CHAPTER 4
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4.1 Introduction:

Background of Theoretical Foundation on Energy:

The economic theories on energy in the field of studies on human utilization of energy resources and energy commodities and the cost of that utilization, that lead economic agents are firms, individuals, governments - to supply energy resources, to convert those resources into other useful energy forms, to transport other users, and to dispose of the residuals. It studies economically efficient provision and use of energy commodities and resources and factors that lead away from economic efficiency. Therefore, the history of energy in Economic theory is divided in two parts, an early modern production theory focused on how a society uses resources provided by nature to produce physical goods and services and a “modern” exchange theory centered on the study of the efficient allocation of scarce resources to satisfy the unlimited demand of consumers. So this chapter dealt with the Classical economical theory approach on energy and Production, Neoclassical economic theory on Demand for energy, supply of energy and growth model, Modern economical theory on energy and consumption, energy and conservation, technology and economic viability, Demand side management, theory of cost, cash flow theory, theory on cost and benefit with empirical evidence.

4.2 Classical Approach

The first, pre – classical and classical economics (1650-1852), evolved economic ideas, energy was not recognized by Adam Smith, Malthus, J.B.Say, J.S.Mill and Ricardo. They explained close and ongoing relationship with early
modern scientific theories of natures, organization including machines, matter theory, chemistry, physiology and psychology. Although the classical economists did not explicitly recognize energy per se as a factor of production, they understood clearly the limits which nature (land) imposes on economic activities, especially in agriculture. Therefore, they divided the economy into two distinct sectors: agriculture and manufacturing. This distinction deeply informs the classical theory of economic growth.

Therefore, the classical economists explored the contributions of land to the economy in order to explain the presence of a surplus, over and above the cost of labor and capital, in agriculture. The father of economics Adam Smith explained of this surplus was direct in agriculture, ‘nature labors along with man’, whereas in manufactures ‘nature does nothing; man does all’, It is “capital employed in agriculture, therefore, not only puts into motion a greater quantity of productive labor than any equal capital employed in manufactures, but in proportion, too to the quantity of productive labor which it employs, labor adds a much greater value to the annual produce of the land and labor of the country, to the real wealth and revenue of its inhabitants”. Therefore, classical economists speak of the ‘fertility of nature.

While, David Ricardo, explained the productive and everlasting powers of the soil’, he explained energy cost of production, “the natural and inherent powers of the soil,” Malthus, said that scarcity of resources, with limited resources and always ever growing population, Malthus describes an unsustainable system in which population always grows faster than subsistence levels on earth. In the Malthus as in theory, some economists have argued that, natural resources are insufficient on earth. Therefore energy conservation and environmentally safe alternatives help preserve our natural resources. J M Culloch, speaks of the earth as “an incredible chemical
workshop wherein many materials and elements are mixed together and worked on (J B Say). But, J B Say was critical of Smith’s emphasis. That is neglect of industrial sources of power. He argued, came not from the division of labor but from Machinery using the forces of nature. This think Smith did not understand the true theory of machines in producing wealth. And also argued that all production was subject to the conservation of energy and required the forces of nature. Therefore, Say’s fundamental contributed of energy and forces of nature in human production (labour). Therefore, he understands the importance of production in economics and economic theory must begin with production before taking up the topics of value, distribution and consumption. J.S.Mill followed by Say’s classification of production inputs under the headings of labour, nature and capital. He wrote, “active energies by which it cooperates, with and even be used as a substitute for labor like, different forms of energy as light, heat, electricity, plant life, wind, elasticity, gravitation these contributes to production, but he sees these forces at work both in agriculture and manufacturing.

Therefore, it observed classical theory of the macro-economy incorporated about the “power” of nature (land) in three steps. First, the classical economists broke down their economy into two sectors, agriculture and manufacturing. Second, they defined the distinctness of agriculture by recognizing that land, labour and capital in both sector. Third is the factor of production. In the third step, they assumed land is fixed variable. The fixed supply of land produced a tendency towards diminishing returns to capital and labor in agriculture.

