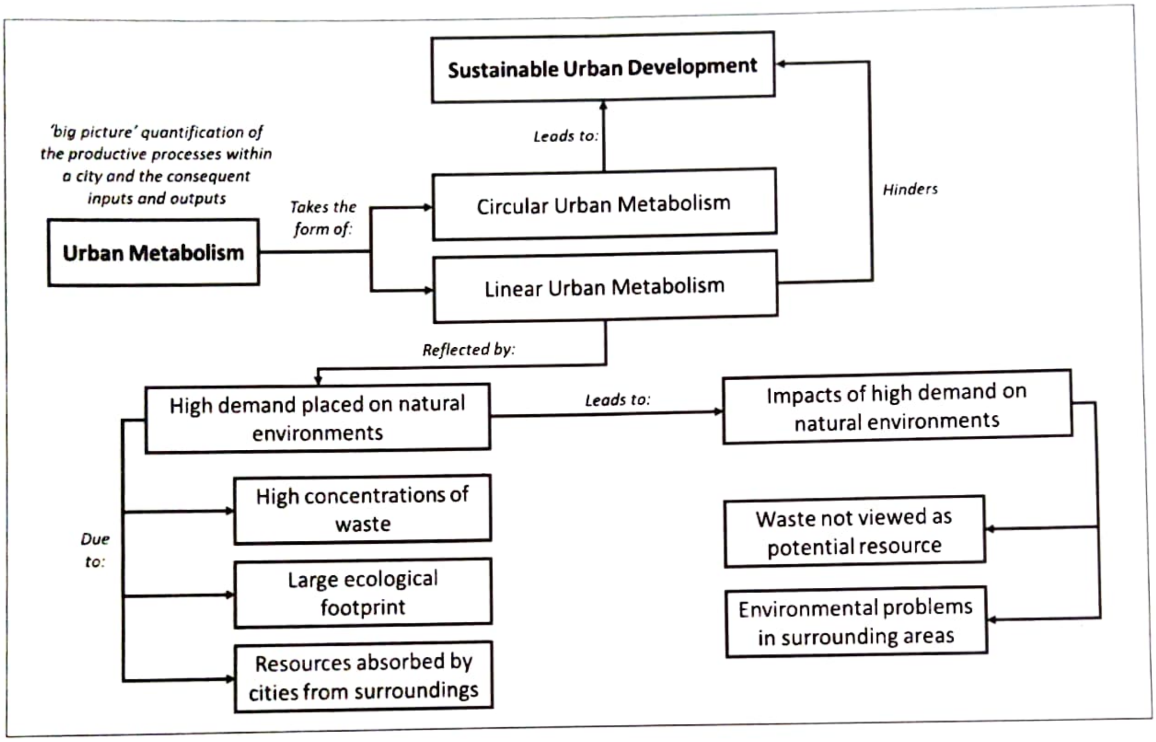
Cluster 1: Sustainable Future and Climate Change

Topic 1.1 Cities in a Sustainable Future

03 Demand Placed on Natural Environments



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Key Question: How does the demand placed on natural environments by urban areas influence progress towards sustainable development?

1. Introduction

In the previous lecture, we discussed urban population trends and how the high urbanisation rates and rapid urban growth pose serious challenges to sustainable urban development.

Specifically, high urbanisation rates and urban growth is a key driver of **resource consumption** and **waste generation**, which then leads to environmental issues that become a challenge to sustainable urban development:

- City-based production currently accounts for the majority of resource consumption and waste generation worldwide. Cities consume more than two-thirds of global energy and produce over 70 percent of carbon emissions (World Bank, 2010).
- Cities also present a number of environmental problems associated with the demands they place on ecosystems, resources and sinks of the surrounding region.

In this lecture, we explore how the demands placed on natural environments by urban areas influence progress towards sustainable development.

1.1 Urban Metabolism and Sustainable Urban Development

The concept of urban metabolism stems from the idea that **cities are similar to organisms, as they both consume resources from their surroundings and excrete waste.** Hence, the study of a city's urban metabolism involves 'big picture' quantification of the inputs, outputs and storage of energy, water, nutrients, materials and wastes for an urban region.

- **'Inputs'** refer to the **resources needed in the city**
- **'Outputs'** refer to the **result of consumption of resources** – e.g. generation of waste.

In order to progress towards sustainable development, a better understanding of how natural resource use correlates with urban economic activities is necessary. The concept of urban metabolism is helpful in doing so as:

- Assessing the metabolism of urban areas provides important clues about the direct and indirect environmental impacts of consuming natural resources.
- The framework of urban metabolism can also help identify the most effective infrastructure design and technology choices for diverse cities in different development contexts, such as those for waste management, as well as the potential for establishing a "**circular economy**" (see Box 1).

