Optimum Depletion of Non-renewable Resources:

Non-renewable resources will be depleted so long as the extraction rate is positive. But it is not sustainable for the society. For sustainability, we need to extract the optimum level of non-renewable resources. For determining the optimum extraction level same condition as in case of reproducible commodity is not applied in non-renewable resources. How optimum extraction level of non-renewable resources is determined that is discussed as follows:

Since an exhaustible resource is limited in quantity and is not reproducible, therefore extraction and the sale of a unit today involves and opportunity cost, i.e., the value that might have been obtained in some future time which is called user cost. Thus in case of non-renewable resources the extractor should consider the marginal cost (mc) and the opportunity cost or user cost.

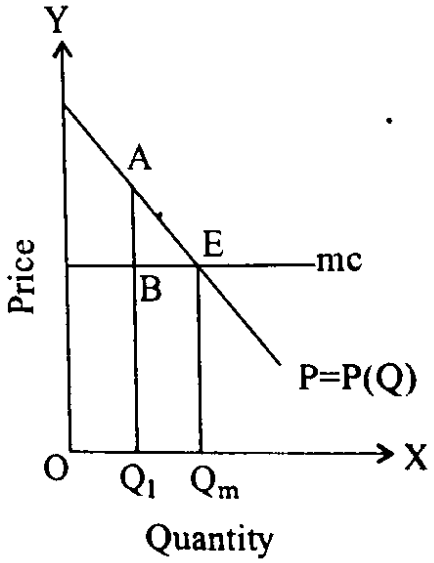
Therefore, in case of non-renewable resources the augmented marginal cost is considered which is the sum of mc and user cost (uc). That is -

amc = mc + uc

For a competitive firm the optimum level of non-renewable resource extraction is determined at that level where 1ollowing conditions are fulfilled:

P = mc + uc where P is the market price.

This is the first condition for optimal depletion. It is explained with the help of following diagram



In the diagram, E is the optimum situation where Q_m is the optimum level of extraction of resource. But a resource planner will extract Q_1 amount leaving positive

difference between p and mc (i.e., AB in the diagram) that indicates positive uc to allocate extraction efficiently over time.

Since the extractor depends not only on the current price, but also on expectations about future prices. Therefore, the decision of the extractor depends on future prices. It derives the second condition for optimum depletion which is discussed as follows:

Suppose for simplicity it is assumed just two periods which is represented by '0' for current period and '1' for future period. If the extractors sell the unit in period 0, he will receive net revenue of P_o-C where c is per unit extractor cost which is equal to mc and remains constant. But forego revenue of P_1-C in the following period. The present value of foregone revenue is P_1-C/1+ r. where r is discount rate.

Hence his return from selling a unit today will be:

$(P_0-C) - (P_1-C) /1+r$..... (1)

P_1- C/1+ r is the present value of the opportunity cost or user cost. If $(P_0-C) > (P_1-C)/1+r$, the extractor will extract and sell the resources in current period and if (Po-C) < $(P_1)/1+$ r, he will sell in future i.e. in following period.

The current extraction is optimum when

$P_0-C = P_1-C/1+ r$ ⟶ (2)
or $P_1-C/ P_0-C = 1 + r.$ ⟶ 2.1
or $P_1-C = (P_0-C) (1+ r).$ ⟶ 2.2
or $P_1 = C + (P_0-C) (1+ r).$ ⟶ 2.3

The equation 2.3 is the second condition of optimal depletion which is described as fundamental equation of exhaustible or non-renewable resource extraction. This equation represents that along the optimum extraction path, where the resource owner is indifferent between the options of extracting or leaving the resource in ground, the price, user cost has to rise at a rate equal to the discount rate.

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BACKSTOP :

Backstop indicates the presence of substitute resource of exhaustible resource. The substitute or back stop resource possibly a renewable resource may be available at a constant marginal cost. For example, the substitute resource of oil or gas is solar energy. It is to be explained how optimal depletion is determined at the presence of substitute resource. In this respect it is to be noted that a limit on the rise of amc and price will be set by the cost of a substitute or backstop. The amc (augmented marginal cost) of the exhaustible resource cannot exceed the mc of the substitute. When the substitute resource is renewable, the society prefers the use of renewable resource as it appears to be cheaper.

The optimal condition at the existence of renewable resource as substitute is explained with the help of following example and diagram-

Let us suppose, solar energy is backstop for oil. The solar energy can be supplied at a marginal cost equivalent to mc_b. This is also the price of energy at which amc of energy = mc of eneergy, since an unlimited solar energy stock cannot have any uc. In this case, the cost of the backstop sets an upper limit on the price and amc of oil and also determines the initial uc to be added to the mc of extraction.

