO2 emissions, namely, carbon taxes and tradable permits to emit carbon. Let us see what other measures can be taken for reducing the costs of controlling emissions.

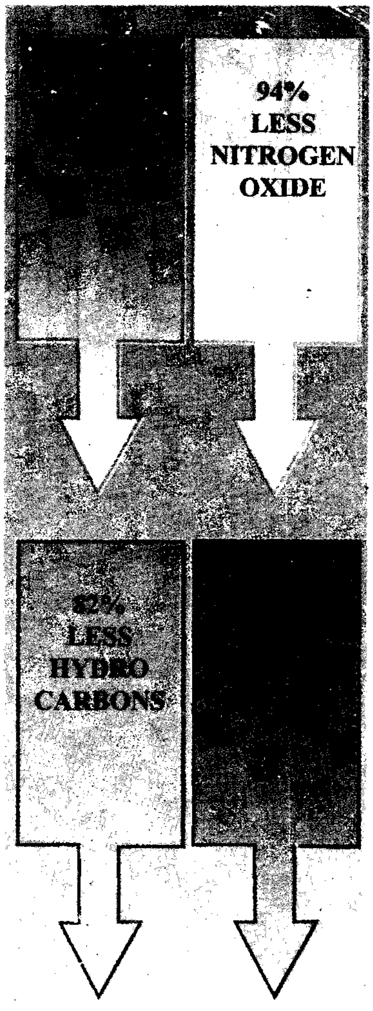

Fig.10.7: The effect of using CNG as compared to diesel buses

10.4.2 Reducing the Costs of Controlling Emissions

The policy of equi-proportionate emissions reductions by region or country, which was described in the previous section, is a relatively costly way of achieving a global emissions target. Some policy reforms could both reduce emissions and improve economic efficiency. These are referred to as "**no-regrets**" **policies** because they would be worth implementing even if global warming were to turn out to be no threat. Substantial costs could also be saved if emissions reductions were timed to minimise transition costs, notably the obsolescence of capital, and to take advantage of the possibility that cheaper abatement technologies may be developed in the future.

Finally, equalising the marginal cost of abatement across countries or regions would ensure that total costs were minimised for a given amount of global abatement. The logic of this last point is straightforward: if marginal costs are not equal, then reducing abatement a little in a high-cost country and raising it by an equal amount in a low-cost one would reduce overall costs. This logic applies equally to firms and plants within a country.

"No-regrets" Policies

The clearest case for a "no-regrets" policy is a shift to better technologies (see Fig. 10.7) and reform of energy subsidies. This priority is recognised in Article 2 of the Kyoto Protocol, which specifies a progressive removal of subsidies and reform of taxes as a means of achieving reduction commitments. Removing subsidies would reduce fossil-fuel use and CO_2 emissions, while at the same time eliminating distortions. Results from the OECD GREEN model indicate that removing subsidies would reduce emissions by 18 percent in 2050 and would increase world real income by 0.7 percent. (Transition costs, however, were not taken into account in this model.) To some extent, countries have already begun to reap such gains: in particular, reforms in China, the central European countries and Russia have helped to close the gap in those countries between domestic and world energy prices.

Emission reductions could also be achieved if the structure of existing energy taxes better reflected the carbon content of fuels. Currently, oil and gas typically face high implicit carbon taxes while coal receives subsidies. Rebalancing existing taxes according to the carbon content of each fossil fuel could reduce OECD emissions by 12 percent and lower the economic cost associated with existing energy taxes from 0.4 to 0.1 percent of GDP.

Another element of "no-regrets" policy would be to encourage technologies that raise energy efficiency. A number of these are already commercially available: improvements in insulation, refrigeration and lighting control; the use of electric vehicles; increased use of public transportation and telecommuting; and reduced vehicle weight. (The next two units focus exclusively on this dimension of energy economics.) The extent to which this is truly a "no-regrets" policy depends in part on why such technologies are not already in wider use. According to one view, firms and households would have already adopted them if they were, in fact, less costly. In this case, inducing their adoption would not truly be "no regrets".