Box 1: Circular Economy

A **circular economy** is a **framework of production and consumption** that incorporates **sharing, leasing, reusing, repairing, refurbishing and recycling of materials and products up to their maximum lifespan**. This approach addresses global issues such as pollution, waste, and climate change, by focusing on three basic principles that provides the transformation to a circular economy:

- eliminating waste and pollution
- circulating products and materials, and

- the regeneration of nature.

A circular economy is often seen as contrasting the traditional linear economy.

Urban metabolism therefore **provides a framework for analysing the technical and socioeconomic processes that occur in cities,** as if the city were an **ecosystem**. It can be used to analyse how urban areas function with regard to resource use and the underlying infrastructures, and more broadly, the relationship between human activities and the (natural) environment.

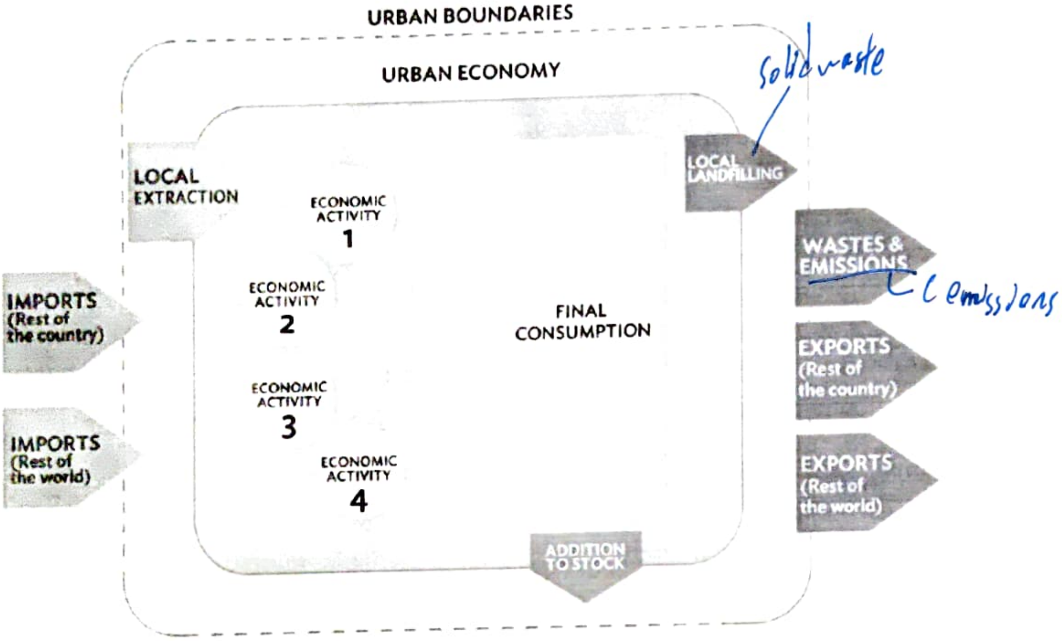

Fig. 1 Schematic Representation of Urban Metabolism

Fig. 1 is a schematic representation of urban metabolism, where the **material flows** of an urban area are illustrated.

- ***Imports*** to an urban area may come from the rest of the country or from abroad.
- Together with ***locally extracted materials***, imports are used by the ***urban economic activities*** to produce goods and services that will be ***consumed*** within the city by other economic activities and by the citizens, or ***exported*** (to the rest of the country and to the rest of the world).
- A portion of the materials consumed is ***accumulated*** in the material stock of the local economy (as buildings, infrastructure, and durable goods).
- The rest leaves the economy as valuable products, ***waste, and emissions*** (to the local environment or beyond).

The difference between natural ecosystems and cities is in **how inputs and outputs move through the system**:

- In natural ecosystems, the output of an organism is frequently **also** an input that renews and sustains the environment – hence inputs and outputs move in a **cyclical** fashion.
- However, inputs and outputs move through a city in a **linear fashion** (*Fig. 2*):
  - E.g. Raw materials are extracted, combined and processed **into** consumer goods, many of which end up as non-biodegradable waste that cannot be absorbed into the natural environment.

- E.g. Nutrients are taken from the land when harvested from food. However, these nutrients are not returned as most urban sewage systems discharge into rivers and coastal waters.