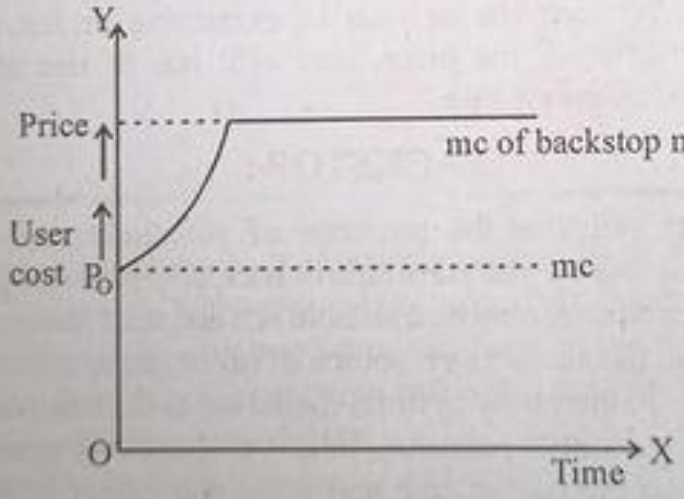
Suppose that the transition from oil to the backstop i.e. solar energy takes place at time T then the price is given by

$P_T = mc + (P_0 - mc)\ (1 + r)^T \rightarrow (1)$ (the equation comes from 2.3 at which C use for mc)

But with unlimited solar resource without any uc, the price PT become equal to mc of backstop (mc_b) which is reflected in the following diagram. Therefore from the above equation we can deduce the following equation.

$mc_b = mc + (P_0 - mc)\ (1 + r)^T \rightarrow \quad (2)$

$(P_0 - mc) = (mc_b - mc)/(1 + r)^T \rightarrow (3)$



This implies that the initial user cost at $t = 0$, $(P_0 - mc)$ is the difference between the cost of the backstop and the cost of oil, discounted back from the date of transition (T), substituting the value of P_0–mc in equation (1) at time period t, we obtain

$Pt = mc + = (mc_b - mc)/\ (1+r)^T.(1+r)^t \quad \rightarrow (4)$

This reflects the price of oil in terms of the cost of backstop at any time $t < T$.

$Pt = mc + = (mc_b - mc)/ (1+r)^{T-t} \quad \rightarrow (5)$

It implies that the user cost rises at the rate *r* to (mcb–mc) and the augmented marginal cost and price rises to mc at time T.

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Natural Resources

Natural resources can be defined as the resources that exist (on the planet) independent of human actions.
These are the resources that are found in the environment and are developed without the intervention of humans. Common examples of natural resources include air, sunlight, water, soil, stone, plants, animals and fossil fuels.
Natural resources are naturally occurring materials that are useful to man or could be useful under conceivable technological, economic or social circumstances or supplies drawn from the earth, supplies such as food, building and clothing materials, fertilizers, metals, water and geothermal power. For a long time, natural resources were the domain of the natural sciences.

Introduction:

Natural resources are derived from the environment. Many natural resources are essential for human survival, while others are used for satisfying human desire. Two basic characteristics are assigned in case of natural resources. The first characteristic is the feasibility of exclusion and the second characteristic is the nature of consumption.

Characteristics :

1. Feasibility of exclusion is a term used to indicate whether it is easy or difficult to control access to a good or service. If anyone can easily access the commodity providing restrictions for others to consume that commodity the higher feasibility of exclusion are reflected and if it is harder for someone to keep other users from accessing the commodity the lower feasibility of exclusion is reflected. The feasibility of exclusion is an important

and maintained along the main walking trails between villages. Many people can sit and enjoy the shade and shelter provided by these trees without in any way reducing their benefits for other people.

The nature of consumption varies depending on the nature of the natural commodity. The environmental commodities like air, water, sunlight, wind, scenic beauty of the nature etc. have the nature of joint consumption. Since in such cases the consumption of one's may not reduce its availability for others. But the natural commodities like community pond, forest area, open grazing land etc. have the nature of subtractive consumption. Since in such cases the consumption of one's may reduce its availability for others.

The nature of consumption, like the feasibility of exclusion, creates incentives and disincentives that influence the way people act toward resources. In general individuals are likely to feel a stronger incentive to protect resources from which they gain subtractive benefits. When the benefits are joint, and often less tangible, people may feel less of a personal stake in the resource, thinking that "someone else will take care of the problem." Such feelings will lead misuse of the natural resources.