4.2a Theory of Production: Physical Theory and Economic Models

In this section, theory of production explained about the scientific or physical basis of the role of energy in production and the increasing scale of production involved in economic growth.
The economics of production, some inputs to production are non-producible, while others can be manufactured at a cost with the economic production system. Primary factors of production are inputs, which exist at the beginning of the period under consideration and are not directly used up in production, while intermediate inputs are those created during the production period under consideration and are used up entirely in production (Stern, 1999) and he said, energy is also an essential factor of production. All production involves the transformation or movement of matter in some way and all such transformations require energy. Some aspects of organized matter might be non-reproducible (Stern, 1997).

Preng(1993), Chean(1994), Stern(1994) and Ruth(1995) argued that information is fundamentally non-reproducible factor of production in the same way a energy, and that ecological economics must pay as much consideration information and its accumulation as knowledge as it pays to energy. Energy is necessary to extract information from the environment while energy cannot be made active use of without information and possibly accumulated knowledge. They said that meaning, energy can provide uncontrolled heating, lighting etc. without any activity on the part of economic agents. But even to use information to make controlled use of energy. Ex: photosynthesis.

Stern (2003) studied the Ayres and Kneese, explanations about thermodynamics. The first law of thermodynamics (the conservation law) implies the mass-balance principle. In order to obtain a given material output greater or equal quantities of matter must enter the production process as inputs with the residual as a pollutant or waste product. Therefore, there are minimal material input requirements for any production process producing material output. The second law of thermodynamics (the energy efficiency law) implies that a minimum quantity of
energy is required to carry out the transformation of matter. Therefore, there must be limits to the substitution of other factors of production for energy. All economic processes require energy, though some service activities may not require the direct processing of materials. However, this is only true at the micro level and at the macro level all economic processes require the indirect use of materials, in either the maintenance of labor or the production of capital.

4.3 Neo-Classical Approach

Neo-classical economist neglects energy into their macro-economic framework, not even implicitly. But they are focused on supply, demand, profit, cost, utilization is based on the factor of production. This flows from their rejection of land as a factor of production; they include land is instead of capital. They motivated the need to explain the new era of sustained growth that began in the nineteenth century. Classical economists could not explain sustained growth: in the long run, their economics ended up in the stationary state, characterized by constancy in the stocks of labor and capital. However, neo-classical economist said and recognized that, sustained growth was being fuelled by the combination of energy from an exogenous source. The neo-classical economists chose to suppress land as a factor constraining growth. This they accomplished by redefining land as capital.

Therefore, mainstream economists (neo-classical) usually think, of capital, labour and land as the primary factors of production, while goods such fuels and materials are intermediate inputs. The prices paid for all the different inputs are seen as eventually being payments to the owners of the primary inputs for the services provide directly in the produced intermediate inputs (Stern, 1999). This approach has led to a focus in the theory of growth on the primary inputs, particularly, capital and
land, and a much lesser and somewhat indirect treatment of the role of energy in the growth process

Stern (1999) observed that, in the mainstream neoclassical economics approach, discussed on the quantity of energy available to the economy in any period is endogenous and economic constraints such as the amount of installed extraction, refining and generation capacity and the possible speeds and efficiencies with which these processes can proceed. However, he said, this analytical approach leads to a downplaying of the role of energy a driver of economic growth and production.

4.3a Mainstream Theory of Growth:

As explained above there is an inbuilt bias in mainstream production and growth theory to downplay the role of resources in the economy, though there is nothing inherent in economics that restricts the potential role of resources in the economy. Stern (1999) studied the basic model of economic growth is the Nobel-Prize winning work by Solow, that does not include resources at all. This model subsequently was extended with non-renewable resources, renewable resources and some waste assimilation services. These extended models are, only applied in the context of debates about environmental sustainability, not in standard macro-economic applications.

Stern also described Solow’s economic growth models, the evolution of a hypothetical economy over time as the quantities and the qualities of various inputs into the production process change. In this model a constant-sized labor force using manufactured capital produces output, which is equal to the national income. The neoclassical model assumes that output increases at a decreasing rate as the amount of capital employed rises. Therefore, he said there is relationship between output and capital. Suppose that the population, assumed to be some constant multiple of the
labor force, saves a constant proportion of its income. Savings are used to build new capital goods.