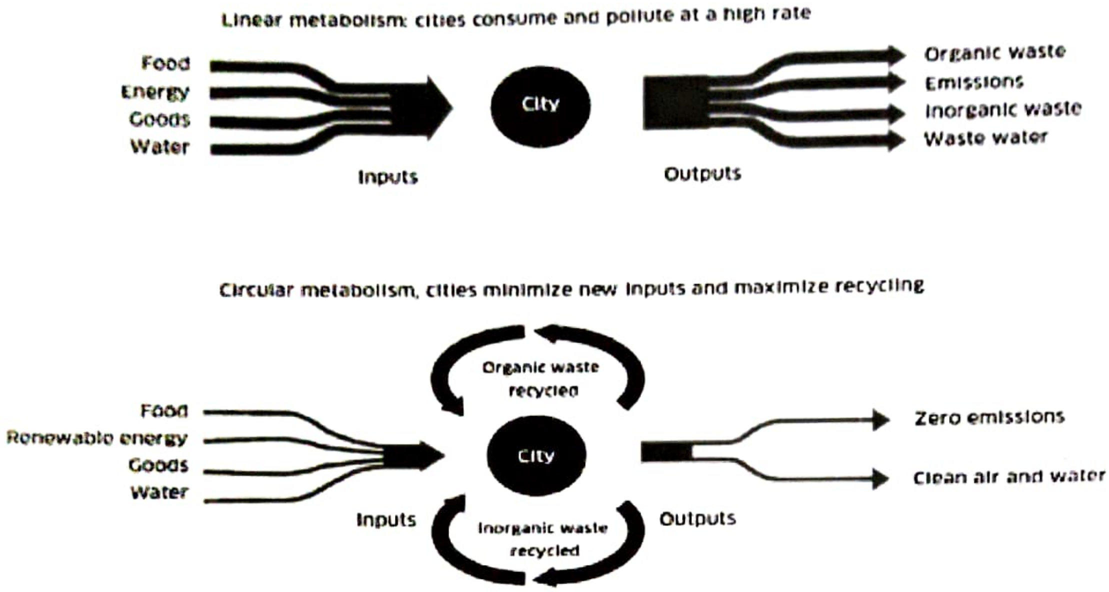

Fig. 2 Comparison between linear and circular metabolism

As seen from Fig. 2, this impedes progress towards sustainable development because **a linear nature of production, consumption and disposal in cities is unsustainable in the long run**, with both the use of resources and the amount of generated waste increasing to staggering proportions. It has therefore been argued that cities need to move towards a **resource-efficient circular metabolism**. The latter differs in that all wastes produced are recycled and reused as inputs for cities, creating a closed-loop system of production and consumption.

With this understanding of the framework of urban metabolism and how it can be applied to cities, we will look at various ways in which the **consumption of resources** (from *inputs* into the city) and **generation of waste** (from *outputs* of these economic processes) place demands on natural environments.

2. Demands placed on natural environments

2.1. High concentration of waste

As highlighted in the previous lecture, there is increasingly high urbanisation rates and rapid urban growth. **With urban growth, consumption rates are also on the rise globally**. Worldwide, cities generate over 720 billion tonnes of wastes every year. This impacts natural environments greatly as **all production and consumption activities also produce wastes** in the form of various gases, particulate matter, chemicals and solid matter.

Complicating this is that **finding physical space for the disposal of solid wastes is an ongoing challenge**, particularly in more developed countries where rates of production are highest.

- In the UK, for example, the average person produces approximately 500 kg of domestic waste annually, and whilst the amount that is recycled is increasing, more than two-thirds continues to go to landfill (DEFRA, 2009).

New challenges for sustainable development also arise as the nature of production and consumption changes. This is especially so when looking into the problem of managing '**e-waste**', which comprises all forms of electrical and electronic equipment including PCs, refrigerators, air conditioners and mobile phones that have been discarded by their users. E-waste is now the fastest growing waste stream in industrialised countries (BAN, 2002). It is growing globally by an estimated 3.5 per cent every year (UNEP, 2007). While there are opportunities in re-use and recycling of e-waste including the extraction of valuable materials such as copper and gold (*refer to section 3.1*), **e-waste also includes toxic substances of environmental health concern, including lead and mercury**.

Thus, the high concentrations of waste brought about by rapid urban growth **place a significant demand on the natural environments.**

- Some of the impacts include pollution and massive disruption to the natural ecosystems and biodiversity of cities and their surrounding areas.
- The high concentrations of waste also **prevents cities from achieving circular urban metabolism**, as the undesired output from the urban boundary remains critically high, posing a massive challenge to sustainable urban development.

2.2. Large ecological footprints

One of the best known practical methods for exploring the human impacts on environment is **Ecological Footprint Analysis (EFA)**. The Ecological Footprint is a concept that has been widely used by businesses, governments, institutions, etc. to monitor ecological resource use and advance sustainable development.

2.2.1 Overview of Ecological Footprint Analysis

What is Ecological Footprint?