Depending on these characteristics the natural resources are in the following form.

Private goods and services

When the feasibility of exclusion is easy and consumption is subtractive, an output is described as a private good or service. If a tree can be protected from outsiders it is likely that most of its tangible outputs fall into this category. This would include building poles, fuel-wood, medicines, fruits, nuts and other forest products. It is also possible to have a private service. The shade from a big tree in the middle of a farmer's field is an example of a private service: it buffers crops planted near it and helps the soil retain its moisture during a drought. These benefits accrue only to the farmer who plants the land under the tree.

Toll goods and services

When the feasibility of exclusion is relatively easy (as with

a private good) but consumption of benefits is joint rather than subtractive, then the output is known as a toll good or service. Parks, tourist place are examples of toll goods or services.

Common pool goods and services

When the consumption of benefits is subtractive (as with private goods) but the feasibility of exclusion is difficult, then the output is known as a common pool good or service. The products of community forests (fuel-wood, medicinal products, nuts, browse) have the characteristics of common pool goods, since it is difficult to exclude outsiders from the benefits of these forests ,but consumption is subtractive. In cases where it is difficult to control access to common pool resources and to regulate their use, individuals do not generally feel an incentive to protect these resources and ultimately destroy the commodity.

Public goods and services

Public goods and services are those that have low or even zero feasibility of exclusion and are consumed jointly. Air, wind, beauty of the nature, biodiversity etc. are public goods.

3. Another characteristic of natural resource is the existence of **market or commercial value**. Assigning property rights some natural resources like mineral resources, forest resources, fishes etc. have been changed to a marketed commodity and maintain the efficient level of extraction.

4. Further, some natural resources are in biotic and some are abiotic. Considering the renewability some natural resources are characterized by renewable in nature and some are non-renewable.

Types of Natural Resources:

Natural resources may be classified in different ways. Resources can be categorized on the basis of origin :

- **Abiotic resources** comprise non-living things (e.g., land, water, air and minerals such as gold, iron, copper, silver).
- **Biotic resources** are obtained from the biosphere. Forests and their products, animals, birds and their products, fish and other marine organisms are important examples.

Natural resources can be categorized on the basis of renewability :

- **Non-renewable Resources** are formed over very long geological periods.Non-renewable Resources are exhaustible or depletable. The stock of non-renewable resources will get depleted by the use of them. These resources are non-replenishable too. Minerals and fossils are included in this category. Since their rate of formation is extremely slow, they cannot be replenished, once they are depleted. Out of these, the metallic minerals can be re-used by recycling them, but coal and petroleum cannot be recycled.
- Renewable resources mean those resources which are inexhaustible or non-depletable. They are public goods too, the consumption of which by some would not in any way affect the consumption of others. Renewable resources, such as forests and fisheries, can be replenished or reproduced relatively quickly. Some resources, like sunlight, air, and wind, are called perpetual resources because they are available continuously, though at a limited rate. Their quantity is not affected by human consumption. Many renewable resources can be depleted by human use, but may also be replenished, thus maintaining a flow. Some of these, like agricultural crops, take a short time for renewal; others, like water, take a comparatively longer time, while still others, like forests, take even longer.

Dependent upon the speed and quantity of consumption, overconsumption can lead to depletion or total and everlasting destruction of a resource. Important examples are agricultural areas, fish and other animals, forests, healthy water and soil, cultivated and natural landscapes. Such conditionally renewable resources are sometimes classified as a third kind of resource, or as a subtype of renewable resources. Conditionally renewable resources are presently subject to excess human consumption and the only sustainable long term use of such resources is within

the so-called zero ecological footprint, wherein human use less than the Earth's ecological capacity to regenerate.

Natural resources are also categorized based on distribution :

- Ubiquitous Resources are found everywhere (e.g., air, light, water).
- Localized Resources are found only in certain parts of the world (e.g., copper and iron ore, geothermal power).

On the basis of ownership, resources can be classified as individual, community, national, and international.

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Biotic and Abiotic Natural Resources

a. Biotic natural resources

The Biotic natural resources are the ones that come from the ecosphere (organic and living materials). These include resources such as animals, forests (vegetation), and other materials obtainable from them. Fossil fuels such as petroleum, oil, and coal are also included in this grouping because they are generated from decayed organic matter.

b. Abiotic natural resources

The abiotic natural resources are the ones that come from non-organic and non-living materials. Examples of abiotic natural resources are water, land, air and heavy metals like iron, copper, silver, gold, and so on.

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