4.4 Modern Economists approach

The modern economists believe that an index of energy could be used as an index of capital-the factor which is essential for development. In economic parlance, energy caters both to the direct consumption and the production of goods: as consumer goods, their consumption tends to vary with changes in income and consumer preferences; as an input in production, their availability and increasing quantity are a sin-qua-non (require energy) of rising national income. Therefore, energy economists opined that energy is considered as an index of economic development. For an overall economic development of a nation, energy is essential to ensure adequate and sustained supply of energy for every sector of the economy. As a matter of fact, energy has come to be viewed as a civilization, destroying the environment and consuming the patrimony of future generation. Environmentalists opined that the level of energy consumption is probably the best index of damage that an individual or a society is inflicting on the environment by polluting it. Hence, energy consumption is an index of development as well as of environmental damage (Ramaswamy S, 2010).

Based on Classical, Neo-classical focused on production but, modern economists have theorized and highlighted the vital role of energy in the process of economic development and energy is direct and predictable relationship between energy consumption and economic development. Therefore, this study tries to analyse the energy production/consumption, economic development, economic growth, energy demand, energy supply, utilization, cost and benefit, market structure, conservation of energy sources, technology development and standard of living.
4.4a Theory on Energy Productivity:

Productivity concept is identified by classical economist, but nowadays to agree the energy productivity measures. It is the output and quality of goods and services generated by a given set of inputs or it is the ratio of value added to energy input (the same as the labor or capital productivity are measured).

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\text{Energy Productivity} = \frac{\text{value added}}{\text{Energy Input}}
\]

\[
\text{GDP} = \frac{\text{Input}}{\text{Output}}
\]

\[
\text{Energy Intensity} = \frac{\text{Energy consumption}}{\text{Production}}
\]

Energy productivity is useful tool to analyze the public-policy aims of demand abatement and energy efficiency because it encapsulates both. In terms of shrinking demand, there is a danger of denying opportunities to consumers, particularly those in developing economies that are strongly under the influence of global energy demand growth. Meanwhile, in case of seeking to reduce end-user demand and thus to enhance the level of comfort, convenience and economic welfare demanded by consumers, there should be a focus on using the benefits of energy most productively.

The concept of energy productivity provides an overarching framework for understanding the evolving relationship between energy demand and economic growth. Energy productivity improvements can come either from reducing the energy inputs required to produce the same level of energy services, or from increasing the quantity or quality of economic output. Within each of these, there are multiple components that can change energy productivity. In other words, energy productivity, which is defined as the ratio of output (GDP from the National Income Accounts as
output) to energy consumption, is useful indicator for understanding the energy efficiency of an economy.

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\text{Energy Productivity} = \frac{\text{Output}}{\text{Energy consumption}}
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4.4b Theory on Energy Consumption:

Energy consumption means the amount of energy used by individuals, companies, countries. The energy consumption is directly related to economic development because the process of economic development is in effect the process of utilizing more energy to increase the productivity and efficiency of human labour and in fact one of the best indications of the wealth of the human population is the amount of energy it consumes per person.

Energy consumption and economic development are related in two respects as energy is consumed for two purposes. On the one hand it is a production input and on the other it is one of the important means of human comforts. As a production input it is a cause for development process. An increase in its consumption means a higher level of economic activity and greater production of goods and services and vice versa. As a means of providing comfort it is a necessary fall-out of development process. Development implies that the standard of living is increasing and people live in greater comforts.

Therefore, Mason, examined the relation between per capita income and per capita energy consumption in 52 countries for the year 1952 and has concluded that no country can enjoy a high per income without becoming an extensive consumer of energy. Felix Fremont has used the 1961 data for 153 countries of the world and showed the relationship between per capita GNP and per capita consumption of
commercial energy. Kindleberger, suggested that the rate of energy consumption accelerates as development gets beyond $200 per capita income. Burnham opined that energy consumption is closely related the GDP and the decline in energy consumption will lead to the decline in output ((Ramaswamy S, 2010). This analysis is based on the historical relationship between percentage change in annual energy consumption and real GDP. Therefore, economic growth is closely related to energy consumption in long-run and short-run.