- EFA is a **quantitative assessment** of all the **biophysical resources** needed to support the consumption by particular groups of people (e.g. a country or city).

- EF is related to the notion of **carrying capacity** – the number of people, animals, or crops which a region can support without environmental degradation.
    - However, rather than asking "How many people can the Earth support?", EF analysis instead asks "How much *land* do people require to support themselves?"

- EF is typically expressed in terms of **global hectares (*gha*) of biologically productive area** (of world average productivity) that are **required to support that activity**.
    - E.g. Part of this includes assessing the amount of raw materials and energy needed to extract, produce, and transport manufactured goods, and for their disposal.

How does Ecological Footprint help measure sustainability?

Consequently, Ecological Footprint Analysis (EFA) seeks to measure the following:

<table>
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1. The population's demand (footprint) for natural resources
i.e. the ecological assets that a given population requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions.
Generally, EF tracks the use of six categories of productive surface areas:
<table>
<tr><td colspan="2">Biologically productive land and water area needed to produce the resources an urban area consumes</td></tr>
<tr><td>Grazing land (pasture)</td><td>Represents the area used to raise livestock for meat, diary, hide and wool products</td></tr>
<tr><td>Fishing grounds</td><td>Calculated from the estimated primary production required to support fish and seafood catches including catches from aquaculture</td></tr>
<tr><td>Forest</td><td>Represents the forest area required for the supply of timber, pulp and fuel wood.</td></tr>
<tr><td>Cropland</td><td>Represents the area used to grow crops for food and fibre for human consumption as well as the area for animal feed, oil crops and rubber.</td></tr>
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2. The supply (biocapacity) of resources that nature (or a given area) can provide.

On the supply side, a city, state or nation's biocapacity represents the productivity of its ecological assets (including cropland, grazing land, forest land, fishing grounds, and built-up land).

These areas, especially if left unharvested, can also absorb much of the waste we generate, especially our carbon emissions.
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Built-Up land	Represents the area of land covered by human infrastructure, including, transportation, housing, industrial structures and reservoirs for hydropower
Carbon footprint (carbon demands on land	Accounts for the area of forest land required to absorb CO2 emissions from burning fossil fuels and land use change and international transport, that are not absorbed by oceans.

From here, the difference between the demand (Ecological Footprint) and supply (biocapacity) can be evaluated.

***Ecological deficit*:** • If a population's **Ecological Footprint exceeds the region's biocapacity**, that region runs an **ecological deficit.** • This means that the population's demand for the goods and services that the region's land and seas can provide — e.g. fruits and vegetables, meat, fish, wood, cotton for clothing, and carbon dioxide absorption — exceeds what the region's ecosystems can renew. • A region in ecological deficit meets demand by importing, liquidating its own ecological assets (such as overfishing), and/or emitting carbon dioxide into the atmosphere.	***Ecological reserve*:** • If a region's biocapacity exceeds its Ecological Footprint, it has an **ecological reserve**.

Ideally, the demand for natural resources (footprint) should not exceed what the Earth can provide (biocapacity).