On the other hand, there may be numerous market failures inhibiting the adoption of these technologies, including inadequate information regarding alternative costs, principal-agent problems (those paying are not those making the decisions about what technology to adopt) and capital-market imperfections (some cannot borrow to pay for the up-front cost of installing the new technology). Overcoming such market failures would both raise welfare and reduce greenhouse gas emissions.

SAQ 5

Outline the main features of "no-regrets" policy for reducing the costs of CO_2 emissions.

The Timing of Abatement

Costs of meeting emissions goals also depend on the distribution of reductions through time. Abatement costs will probably fall over time because abatement technology will improve and alternative low-carbon sources of energy will become available or less costly. Phasing in abatement could also reduce costs by allowing natural depreciation of existing capital equipment. On the other hand, delaying action involves risks, since it would result in higher atmospheric carbon concentrations, all else equal. Early reductions may therefore be justified as risk management. The possibility of unexpected and catastrophic consequences from global warming adds weight to this argument.

Although models have been used to assess the costs of alternative time paths of emission reductions, the results are subject to a great deal of uncertainty. In addition, the relative costs of such paths also depend on the likelihood of cost-reducing abatement technologies being discovered, the social discount rate used and, in view of the risk-management issue, the degree of risk aversion assumed.

Equalising Marginal Emissions Costs

Since the marginal cost of greenhouse gas abatement differs widely across countries and regions, the equi-proportionate cuts of the scenario discussed above is a costly way to meet a global emissions-reduction goal. Equalising marginal abatement costs would mean those countries or regions with lower costs would abate more. Such an outcome could be implemented either through a uniform world-wide tax on carbon emissions, or through a global market for tradable emissions permits with a single price for all countries.

10.5 SUMMARY

- Energy demand is derived from preferences for energy services and depends on availability and properties of conversion technologies and costs of energy and technologies used for conversion. In general, increased energy prices reduce demand by reducing use of energy services and motivating selection of higher conversion efficiency equipment.
- Energy commodities are typically economic substitutes for one another. Substitutability of energy is made possible by and is limited by the available set of

energy conversion technologies. Technological advances can be expected to bring prices of these energy commodities closer together over time.

- Energy is often described as an essential good because human activity would be impossible absent use of energy: living requires food embodying chemical energy.
- Energy is generally believed to be a limiting factor for economic growth in the developing world while it remains a fundamental resource for continuing economic prosperity in the developed countries. Economic growth and social development in developing countries are hindered by a lack of adequate, efficient supplies of quality modern energy.
- Despite subsidies, poor households in Asia pay a larger fraction of their incomes for energy than middle- and high-income households and continue to depend predominantly on traditional fuels.
- The ability to create a business environment that will attract the investments necessary to provide adequate, efficient supplies of quality modern energy is constrained by many problems such as.
- Policies to slow the rise in concentrations by controlling greenhouse gas emissions that are expected to grow by 0.5 to 1 per cent per year, depending on assumptions about economic growth and energy efficiency, raise a number of economic issues.
- Costs of environmental damages are generally not incorporated into prices for energy commodities and resources Emissions abatement and global warming would generate both transition costs and longer-term costs once a new equilibrium had been reached. Emission reductions could also be achieved if the structure of existing energy taxes better reflected the carbon content of fuels. Costs of meeting emissions goals also depend on the distribution of reductions through time.
- **"No-regrets" policy** specifies a progressive removal of subsidies and reform of taxes as a means of achieving reduction commitments.
- Abatement costs will probably fall over time because abatement technology will improve and alternative low-carbon sources of energy will become available or less costly.
- Economic instruments allow firms and households to meet environmental goals in a least-cost way, whereas regulations often lock in technologies or market practices that turn out to be inefficient.

10.6 TERMINAL QUESTIONS

1. Explain how technological advances can bring prices of energy commodities closer together.
2. Explain why we need to consider environmental damage in energy costing.
3. Analyse the linkages between energy, economic growth and sustainability.
4. Discuss the economic instruments used globally to control CO_2 emission.