Therefore production and consumption of energy theory based on energy is closely related on GDP, Labor force, Capital

**Empirical Evidence of the theory of Productivity and Consumption related on energy:**

Stern (1993) tested Granger causality in a multivariate setting using a vector auto regression model of GDP, energy use, Capital and Labor inputs. He also used a quality-adjusted index of energy input in place of gross energy use. The multivariate methodology is important because changes in energy use are frequently countered by the substitution of other factors of production, resulting in an insignificant overall impact on output.

Phillips (1993) showed that the distribution of the test statistic for block exogeneity in a VAR with non-stationary variables is not the standard chi-square distribution. This means that the significance levels reported in previous studies of the Granger-causality relationship between energy and GDP may be incorrect, as both variables are generally integrated series. If there is no co integration between the variables then the causality test should be carried out on a VAR in differenced data, while if there is cointegration standard chi-square distributions apply when the co
integrating restrictions are imposed. Thus testing for co integration is a necessary prerequisite to causality testing.

4.4c Depletable Energy Economics to the Transition to Renewable Resources

Theory:

General theory of economically efficient depletable energy resources supply implied this theory says, resources are heterogeneous, with mining costs that vary systematically over time with depletion of resource deposits, and that resources can be augmented through exploration and development. Moreover, a complete theory must account for the high degree of capital intensity of the extractive sector and the implications of this in terms of potential constraints on productive capacity. Depletable energy resources supply mean, a present value of current and future net revenue that accrue over time from a sequence of production decisions only non-renewable energy resources (Sundar I, 2009)

William Nordhaus has worked the efficient allocation of energy resources, he has tried to work out the competitive price of oil, and so did many others – a quick search for “backstop technology” it was clearly not a fossil fuel it could have been nuclear fusion or solar or wind energy. The only economic role it played was in setting an upper limit to the price of fossil energy, an endpoint for the price path of an exhaustible resource.

The study of depletable resource economics began with by Lewis Grey (1914) and Harold Hotelling(1931), explained economically inter-temporal optimal extraction from a perfectly known stock of their sources, with perfectly predictable future prices of the extracted commodity. This is optimal extraction paths the resource owner recognizes (explicitly or implicitly) an opportunity cost, rent in addition to the marginal extraction costs. All information about the role of future
prices and costs would be embodied in this opportunity cost. The competitive firm would extract at a rate such that the marginal extraction cost plus opportunity cost would equal the selling price for the extracted commodity. Price would thus exceed marginal cost, even if the firm were operation perfectly competitive. This opportunity cost would evolve smoothly over time. As the resource neared depletion, the opportunity cost and the marginal extraction cost even at very low extraction rates would together have increased until they equaled the commodity price, at which time extraction would cease.

In depletable resource theory, market prices would increase gradually to the cost of producing substitutes, reaching that cost only as the depletable resource were nearing depletion. Substitutes would be produced only in small quantities until near the time of depletion. Market forces would automatically and optimally guide commodity prices upward so that when the depletable resources were nearing depletion, commodity prices would have raised to point at which the demand could be fully satisfied by the substitutes. In this theory of economic cycle for depletable resources is far more complex and more level to error and surprises. This theory shows that it create complexity and uncertainty of demand and supply of non-renewable sources. It is based on the technology innovation and utilization of non-renewable energy and opportunity cost would depend on the future prices of extracted commodity.

If markets work well, the renewable resources will then be available in sufficient quantities and at reasonable costs. A transition to renewable energy resources will have been successfully accomplished and there would always be an adequate energy supply to satisfy all demands at the prevailing market price. However, it may be that fossil fuels saved for the future will ultimately never be
needed because substitute forms of energy become available at a lower cost and at an earlier time than expected.