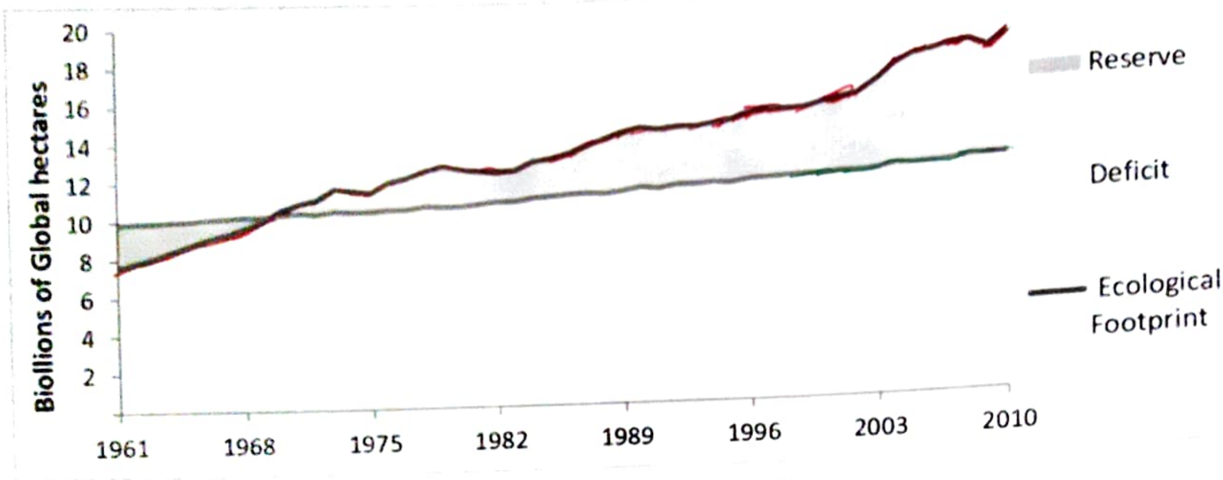

Fig. 3 Ecological footprint of the world

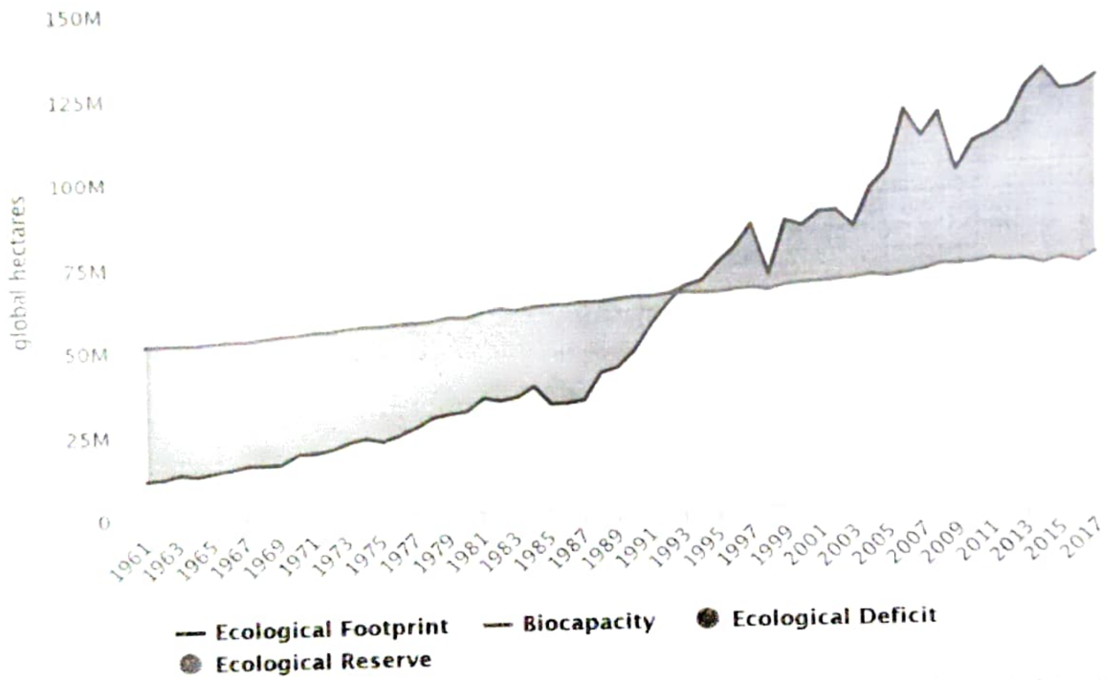

Fig. 4 Ecological footprint of Malaysia

2.2.2 Large ecological footprints of cities

Cities, due to their dense population concentration, have large ecological footprints.

- In many countries, one or two major urban centres are major contributors to the national Ecological Footprint and also run significantly higher per capita Footprints than the average for their nations. Cities have become ground zero for footprint reduction.
- Thus, comparing city and national Footprints and biocapacity can shed more light on potential leverage points for improving urban sustainability.

2.3. Vast quantities of resources absorbed by urban areas from the surrounding areas

All forms of basic economic and social activity make demands on the resource base:

- As **raw materials** such as soil and water within agricultural production
- As **sources of inputs and energy** into industrial production and in the construction and maintenance of human settlements and urban lifestyles *(recall: concept of urban metabolism and input into urban boundaries).*

Economic development to date has been closely correlated with mounting rates of **resource extraction** worldwide, in terms of energy and water.

Urban areas are the central focus for economic development in a country

2.3.1 Extraction of biofuels to meet energy demands of cities

Current rates of growth in energy demand are unprecedented historically.

- Total world energy consumption is predicted to rise by 49 per cent (over 2007 levels) by 2035 (UNEP, 2007).
- Whilst over 80 per cent of this increase is projected to come from developing countries, the more economically advanced countries currently account for almost 50 per cent of world energy demand. In China alone, energy consumption grew at nearly 10 per cent per year between 2000 and 2005
- **As seen in Fig. 5, fossil fuels such as oil, coal, and gas, supply over 80 per cent of the world's current energy needs.** However, fossil fuel use is also the principal source of the global increase in carbon dioxide emissions (IPCC, 2007).