The Green economist **Kenneth Boulding** focused on limits to growth. He first attempted on economics and ecology aspects to green economics, in the book is “Evolutionary Economics, Published in 1944. He argued one of the first major neoclassical casualties of this perspective of the usual factors of production like land, labor and capital. He considered labor instead of distribution. He also argued that approach of interdisciplinary and also for the importance of the normative aspects that economics often sidelines. Among green economists Boulding is perhaps best known for his comment that ‘Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist’. Because, as an early proponent of the need to move towards non-growth or steady-state economy. Therefore he says, “Earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in cyclical ecological system which is capable of continuous reproduction of materials even though it cannot escapes having inputs of energy. Its mean say that, it provided principle of green economic: the importance of the circular flow of materials around the planet and the need to handle wastes positively.

Boulding was also critical of the straight-line thinking inherent in mainstream economists: this he described as a linear economy which extracts fossil fuels and ores at one end and transforms them into commodities and ultimately into waste products which are spewed out the other end into polluted reservoirs.

The economist **Nicholas Georgescu-Reegen** say that, traditional neoclassical economic theory basically claims that an additional investment in technical and economic development. It is the only solution to the environmental problems.
Technology advances make it possible to minimize resource and energy use and resource waste products. Therefore, many neoclassical environmental and resource economists have used cost-benefit analysis, welfare and price theory. Then he argued, in his own study ‘The entropy law and the economic process (1971)’ that the economy was actually a giant thermodynamic system in which entropy increases inexorably and our material basis disappears. If continue to produce with the techniques have developed, society and earth will disappear faster than if introduce small scale production, resource saving technology and limited consumption. Therefore, he concluded, to promote the renewable energy technology and utilization will save the resource and reduce the environmental pollution.

The British Economist Ernst Friedrich Schumacher explained the basic development theories have been summed up in the catch-phrases intermediate size and intermediate technology. He published the first in 1973 “Small is Beautiful”. This book first chapter is the problem of production, he argues that the modern economy is unsustainable, natural resources like fossil fuels are treated as expendable income, in this fact they should be treated as capital. But they are not renewable, this are depletion. He argues that nature’s resistance to pollution is limited as well. He concluded the government effort must be concentration sustainable development because some improvements of technology transfer. Therefore He worked on green economics to say that, important of scale and technology develop. Its mean technology is most important to save depletable energy.

and social justice and indeed how these are inextricably joined. She said, an economy based on renewable resources carefully managed for sustained yield and long-term productivity of all its resources can provide useful. However, it simply cannot provide support for enormous pyramided capital structures and huge overheads, large pay differential, windfall returns on investment, and capital gains to investors. Henderson has concerned to green economists: land ownership, ethical consumption, money creation and control, the absence of freedom in the free market, the need for smaller scale, revitalized local economies and she also worked viable of alternative sources in her own local community.

Amulya Kumar N Reddy explained conventional paradigm for energy planning. Development is measured by the magnitude of the GDP. Then the paradigm argues that the only way we can increase growth is by pumping moving energy in to the economy. So we must identify various energy sources to meet the demand. This conventional paradigm on energy should be called the growth oriented supply sided consumption directed paradigm for which the acronym is GROSSCON. Found that almost all those statements illustrate this GROSSCON paradigm but the conventional paradigm has led in to is one of environment degradation, mounting costs and conflicts with the people located at the site of project. Clearly India should reject this conventional paradigm for energy planning. A.K.N Reddy introduces all these require a fundamentally different paradigm for energy planning like to call a DEFENDUS paradigm where DEFENDUS is an acronym for “Development focused end-use oriented service directed. It is the only kind of scenario that can defend us in the present crisis. The new paradigm of thinking in lists that development necessarily requires increase of energy services, but not necessarily an increase of energy consumption. According to the DEFENUS paradigm, what is required is an increase
of energy services- the essential basis of developments, decentralized renewable sources and centralized sources.

Therefore, the green economist theory above has, explained the depletable energy production, consumption, economic growth, Environmental problems, technology promotion, promotion for renewable energy, natural resources, sustainable development, economic development, growth theory, cost and benefit, utilization. These studies will help in the less consumption of conventional energy and promotion for renewable energy through technology improvement and assume economy development. These are economically related and based on that empirical evidence of Cost analysis, Life Cycle cost analysis and Techno-economic analysis empirically evidence of theory based as seen in chapter 2.