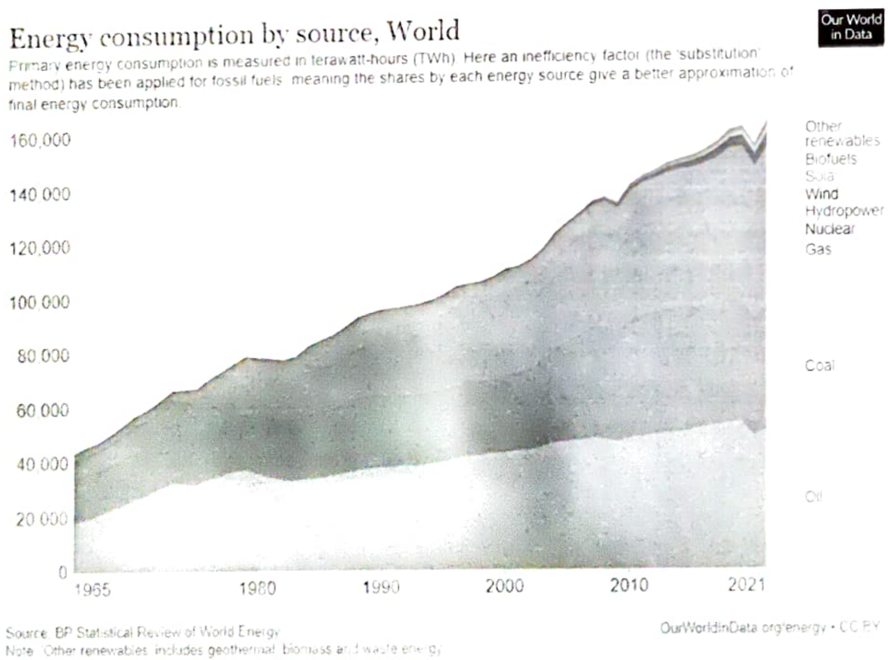

Fig. 5 World energy supply by source, 1965-2021

Biofuel is a fuel that is produced over a short time span from biomass, as compared to the very slow natural processes involved in the formation of fossil fuels, such as oil. Biofuel can be produced from plants or from agricultural, domestic or industrial biowaste. In many developing countries, as much as 90 per cent of total energy consumption may be supplied by biomass sources such as fuelwood, charcoal and animal dung.

However, there is a significant environmental cost in the surrounding areas of cities to meet this massive demand for biomass (*see Box 2*):

- **Demand from city-based activities for the products from forests, farmlands and watersheds located outside city boundaries** present substantial challenges for sustainable urban development
    - E.g. Research has shown that fuelwood for the urban population of Bangalore comes typically from over 150 km away and from over 700 km in the case of Delhi (Hardoy et al., 2001).
    - E.g. The twentieth-century growth of Sao Paulo was fuelled by the expansion of coffee and sugar cane plantations in south-east Brazil, helping to make Sao Paulo the country's most economically developed state with 34 per cent of Brazil's GNP. In consequence, the natural forest cover of Sao Paulo State has reduced from 82 per cent in 1860 to no more than 9 per cent in 2010 (Rodrigues et al., 2011).
- This demand encroaches on some of the last-remaining and most-valued reserves of natural vegetation, including mangrove swamps, protected wetlands, prime agricultural lands and involves transformation of the land surface, valley reshaping and the extraction and movement of rocks and other materials.

Box 2: State of Food and Agriculture Report

In 2008, the risks and opportunities of biofuel production were the focus of the Food and Agriculture Organisation's State of Food and Agriculture Report. The report identified that **biofuel production strongly enhances the risk of large-scale land-use change**, including deforestation, and in many cases, the net effect on emissions is unfavourable. Further environmental impacts include **depletion of water resources and biodiversity.**

The report identified the fact that the rapidly growing demand for biofuel feedstocks had contributed to higher food prices and undermined food security of he poor in both urban and rural areas. Demand for agricultural feedstocks for liquid biofuels pushes up prices of these goods and the resources (fertilisers, etc.) used to produce them, which impacts heavily on the poor.

To date, the production of biofuels has principally been in the US and EU. However, high targets are being set, particularly in South East Asia where investment is largely by overseas companies and for export (DEFRA, 2008). For example, Indonesia has already cleared 18 million hectares of forests for palm oil production and an additional 20 million hectares is identified in regional development plans for further expansion.

Source: Jennifer Elliot (2013)

2.3.2 City demand for water resources

Water is a resource with a strong regional dimension.

- Most cities rely on freshwater resources largely from within and around the urban centre as, unlike other resources, water cannot be imported easily from great distances.
- However, **in most parts of the world, the spatial range of urban water withdrawals is expanding** (McGranahan et al., 2004). extract water from further away
    - Research in Africa suggests that whilst many major cities in the 1970s were using groundwater supplies as their primary sources, **by the 1990s, their principal sources were more likely to be rivers more than 25 kilometres away**.
    - For example, Johannesburg in South Africa draws its water supply from 700km away in neighbouring Lesotho (UNCHS, 2001).

This tremendous demand for water resources can be witnessed in many urban areas across the world, and has serious environmental implications on areas distant from the city.

- E.g. the **rising consumption of water from the fast-growing economy and an increasingly urbanized population** is having a serious impact on the **Yellow River**, China's second longest river (Feng et al., 2012). The Yellow River basin had a population of some 115 million in 2010 – more than double the 1950 population – with a 30 per cent urbanisation rate. The strain on water resources is indicated by the fact that the average urban household in the basin consumes more than twice as much water than a rural household. This reflects the **higher income levels of urban households, allowing them higher consumption rates of all types of water-intensive goods and services, from food to footwear.**

causes illegal well drilling

Box 3: Urban water supply issues in Amman, Jordan

Amman, the capital city of Jordan, is one of the ten most water scarce nations in the world. In 2004, the total water consumption for the city area was 105 million cubic metres and local resources are insufficient to meet this.

In its National Water Master Plan 2004, the Jordanian government stressed that the first priority is to meet the basic needs of the people. Indeed, as the population of the city has grown, various strategies have been implemented, most notably the transfer of waters from the Jordan Valley, from distant reservoirs and aquifers and the recycling of wastewater.

Today, Amman receives around 50 per cent of its water from the Jordan Valley. Water is pumped from a depth of 225m in the Jordan Valley to a modern treatment plant at Zai, which is located to the north-west of the city at an altitude of 1035m. The remaining water demands of the city are met from the Al-Mafraq Well, the Azraq aquifer (some 70km east of Amman), and from Qatrana, Swaqa and Wala to the south of the city.

Looking to the future, providing the city with adequate water is a priority for the government. One of the major projects to achieve this is the Disi Project. This involves the proposed construction of a 325 km pipeline from the Disi aquifer that lies on Jordan's border with Saudi Arabia. This will provide the city with around 100 million cubic metres per year for the next 100 years at an estimated base capital cost of $US 600 million.

Source: Robert Potter et. al. (2013)

water shortage causes lack of food security as well

Box 4: Aral Sea in Central Asia

Diversions of water from the Amu Darya and Syr Darta rivers, rivers that lead to the Aral Sea, to irrigate plantations, predominantly growing cotton, has had severe impacts on the inland Aral Sea since 1960.

Expansions of the irrigated area in the former Soviet region of Central Asia, from 2.9 million hectares in 1950 to about 7.9 million hectares by the late 1980s, was spurred by Moscow's desire to be self-sufficient in cotton. Asa result, the annual inflow to the Aral from the two rivers, the source of 90 per cent of its water, had declined by an order of magnitude between the 1960s (about 55 km^3/year) and the 1980s (about 5 km^3/year).

Human use of water resources in the Aral Sea basin dates back more than 3000 years, but the unprecedented intensity of water use dating from about 1960 has clearly been responsible for the falling sea levels since then.

- In 1960, the Aral Sea was the fourth largest lake in the world, but since that time its surface area has shrunk by 75 per cent, it has lost 90 per cent of its volume, and its water level has dropped by more than 25 m.
- The average water level in the Aral Sea in 1960 was about 53 m above sea level. By 2003, it had receded to about 30 m above sea level.
- In some parts, the Aral Sea's remaining waters are several times saltier than sea water in the open ocean.

Source: Nick Middleton (2013)

3. Consequences of the high demand placed on natural environments

3.1 Consequences of waste not being viewed as a potential resource

When waste is not viewed as a potential resource, the urban metabolism of cities reflects a very **linear** pattern of **high resource consumption and high generation of waste output**, therefore

Some degree of **waste recovery** does actually occur in most cities.

- E.g. In many cities in less developed countries, large numbers of residents are self-employed in the business of garbage recycling. For example, in Brazil, more than 500,000 people survive by collecting and marketing solid waste in large cities, and it is estimated that they reduce the amount of waste that goes into landfills by up to 20 per cent (Fergutz et al., 2011).
- E.g. In the case of Cairo, Egypt, the Zabbalean religious sect has traditionally run a very efficient garbage collection business, scavenging and recycling, feeding edible portions to their domestic livestock and selling inorganic materials to dealers.

However, this informal economy of waste recycling is usually seen as undesirable, and government crackdowns to eliminate these practices are frequent.

- E.g. For example, in the case of the Zabbalean religious sect in Cairo, the continuation of the community's way of life is jeopardized by the privatisation of municipal solid waste services in Cairo and an official policy of moving the Zabbalean further out of the city, on the grounds that this will turn their neighbourhoods into cleaner and healthier living environments (Fahmi and Sutton, 2010).

This **reflects the larger view that waste is usually seen as simply waste, rather than as potential resources**. This further encourages the massive volumes of waste generated by cities, placing significant demand on the natural environments and hindering sustainable urban development.

3.2 Environmental problems in surrounding areas

To support both people and productive activities, cities depend substantially on inputs of raw materials and goods of various natures from the surrounding region. While wealthy cities have long had the capacity to draw resources from far beyond their immediate region, this capacity has greatly increased in recent decades, particularly as the relative cost of transportation has declined.

However, **the environmental impact of cities extends far into the distant surrounds, and the burden falls on these areas** despite the benefits being reaped by cities. There is a widening concern that resource extraction in many parts of the developing world, to meet the demands of a productive city, is having profound environmental consequences, locally. Some environmental problems due to resource extraction include deforestation and the consequent loss of land biodiversity in the surrounding areas where resources such as biomass are obtained, and **negative impacts on water supply and water quality** *(see Box 5)*.

It is also important to note that while cities (and particularly the more affluent ones) can be considered to have performed better in terms of meeting the needs of their current populations, historically these have been met by displacing the environmental burdens elsewhere. For example, sewers have been put in to take human waste out of the city and goods whose production may have been resource intensive or damaging have been imported.

3.2.1 Example – Consequences of logging

In many instances, the benefits of logging, mining and so on go to government elites and foreign investors, whereas the burdens are felt by local people in terms of loss of land, environmental devastation, social impacts and the abuse of human rights.

One prominent example is in the Niger delta of Nigeria:

- Since the 1970s, oil corporations (most notably, Shell) and the government have received the benefits of oil extraction
- However, the Ogoni people have suffered degradation of the resources on which their livelihoods depend (such as through the loss of land directly and the sterilisation of soils and water pollution) and are living in increasingly dangerous and unhealthy environments.

3.2.2 Example – Consequences of extraction of groundwater

The high demand for water and consequent extraction of water supplies from surrounding areas also has significant environmental consequences for these areas.

As discussed in section 2.3, the water needs of urban population and industry are often supplemented by pumping from groundwater, much of it from aquifers distant from the city centre. A frequent outcome of overusing groundwater is a **lowering of water-table levels** and consequent **ground subsidence**.

Mexico City is one of the most dramatic examples of how overextraction of groundwater supplies has led to ground subsidence:

- The use of subterranean aquifers for 100 years and more has caused subsidence in excess of 8 m in some central areas.
- Since groundwater pumping was banned in downtown Mexico City in the 1960s, the rates of subsidence in central parts of the city has slowed to less than 100mm/year, but water is still drawn from more recent wells sunk on the outskirts of town in the late 1970s and early 1980s and subsidence at some sites near the newer wells has exceeded 300mm/year.

Box 5: Ecological demise of the Aral Sea

The massive, uncontrolled use of water from the two rivers, Amu Darya and Syr Darya, that flows into the Aral Sea has had far-reaching effects, both on-site and off-site:

- The Aral Sea **commercial fishing industry**, which landed 40,000 tonnes in the early 1960s, had **ceased to function** by 1980 as most of its native organisms died out.
- The **delta areas** of the Amu Darya and Syr Darya rivers have been **transformed due to the lack of water**, affecting flora, fauna, and soils
- The diversion of river water has also resulted in the **widespread lowering of groundwater levels**.
- The receding sea has had **local effects on climate**, and the exposed sea bed has become a **dust bowl** from which up to 150 million tonnes of saline material is deposited on surrounding areas each year.
    - This dust **contaminates agricultural land several hundred kilometres from the sea coast**, and is suspected to have **adverse effects on human health**.

4. Conclusion

Cities represent a completely artificial environment; they absorb vast quantities of resources from surrounding areas and create high concentrations of wastes to be disposed of. The degree to which cities impinge on their hinterlands, their ecological footprint, is indicated by a few examples in this lecture, such as the impacts caused by the extraction of biomass and water.

An understanding of the urban metabolism of cities is helpful in achieving sustainable urban development. While a circular urban metabolism is key to achieving sustainable urban development, most cities reflect a highly linear urban metabolism with high resource extraction and generation of huge volumes of waste, placing high demand on natural environments with many adverse environmental implications.

<u>SAMPLE ESSAY QUESTIONS:</u>

1. **'Urban areas place significant demand on natural environments.' Evaluate this statement. [13]**

2. **Evaluate the environmental impact of the demand placed on natural environments by cities. [13]**